Universidade de Aveiro Departamento de Educação
Ano 2014 Departamento de Comunicação e Arte

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U-TRACER®: O USO DAS TECNOLOGIAS DA COMUNICAÇÃO NO ENSINO SUPERIOR

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Uma ferramenta de visualização de informação para o contexto do Ensino Superior Público Português

U-TRACER®: THE USE OF COMMUNICATION TECHNOLOGY IN HIGHER EDUCATION

An information visualization tool for the context of Portuguese Public Higher Education

Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Multimédia em Educação, realizada sob a orientação científica do Doutor Rui Raposo, Professor Auxiliar do Departamento de Comunicação e Arte da Universidade de Aveiro, e Doutor Fernando Ramos, Professor Catedrático do Departamento de Comunicação e Arte da Universidade de Aveiro.

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A Isaura Pinto, e a Conceição Ferreira (em memória).

o júri

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palavras-chave

ensino superior, visualização de informação, tecnologias da comunicação, ensino e aprendizagem.

resumo

A Visualização de Informação emerge gradualmente como uma área que assiste a representação e a compreensão de dados sobre as instituições de Ensino Superior. Esta compreensão e conhecimento aprofundado sobre as instituições de Ensino Superior tem uma importância internacional reconhecida. Uma das áreas emergentes do Ensino Superior, com um impacte transformador das práticas educativas em todo o mundo e que urge conhecer e compreender de forma sistematizada, relaciona-se com o uso das Tecnologias da Comunicação no suporte às práticas pedagógicas.

No foco deste trabalho está a necessidade de representar visualmente um conjunto de dados recolhido no âmbito do projeto TRACER, sobre e o uso que as Instituições de Ensino Superior Público Português fazem das Tecnologias da Comunicação como suporte aos processos de ensino e aprendizagem. O projeto TRACER identificou esta necessidade e fez uma recolha de dados a nível nacional. Este estudo desenvolveu-se no âmbito deste projeto, e utilizou os dados recolhidos com o objetivo de conceptualizar uma ferramenta de visualização de informação - U-TRACER® - que daria visibilidade a esses dados.

Os principais objetivos deste estudo prendem-se com: a conceptualização da ferramenta de visualização de informação denominada U-TRACER®, para o contexto do Ensino Superior Português; a compreensão sobre a utilidade desta plataforma para decisores das instituições de Ensino Superior Português, no suporte a processos de tomada de decisão.

Os objetivos permitiram contextualizar o fenómeno das ferramentas de visualização da informação com dados sobre instituições de Ensino Superior, perceber as tendências de uso da visualização de informação nesse contexto.

resumo (cont.)

A investigação de natureza qualitativa, seguiu princípios de Investigação & Desenvolvimento adotando o método de estudo de caso desenvolvido em quatro fases de recolha de dados. A primeira fase prendeu-se com a conceptualização da plataforma U-TRACER®, tendo-se desenvolvido duas sessões de *focus group* com profissionais do ensino superior, com o objetivo de conhecer de definir os requisitos de interação da ferramenta. A segunda fase deu origem à proposta de representação gráfica dos dados recolhidos no Âmbito do projeto TRACER "O uso das Tecnologias da Comunicação no Ensino Superior Público Português", e um teste à eficácia de leitura dos gráficos propostos. A terceira fase envolveu um teste de usabilidade à ferramenta U-TRACER®, por profissionais do Ensino Superior enquanto utilizadores finais, tendo resultado na proposta de melhorias ao protótipo final. A quarta fase de recolha de dados envolveu a realização de entrevistas semi-estruturadas, realizadas a decisores de Instituições de Ensino Superior Público Português, com o objetivo de compreender a sua perceção relativamente à utilidade da U-TRACER®.

Considera-se que os resultados deste estudo contribuíram para a área da visualização de informação como suporte à representação de dados sobre o Ensino Superior; refletir sobre a necessidade de envolvimento dos utilizadores finais no processo de conceptualização da ferramenta; a importância da representação gráfica na comunicação eficaz da informação; e conhecer a perceção dos decisores das instituições do ensino superior sobre a utilidade desta ferramenta utilizada como meio para a comunicação de informação sobre a sua instituição, como exercício de benchmarking, e a sua utilidade como suporte a processos informação e decisão que envolvem o uso das Tecnologias da Comunicação. Este estudo contribui ainda para a reflexão sobre a abertura de dados de instituições de Ensino Superior num mercado global.

keywords

higher education, information visualization, communication technologies, teaching and learning.

abstract

Information Visualization is gradually emerging to assist the representation and comprehension of large datasets about Higher Education Institutions, making the data more easily understood. The importance of gaining insights and knowledge regarding higher education institutions is little disputed. Within this knowledge, the emerging and urging area in need of a systematic understanding is the use of communication technologies, area that is having a transformative impact on educational practices worldwide.

This study focused on the need to visually represent a dataset about how Portuguese Public Higher Education Institutions are using Communication Technologies as a support to teaching and learning processes. Project TRACER identified this need, regarding the Portuguese public higher education context, and carried out a national data collection. This study was developed within project TRACER, and worked with the dataset collected in order to conceptualize an information visualization tool U-TRACER®.

The main goals of this study related to: conceptualization of the information visualization tool U-TRACER®, to represent the data collected by project TRACER; understand higher education decision makers perception of usefulness regarding the tool.

The goals allowed us to contextualize the phenomenon of information visualization tools regarding higher education data, realizing the existing trends. The research undertaken was of qualitative nature, and followed the method of case study with four moments of data collection.

abstract (cont.)

The first moment regarded the conceptualization of the U-TRACER®, with two focus group sessions with Higher Education professionals, with the aim of defining the interaction features the U-TRACER® should offer. The second data collection moment involved the proposal of the graphical displays that would represent the dataset, which reading effectiveness was tested by end-users. The third moment involved the development of a usability test to the U-TRACER® performed by higher education professionals and which resulted in the proposal of improvements to the final prototype of the tool. The fourth moment of data collection involved conducting exploratory, semi-structured interviews, to the institutional decision makers regarding their perceived usefulness of the U-TRACER®.

We consider that the results of this study contribute towards two moments of reflection. The challenges of involving end-users in the conceptualization of an information visualization tool; the relevance of effective visual displays for an effective communication of the data and information. The second relates to the reflection about how the higher education decision makers, stakeholders of the U-TRACER® tool, perceive usefulness of the tool, both for communicating their institutions data and for benchmarking exercises, as well as a support for decision processes. Also to reflect on the main concerns about opening up data about higher education institutions in a global market.

INDEX

INDEX OF FIGURES

INDEX OF TABLES

LIST OF ACRONYMS

AHELO	Assessment of Higher Education Learning Outcomes
CT	Communication Technology
DGEEC	Direção Geral de Estatísticas da Educação e Ciência
EHEA	European Higher Education Area
EUA	European University Association
HE	Higher Education
HEI	Higher Education Institution
ICT	Information and Communication Technology
IEA	International Association for the Evaluation of educational Achievement
OECD	Organization for Economic Cooperation and Development
PPHEI	Portuguese Public Higher Education Institutions
THE	Times Higher Education World University Rankings
UNESCO	United Nations Educational, Scientific and Cultural Organization

Chapter 1. Introduction

The U-TRACER® is an information visualization tool that serves the purpose of representing a full dataset regarding the use of Communication Technologies in Portuguese Public Higher Education Institutions. Dataset that was collected by project TRACER, developed at University of Aveiro between 2011 and 2014. In this study, the information visualization tool entitled U-TRACER® was conceptualized, supported by a qualitative study that followed principles of Development Research, and validate by a set of interviews made to higher education decision makers who provided the data to project TRACER.

1.1. Context of the study: Where are we now?

In the era of information, anyone who is able to access and make sense of the growing volume data and information that is produced and stored, has a wealth of potential towards deeper understanding and knowledge. In a global economy knowledge driven, access to information is relevant for all the stakeholders of all fields. Accessing information is frequently a time consuming process, due to the vast disperse and diverse formats in which information is made available. Making sense of the data and information accessed requires knowledge of how to effectively analyse and communicate the results of the analysis to a broad audience. Information visualization is growing as a desired outcome of the analysis and communication processes, making it crucial to embrace transparency, rigorous analysis and communication of the data, and adopt effective visual and interactive features.

Regarding education, in the last 20 years, the Organization for Economic Cooperation and Development (OECD), the European Commission and national agencies, have approached education towards statistical comparability (Lawn, 2013). These organizations contributed to the openness of the data collected and assisted its' communication to a broad public through by also using information visualization.

Making sense of information, translating it into valuable perceptions and knowledge (Eick, 2004) are the main challenges Information Visualization (infovis). HE is but one of the fields gradually grasping the advantage of the adoption of infovis solutions to access and make accessible data to foster transparency.

In the European context, there is a demand for higher education institutions to adhere to processes that systemize and communicate on their diversity, and some of the emerging solutions implemented concern information visualization techniques. The European Higher Education Area (EHEA), in 2008, called for greater accountability and transparency of the European Higher Education diversity, through the development of mechanisms that provide more details about the institutions through benchmarking exercises, classifying and ranking Higher Education (HE) institutions study programs, creating quality profiles and offering comparable information (EHEA, 2012). Data regarding HE is valuable to decision makers, and its visibility on the web may give institutions prestige, being advantageous to help attract students, scholars and funding (Ortega, 2008; Butler, 2010), spreading the prestige of these educational institutions nation and world-wide.

The analysis to 13 international university rankings (Rauhvargers, 2011), show clearly that infovis is emerging slowly in assisting that data representation, where only two of the total rankings take advantage of infovis interactive features. The ranking tools assist the comprehension of large datasets about HE institutions, decreasing the time a person needs to read and interpret the information, and simultaneously disseminating it on a large scale, online.

Although today a more heterogeneous audience is apt to make a successful connection between the accessing information through infovis and understand it, infovis practices have only increased in the recent years becoming widespread and widely used supported by web interfaces.

Research based on comparative analysis of Higher Education pedagogical practices supported by Communication Technologies is vast and disperse, making it exceedingly difficult to reveal trends and insights crucial to shape policy and support decision making processes within HE, and contribute towards effective change of educational practices. Nevertheless the importance of gaining insights and knowledge regarding Higher Education is little disputed. The same relevance is understood towards the use of Communication Technologies and its' transformative impact on educational practices worldwide.

Education and Information Visualization are the two fields under study within this thesis. Regarding the field of education, the focus is Higher Education (HE) and the use of Communication Technologies (CT) as a support for pedagogical practices. Regarding the field of Information visualization the focus is in transforming a specific dataset into information presented with visual and interactive features, that may be useful in decision making processes, fostering transparency and comparison of information relevant to Higher Education Institutions (HEI).

Reviewing the research concerning the use of Communication Technologies that support teaching and learning practices in Portuguese HEI we find the existing statistics are not relate to indicators of CT use to support pedagogical practices. Data and information focused on the use of CT to support teaching and learning practices in HE institutions, derives from academic research, which is vast and dispersed, making it very difficult to access and more difficult to compare. Aware of this, the TRACER project undergone at University of Aveiro proposed to collect that data and map the use of CT in Portuguese Public HEI. Consequently, with the data collected by TRACER, this study arose as a contribution to the dissemination of the data supported by information visualization techniques. The goal is therefore to conceptualize an infovis interface to present data concerning the use of CT by public Portuguese HEI in support of educational practices and making this information accessible to decision makers; and understanding if HE decision makers perceive usefulness to the infovis tool as a support for decision making.

1.2. What is being visualized?

At University of Aveiro, the research project TRACER[1] developed between 2011 and 2014 and entitled “The use of Communication Technologies in Portuguese Public Higher Education Institutions”, collected data at a national level regarding the use of CT Portuguese Public Higher Education Institutions were making to support teaching and learning practices, from an institution and teachers perspective. In the TRACER study CT is defined as the hardware and software that allow and promote communication and information distribution supported by the Internet (Armstrong & Franklin, 2008; Grodecka, Wild, & Kieslinger, 2009). The TRACERs’ data we will use concerns the institutional perspective of the use of CT, data provided by nine HEI – rectors’ team; presidents team; directors of organizational and research units; coordinators of courses - who by filling an online questionnaire between January and May of 2012, provided TRACER with the necessary data regarding the institutions’: Profile of the institution; Resources and functionalities of CT; Infrastructures to support the use of CT; Equipment and supports for the use of CT; Training for CT use.

The relevance of working this dataset and information is that the use of CT are transforming HE institutions world-wide, at all levels, from management to teaching and learning practices. In Europe this was greatly felt as an outcome of the Bologna process, affecting all European Higher Education Institutions. Therefore the first domain, the context of the data that will be visualized in this study, regards Portuguese public HE institutions and their use of CT to support teaching and learning practices.

This data contributes to the transparency of HE, also an incentive made by the European Commission towards the promotion for feasibility studies on so-termed ‘transparency instruments’ as a by-product in the provision of public information (EURASHE, 2012), instruments which are currently making use of information visualization techniques in web interfaces for data analysis.

Why visualize this data?

[1] TRACER project http://cms.ua.pt/TRACER/

Firstly, Information Visualization is both an emerging field and a powerful and attractive way of communicating data that to frequently is only disseminated through traditional forms and seen by a small group people who are interested and knowledgeable to consult and understand the data. Secondly, Communication Technologies are being widely used in educational contexts including HE. The use of CT to support teaching and learning practices has emerged as a trend with transformative impact in educational practices as well as institutional practices. This has driven a vast and diverse research world-wide, mainly focusing on teaching and learning practices within a class, a course or an institution. Therefore information so valuable to assist researchers, teachers and educational institutions that face the new impacting trends, generating the need to systematize and communicate information in a more easy and immediate way.

The participation as research fellow in project TRACER and being a first year Ph.D student in Multimedia In Education, led to embrace the challenge of developing this study as a contribution to the emerging field of infovis, as a support to disseminate information about the use of Communication Technology in Higher Education institutions. One of the outcomes of project TRACER was an online information visualization tool, entitled U-TRACER®, that would assist the communication of the data collected in a more accessible way. The expected results for the U-TRACER® are therefore:

> "The development of a technological tool that renders possible the visualization of information based on the correlation of collected data using filters. According to specific needs of the users, the tool will, for example, allow to:
>
> a) obtain geo-referenced representation of the use of CT in all the HEI included in the study;
>
> b) display, according to metaphors negotiated by the team members, the correlation of data established in accordance with the filters selected by the user." (TRACER, 2011)

The challenge within this Ph.D study was to conceptualize and validate the infovis tool U-TRACER®, assisting the analysis and communication of the data collected within project TRACER.

1.3. Research questions and goals

The research questions that drive this study relate to the need to communicate data provided by Portuguese Public HEIdecision makers - rectors' team; presidents team; directors of organizational and research units; coordinators of courses - regarding the institutional use of Communication Technologies that support teaching and learning practices, by making use of information visualization features that comprise the U-TRACER® tool. The research questions and goals that frame this study integrate this context.

Question 1: What information visualization proposal is most adequate, to represent the dataset concerning the use of Communication Technologies that support teaching and learning practices in Portuguese Public Higher Education institutions?

Question 2: What is the perception of Portuguese Public Higher Education decision makers, regarding the usefulness of the U-TRACER®?

Research goals for question 1:

- Understand how information visualization is being used to represent data concerning Higher Education institutions.
- Critically reflect on the challenges of information visualization in the context of the higher education data.
- Understand the concepts of information visualization and adapt them to the dataset about “The use of Communication Technologies to support teaching and learning practices, in Portuguese Public Higher Education Institutions.
- Conceptualize the U-TRACER® tool, with information visualization features, considering the dataset and profile users as the stakeholders of Higher Education.

Research goals for question 2:

- Critically analyse the acceptance of information visualization tools within the European context of Higher Education.
- Understand the possible relation between the use of the information visualization tool U-TRACER® by Higher Education decision makers, and its use to support decision making processes.
- Understand decision makers’ perceptions towards the usefulness a U-TRACER®.
- Understand the advantages, disadvantages and concerns decision makers identify in the U-TRACER®.

To achieve these goals, this thesis deeply explores information visualization used in the transparency tools within European HEA, the usefulness and concerns related to the information visualization of data from the context of higher education institutions. It also studies the contribution of information visualization towards the support for decision making processes by higher education decision makers.

1.4. Methodological approach

We opted for a qualitative methodological approach with methods process-oriented (Carmo, 1998), developed to achieve a richer understanding of the processes of conceptualization and validation of U-TRACER® tool, enabling full descriptions of the data collected (Carpendale, 2008).

The process of conceptualization of the U-TRACER® followed principles of Development Research (DR), involving end-users as participants in the different moments of the conceptualization, usability testing and validation. These are empirical evaluation methods that involve real users, allowing the researcher to obtain qualitative data to design the tool (Mazza, 2007).

The conceptualization process in what I concerns the stages of development of the web interface of U-TRACER® was a result of a joint work with the company contracted by project TRACER. Its advantages and limitations will be described in each section, being the course of the work, of sole responsibility and the perspective as an individual researcher.

1.5. Structure of the thesis

This document is structured in 6 related chapters, from the theoretical and conceptual framework, to the empirical work, in order to help answer the research questions listed.

In the present **chapter 1 - Introduction**, we proceeded to frame the study, presenting the motivations that underlie the work. The research questions and research goals to achieve the answers were listed, and a summary of the methodological stances that guided the development of the work.

In **chapter 2 - Information Visualization and Higher Education data**, we proceed to the state of the art about information visualization, its history, techniques and emerging application to web interfaces, and to the recent application of information visualization to communicate data about education and higher education institutions, where we are and the trends. We also make a state of the art relating existing comparative data about education and higher education. Additionally we describe the HEI world rankings, list and describe a set of transparency tools that aim to support decision makers as tools for management, and which make use of information visualization features to communicate data. Reflects also about how data about Higher Education Institutions is being communicated internationally and nationally.

In **chapter 3 - Methodological approach for the conceptualization and validation of the U-TRACER®**, is presented the description of the methodological stances that guided the development of the research. Based on the research questions, it is presented the research methodology adopted. All phases of data collection are describes along with the data collection instruments, and the participants who collaborated in each phase. In this chapter we also present the model of analysis and its theoretical ground, which supported the content analysis of the data collected.

In **chapter 4 - Conceptualization of the U-TRACER® an Information Visualization tool**, we attempt to answer the first research question, and present the analysis of the data collected in research phases one, two and three, which enabled the conceptualization of the U-TRACER® tool.

It describes the detailed process of conceptualization of the tool and final layouts, simultaneously discussing the results obtained.

In **chapter 5 - Validation of the U-TRACER®** is dedicated to answer the second research question, and present the validation of the tool result of the analysis of the interviews made to 10 Higher Education decision makers. Adding to which we present the discussion of these.

Finally **chapter 6 - Conclusions and future research**, presents a final reflection about the contribution of the study developed and future implications.

Chapter 2. Information Visualization and Higher Education data

What is information visualization and how does it weave with higher education data?

2.1. Information Visualization

We live in the information age where each person has access to an unaccountable vast amount of human knowledge through the web, more than can be processed by people alone, requiring the support of technology to store, disseminated and assist its understanding. Information Visualization is one of the fields that supports the understanding of vast amounts of information and data (infovis).

As a result of the technological advance, Information Visualization is broadly defined as computer driven interactive visual representations of information and abstract data, to amplify cognition (Chen, 2005; Shneiderman, 1998; Card, 1999). Nevertheless, in its definition infovis also goes beyond the technology it involves, establishing the relation between the aim and context it wants to reach (Masud, 2010).

The questions we attempt to answer in the following sections are: What are the historical foundations of infovis? What are the principles of infovis? Which infovis is being developed today and what are the trends?

2.1.1. Brief history overview about Information Visualization

A brief historical analysis of Information Visualization will guide through the understanding of its evolution and reveal some of the people whose work still influences infovis creators nowadays.

The history of information visualization, the graphic representation of quantitative information goes back to map-making, cartography, statistics, and involves the fields of science, medicine and many others. It connects with the rise of statistical thinking in the 19th century and evolves to the technological computer developments in the 20th century with new types of representation (Friendly, 2006).

Because an important part of our work will focus on statistical data about the specific context of education, we choose to focus on the historical overview of the statistical representations data, told through the story of **some relevant authors in this area**, who drew the numbers in such ways that their innovative visual displays is widely recognized and used today.

The earliest visual representation of statistical data goes back to 1644, drawn by Michael Langren, a Flemish astronomer who represented the distance between Toledo and Rome, measured in 12 different scales (Tufte, 1997).

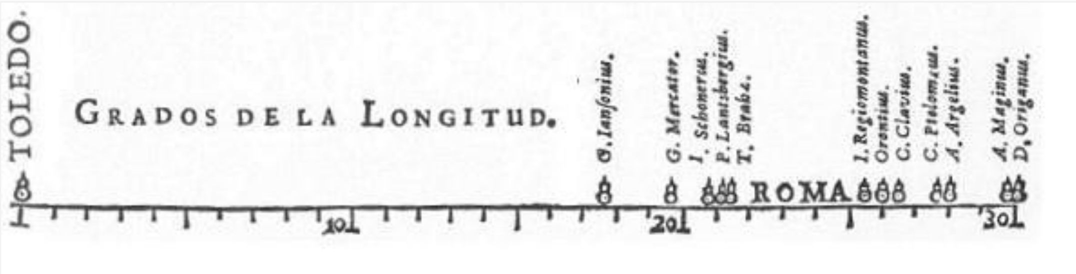

Figure 1. Michael Langren, Statistica graph (1779)[2].

Only much later, in 1779, appeared the first drawing of a *time series-chart* published in a in scientific paper which was created by the mathematician Lambert, known as the first graph with economic data (Tufte, 1983). Only a few years later, in 1781, was created the first *bar chart* considered a new method to represent data through the perspective of comparing data in its form, by William Playfair a Scottish engineer and political economist (Tufte, 1983).

William Playfair (1759-1823), a statistician and a writer of political issues is a key figure in the representation of quantitative data, and creating the basic styles of line graph including for time-series, of bar and pie graph (Spence, 2004). Playfair was aware of the importance of visualization to facilitate the communication of information, and was concerned both by creating graphs as alternatives for a non-specialist reader as substitution of the standard use of the table, and concerned by assisting “men of grate rank”, business men, who had little time to read the extensive numbers and details to benefit from the charts that assisted the reading of general outlines of the information (Costigan, Macdonalds, 1990). He understood the impact of visual displays of data, and during a span of 36 years contributed to develop graphical methodology mainly focused in three clusters of graphical development: development and experimentation with the design of curves; circles and sectored circles (Costigan, Macdonalds,, 1990). The first cluster of graphs Playfair drew was in 1786 when he published the Commercial and Political Atlas, the first publication to contain statistical charts. These charts were mainly time-series line graphs and a bar graphs, having made use of parallel lines in the graphs as well as use of color coding and grids to represent actual, missing and hypothetical data (Figure 2) (Spence, 2004). Playfair updated the graphs in following editions of the Atlas by introducing numerical data and discarding the tables that

[2] Figure 1: retrieved from http://en.wikipedia.org/wiki/File:Grados_de_la_Longitud.jpg

supported the graphs (Spence, 2004). The graphs employed then differ little from todays' graphs which use the same techniques.

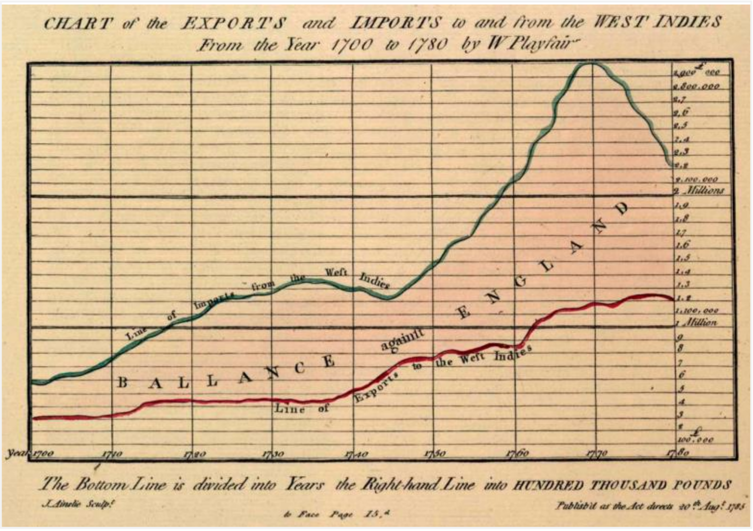

Figure 2. Trade-balance time-series chart, William Playfair (1786), "Commercial and Political Atlas".

The second cluster of graphical development is time framed between 1801 and 1805. In 1801 was published the Statistical Breviary, presenting graphs representing the relative sizes of geographical regions by introducing the circle diagram and pie chart (

Figure 3). In 1805 was the publication of Decline and Fall of Powerful and Wealthy Nations (Costigan, Macdonalds, 1990).

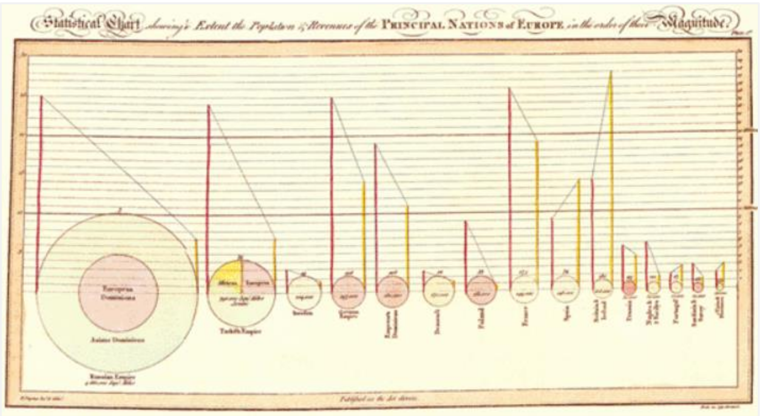

Figure 3. Pie chart. William Playfair (1801), "Statistical Breviary".

The final cluster of graphs was between 1821 and 1822 published in 'A Letter on our Agricultural Disaster Their Causes and Remedies', where Playfair experimented further into the design of curves (Figure 4) drawing a map of the weekly wages of a "good mechanic" and a quarter of wheat and the with the periods of monarchs displayed along the top (Costigan, Macdonalds, 1990). In this graph, Playfair used the vertical axis to represent prices and the horizontal axis to represent time, which was a novelty in his time.

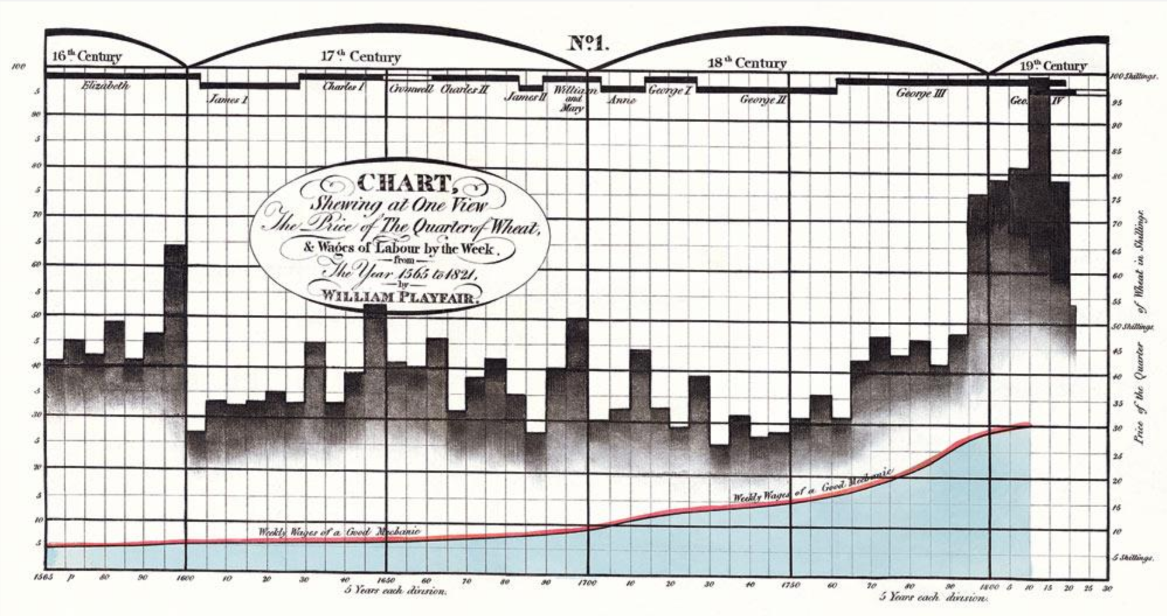

Figure 4. Bar and line chart representing the unfair prices of a quarter of wheat when compared with the wages of a "good mechanic". William Playfair (1821), "A Letter on our Agricultural Disaster"[3].

Florence Nightingale (1820-1910), mostly known for her role as a nurse during the Crimean War (1854–1856), she was the first woman to hold an official position in the Army and the first to be elected a Fellow of the Royal Statistical Society in 1860, but whom had also an important role in advocating for women's education creating a nurses training school for women (Attewell, 1998). In 1856, in reaction to the governments limited enquiries into the mismanagement of hospitals during the war, which had caused four times more deaths from disease than from battle, Nightingale commissioned an enquiry of the whole process gathered evidence of hospital mismanagement and organizing statistics of mortality (Attewell, 1998). From this inquiry, Nightingale put a big effort into campaigning to improved sanitary conditions in the battlefield of soldiers in treatment, and in this effort to create awareness to the high number and causes of deaths in the army of the East, she created the graph called 'rose diagrams' or 'coxcombs' (Figure 5) representing that same data (Friendly, 2008).

[3] Figure 4: retrieved from http://cdn.static-economist.com/sites/default/files/images/2007/12/articles/body/3.jpg

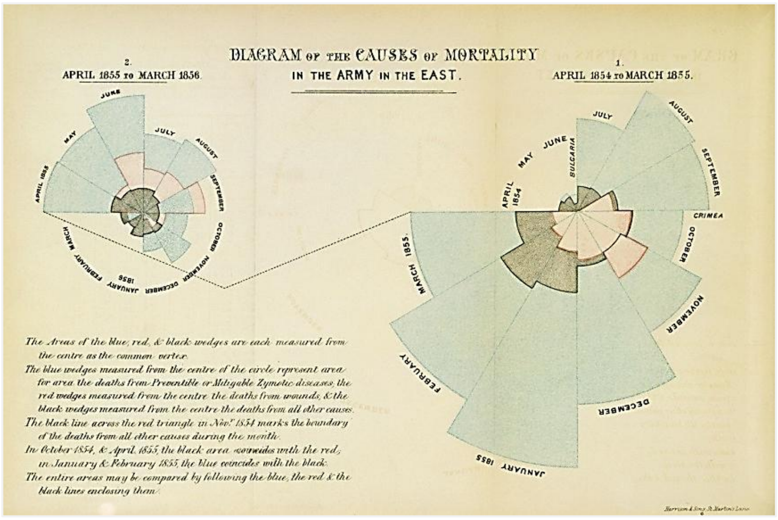

Figure 5. Diagram of the causes of mortality in the army in the East.
Florence Nightingale (1858)[4].

Nightingale provided adjacent information to the graph, with a note explaining how the graph had to be read, and although the actual number of deaths is not depicted, the intention was to represent the relative size between them showing three areas: the blue area shows “preventible or mitigable zymotic diseases” (infectious diseases); the red area shows “wounds”, and the black area shows the “all other causes”. Nightingale explains that the each slice has its measure from the centre (radius). In fact the graph left no doubts about the cause of deaths of the soldiers.

William Playfair and Florence Nightingale were not contemporary to each other, but both were staticians and social reformers who believed that data served the purpose to inform, persuade and campaign.

Graphs evolved to represent more complex datasets, as did Charles Minard and Harry Beck, who contributed to the innovation of visualization by using graphs as classical examples of those structures.

Following to the author **Charles Joseph Minard** (1781-1870), a French civil engineer of roads, canals and railways, who nurtured a great interest in economic geography used graphics in engineering and statistics. Minard produced over 50 maps during his life, mostly of economic flow, flows of differential price rates for the transport of goods by land and water, and flows of people (Wainer, 2003). The flow map of French export of wines (Figure 6) is one example that depicts the quantity and direction of wine exports, accompanied by a time-series chart, or the flow map showing the impact prior, during, and after the American Civil War, on European cotton trade. The flow maps are represented by colored bands and its width represents the quantities of wine or cotton. Minard had an envisioned commercial application of the flow maps, developed in 1846, and

[4] Figure 5: Royal Collection © Her Majesty Queen Elizabeth II, retrieved from http://www.royalcollection.org.uk/collection/1075240/notes-on-matters-affecting-the-health-efficiency-and-hospital

almost exclusively used until 1864, as he wrote: "I realized, by substituting merchandise for voyagers, my maps and graphic tables acquired numerous commercial applications" (Minard,1869, p. 8, In Friendly, 2002).

Minard was also a pioneer in using pie charts in maps, as shown in Figure 7, to represent amounts and proportions and in the case of the figure referenced, of the meats supplied to the butcher's in the Paris market (Friendly, 2002).

Minards' contribution to visually based planning, in the mid-to-late 1800s, had great influence on all Ministers of Public Works in France, which had their portraits painted with one of Minard's maps in the background ("Europe Raw Cotton Imports in 1858", 1864 and 1865).

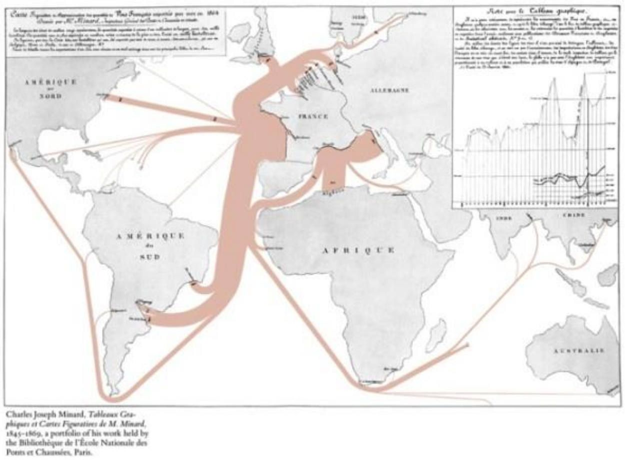

Figure 6. French wine export map. Charles Minard (1864).

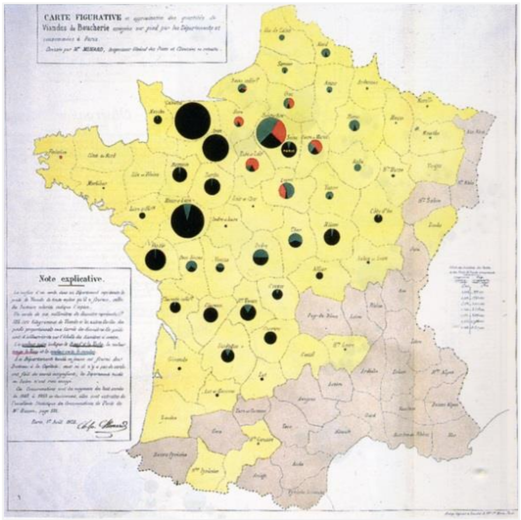

Figure 7. Carte figurative et approximative des quantités de viandes de boucherie envoyées sur pied par les départements et consommateurs à Paris. Charles Minard (1858)[5].

Near the end of his life, at the age of 80, Minard created Napoleons army graph (1869) (Figure 8), considered a masterpiece, representing the continuous defeats of his army showing the death of 400,000 men in a combination between a map and a time series. The story is told with multivariate data (Tufte, 1983), using color code, three methods and measurement scales (Tufte, 2006).

[5] Figure 7: retrieved from http://en.wikipedia.org/wiki/File:Minard-carte-viande-1858.png

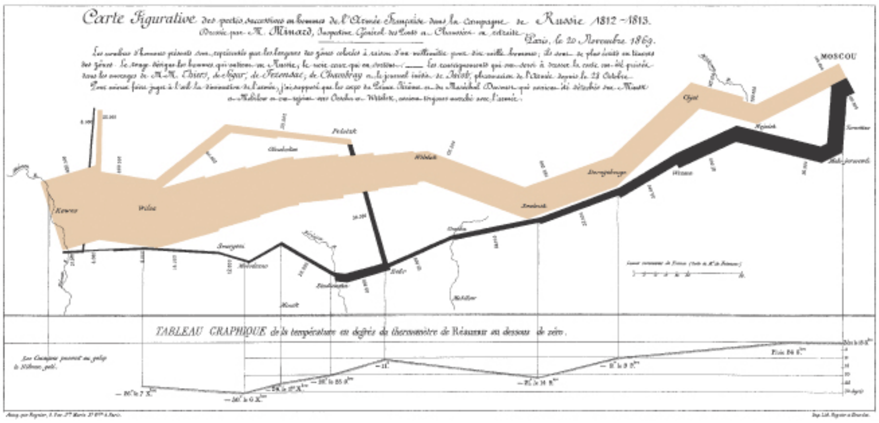

Figure 8. Losses suffered by Napoleon's army in the Russian campaign of 1812.
Charles Minard (1869).

All authors of the innovative graphs, pioneered in their attempt to substitute tables despite belonging to a generation of ‘table people’, statisticians who looked at graphs with suspicion (Costigan, Macdonalds, 1990; Friendly, 2008) , and pioneered in putting emotions into the drawing of the graph used to reveal life events that all felt impelled to call attention over.

From 1900 to 1950 statistical graphics became mainstream by entering publications such as textbooks, standard government publications, science and commerce. But there were few graphical innovations, and graphics were supplanted by formal quantification models (Friendly, 2008).

Other fields such as science, there were also few innovations that brought new insights through graphics. Two innovations were the Maunders ‘butterfly diagram’ (1904) showing the variation of sun spots overtime, and Hertzprung-Russels’ diagram showing the changes in luminosity as a star evolves (Friendly, 2008).

Computer and the Internet

In the 20th century the computer began to be used to draw graphs around the end of the 70s’ (Tufte, 1983), revealing new graph representations and maps. It was only in 1987 that the term of information visualization was first used, by McCormik, within the context of scientific computational visualization. At this time both areas of scientific visualization and interactive computer graphs converged and began to be understood as valuable for analysis, and to allow a more in depth comprehensiveness of the data, serving as a tool to draw scientific experiments (McCormick, 1987). This was considered a crucial tool for the communication of modern science, and potentiated well known examples such as the image of the DNA molecular structure in double helix, routes simulations, weather images and space explorations, or medical, engineering and dynamic fluids (Card, 1999; McCormick, 1987). Two years after McCornik first used the term information visualization, Robertson et al (1989) also used the term this time related to the description of 2D and 3D animation, to explain and represent information and its structure, inspired by the techniques of scientific visualization. The interaction with objects 2D or 3D would alter the structure of information.

Additionally to the computer came the creation of the World Wide Web hypermedia for global information sharing in 1989[6,] which popularization begun to make more data available through publications of official statistical data, research results, statistical databases were developed to be accessed by anyone via the Internet (Yamamoto, 2008). Many data sets already exist and many more are being created.

The phenomenon of the Internet, the rhizomatic system of hypertext able to aggregate multiple web pages at an astounding rhythm, changed the scene of massive amounts of data possible to interconnect (Lima, 2011).

> "Before software, visualisation usually involved the two-stage process of first counting or quantifying data, and then representing the results graphically. Software allows for direct manipulation of the media artefacts without quantifying them."(Manovich, 2011)

New target areas in statistical analysis emerged, such as networks, originating what was considered one of the greatest challenges to information visualization, the representation of that abstract knowledge in a way that could become intuitive to understand (Chen, 2004).

As stated by Lima (2011), scientists over the XVII, XVIII and IXX centuries tried to understand the influence of one variable over another, while in the second half of the XX century researchers designed systems with multiple variables interacting randomly and chaotically.

This represents the new challenges of thinking in network, creating the need to make sense of this network information and to be able to use this massive amount of data into more accessible formats. As Eick (2004) states, of making sense of the massive amounts of data:

> "With the growth of networking and decreasing cost of storage it has become technically feasible and cost effective to store and access vast sets of information. The academic, business, and government challenge is how to make sense of this information and translate the insights into value producing activities".

We are in also living a disruptive change in the way data is accessed, from limited use covering mainly research and knowledge transfer, to open data accessible to a broad public (Callaert, 2012).

[6] W3: http://www.w3.org/People/Berners-Lee

2.1.2. Information Visualization Features

Data is the core of visualization, and visualization can be applied to practical problems of data analysis. Thanks to the use of computer today the process of simplifying and reducing data into smaller numbers of categories of information, or working with vast amounts of data is easier.

A common aspect of visualizations is that the viewer of a graph creates in his mind an understanding or an interpretation of something, and the expected result is for that person to have a sense that a useful discovery has been made (Figure 9) (Spence, 2007). Data in whatever form can be transformed and represented in an image by a wide number of visual encodings, such as with the visualization of Florence Nightingale, who used color to differentiate mortality causes, or Minards' chart showing the number of deaths in Napoleans' army by applying line thickness. Data is encoded to help telling a story and to best make a fact evident. There are many different techniques that can be used to visually represent data, but it depends on the type and complexity of the data to represent, and ultimately on the interpretation of who reads it (Spence, 2007)

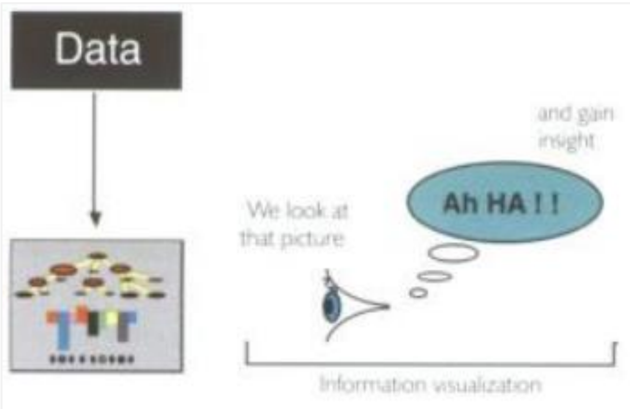

Figure 9. The process of information visualization (Spence, 2007).

2.1.2.1. Data Type

Data has to be understood in order for it to tell a story, and it is crucial to start at the beginning of the data structure. The visual representation depends on the data type and encoding methods, namely to take abstract data and represent it visually, aiming to inform the user (Spence, 2007; Ware, 2004). Understanding the dataset and dividing it into its subsets, understanding correlations and gaps in the data is the first step (Steele, 2010). Data type can be divided into attribute of dimension and attribute of quality, and its' the relation between both that define the structure of the data, necessary to be depicted.

Attribute of dimension is defined by Shneiderman (1996) and Shneiderman & Plaisant (1998) as having seven data types:

- 1 Dimension: linear data which objective is to make the user aware of one number.

- 2 Dimension: data with two attributes to be represented in a two dimensional space.
- 3 Dimension: data characterized by three attributes represented in a three dimensional space.
- Multidimensional: data with many attributes represented in a n-dimensional space.
- Temporal: items have a start and finish time and may overlap.
- Tree: hierarchy items which have a link to one parent item, except for the root
- Network: when items can be linked arbitrarily to other sets of items.

A similar definition for 1D, 2D, 3D and multidimensional data, was approached by Spence (2007), using synonym terms of univariate, bivariate, trivariate, hypervariate data.

The attribute of quality relates to the levels of measurement of the data, with four scales of measurement: nominal, ordinal, interval and ratio (Ware, 2004; Spence, 2007). These scales are largely defined in the quantitative methodological research literature (Tuckman, 2000; Stevens, 1946).

1) Nominal: the numbers have a label function.
2) Ordinal: derives from an ordering or ranking scale of numbers.
3) Interval: interval scale of measurement.

Visualization deals with quantitative data and qualitative data that can be in the format of text, audio or image. The characterization of the data types is important because it restricts the type of visual representations possible to apply to the dataset.

2.1.2.2. Visual Representation

Data can be represented visually through different techniques (Spence, 2007), which have been categorized by authors such as Behrens (2008) and Heer, Bostock & Ogievetsky (2010), in an effort to systematise the categories which relate to different types of datasets to specific set of design patterns.

Behrens (2008) proposes the following eight categories of visual representation techniques according to the type of dataset:

1. Correlations: Scatterplot; Bubble Chart.
2. Continuous quantities: Line chart; Stacked chart; Sparklines.
3. Discrete quantities: Bar chart; Multiple Bar chart; Dot matrix; Stacked bar chart; Isometric bar chart; Span chart.
4. Proportions: Pie chart; Ring chart.

5. Flows: Sankey Diagram; Thread Arcs.
6. Hierarchies: Tree diagrams; Tree map
7. Networks: Diagram map; Relation circle; Pearl Necklet.
8. Spatial configurations: Topographic Map; Thematic Map.

The authors Heer, Bostock & Ogievetsky (2010), for the same attempt to propose visualization techniques according to the types of datasets, propose 5 categories:

1. Statistical distributions: Stem-and-Leaf Plots; Q-Q plots; Scatter Plot Matrix; Parallel Coordinates.
2. Time-Series: Index chart; Stacked graph; Small multiples; Horizon graph.
3. Maps: Flow map; Colorpleth; Graduated Symbol Maps; Cartograms.
4. Hierarchies: Node-link diagrams; Adjacency Diagrams; Sunburst; Enclosure Diagrams.
5. Networks: Force-directed Layouts; Arc Diagrams; Matrix Views.

Both proposals have common visualization techniques for similar type of datasets, which evidences the widespread use of the visual displays.

Visual displays use similar visual encodings - methods that guide the user through common tasks of infovis (Spence, 2007). The category of encodings, proposed by different authors have commonalities. Authors such as Tidwell (2005), Bertin (2011) and Mackinlay (1986) propose three set of encoding methods to support common visualization tasks (**Erro! A origem da referência não foi encontrada.**). Tidwells' and and Bertins' categorization are very similar, although Tidwell covers more options of color encodings, and only Mackinlay proposes the category volume.

Table 1. Encoding methods by Tidwell (2005), Bertin (2011) and Mackinlay (1986)

Tidwell (2005)	Bertin (1983-2011)	Mackinlay (1986)
Color hue	Color	Color
Position		Position
Color brightness	Value	Density
Color saturation		
Texture	Texture	Volume
Orientation	Orientation	Angle Slope
Size	Size	Length
Shape	Shape	Area

Tidwell (2005) states there are approximately eight variables that can be used (Figure 10) and are important if one wants to highlight data, which may be used separately or simultaneously in the same representation as appearing in different layers: hue, position, color saturation; size, brightness, position, alignment, orientation, texture and shape.

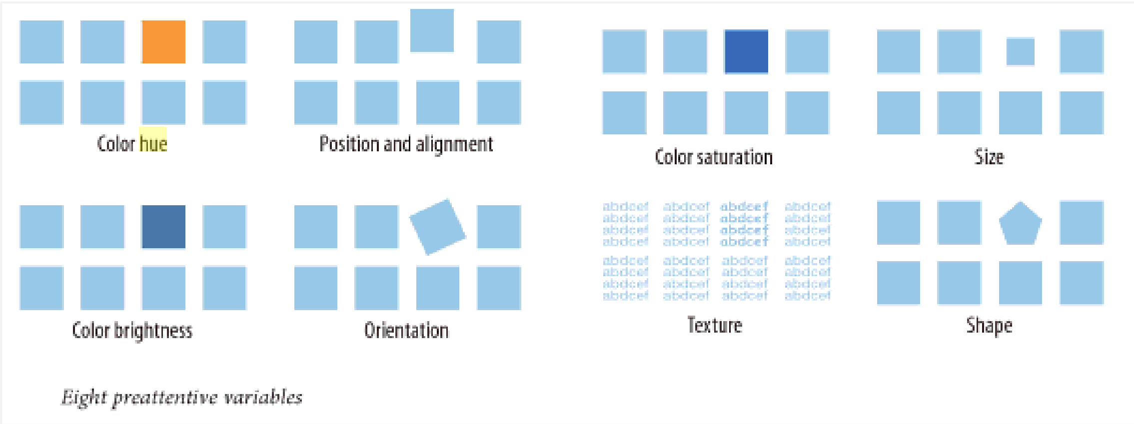

Figure 10. Eight preattentive variables (Tidwell, 2005, p.286)

Color can be used in vast datasets, allowing a quick identification of patterns, trends and anomalies, but less useful in reduced or only two dimensional datasets, because the differences may be too subtle to be distinguished easily and it is sufficient to use only one color (Steele, 2010). However the color can be an asset for data with multiple dimensions, encoding these extra dimensions within the color space. Encoding by size is commonly used because it allows rapid differentiation of objects represented (Matthias Shapiro *In* Steele & Iliinsky, 2010, p.20).

Tufte (2006) states that a graph to be of excellence must respect fundamental principles of analytical design such as to show comparisons, contrasts and differences, to show more than one or two variables, also to completely integrate words, numbers, images and diagrams. Also the graph should document and describe the evidence, providing detailed title and data sources, showing the complete measurement scales, pointing relevant issues, and also that it depends on the quality and relevance of the content represented.

In visualization, taxonomies can also be based on tasks performed by users, in order to process information (Chen, 2012), such as:

- Information retrieval: exploring data through interaction techniques (Shneiderman, 1996).
- Information analysis: attempts to gain insight from data, including tasks such as filtering, making comparisons, sorting, identifying correlations.
- Information dissemination: operations which help the user comprehend the data, such as annotation, animation.

Therefore efficient design of data representation is complemented by combining the data mapping and the visual taxonomies (Heer, 2010).

2.1.2.3. Interaction features

However, graphical perception can be enhanced with an appropriate balance with interaction design and aesthetics (Heer et al., 2010). Interactive information visualization can promote simultaneously an output through the visual representation, and an input, recording ideas or actions performed by the user (Ware, 2004).

Interactive visualization systems, created by computer, combine visualization and interactivity with the principle of active manipulation by the user who immediately views the result of his interaction with the visual display: “Overview first, zoom and filter, then details-on-demand” (Brodbeck, Mazza, & Lalanne, 2009, p. 3).

Interaction indicators may cover a wide range of techniques (L. Manovich, 2010), happening through a predetermined set of tasks and processes of exploration (Heer & Shneiderman, 2012; B. Shneiderman, 1996) that increase the ability to explore and understand data by viewing, navigating and sharing insights with others (Zudilova-Seinstra, Adriaansen, & van Liere, 2009). According to Ware (2004) interactive infovis is increasingly seen as the interface between computer resources and the World Wide Web, which allows information seeking behaviour, supporting activities that allow data exploration. Shneiderman and Plaisant (1996) present six of the seven basic interaction tasks also adopted by other authors:

- Overview task: allows the user to gain a complete overview of the data collection.
- Zoom task: zoom items of the collection in which the user has more interest, adjusting the zoom field or moving the zoom controls.
- Filter task: users can control the highlight and control of items displayed, by filtering interesting or uninteresting items.
- Details on demand task: relating items of the collection, showing its relations by the use of different encoding methods.
- History task: giving the user the possibility of keeping history of actions, sequences of searches, that support him in a progressive refinement of the visualization and information results wanted to obtain.
- Extract task: extract and save the sub-collections as well as query parameters, allowing the user to save for future reference, or to share it with others.

Processes and provenance are also interaction techniques part of the diversity of interaction operations performed by anyone who seeks to understand the data, involving the iterative exploration which is not limited to the manipulation of the visual representation of data, but can also involve the potential of the Web and Web2.0 to augment the iteration process (Heer & Shneiderman, 2012):

- Record: users may analyze data in an exploratory way, generating several views presenting questions and answers and may need to review them. It may be necessary to analyze interaction history, by having a basic undo support, revisit prior analysis, resume incomplete explorations.
- Annotate: allows the user to annotate insights gained during exploration, by graphical annotations, hand drawing, among others.
- Share: to support social interaction, tool should allow the user to export views or data subsets for sharing. An URL can be generated allowing to rapidly navigate to a view of interest.
- Guide: It may be a very simple guide to exploring the workflow to visual analysis. Strategies that guide newcomers through a visual analytics process, and provides experts with progress indicators.

Spence (2007) adds a reference to an alternative visual representation of the data, as a task of interaction, meaning that more than one type of visual display of the data is offered to the user who may choose the one with which he best reads and understands the graph.

2.1.2.4. Aesthetics in information visualization

Aesthetics is today a key factor of infovis which can be associated to the art of visualization, to "the creative translation of data into visual representations" (Cox, 2006, p. 94). New forms of aesthetic emerge enhanced by online media, seeking to attract users by using visual appealing images (Lau & Moere, 2007), focusing on the aesthetic experience. The interpretation of data and the interaction comprise a set of techniques that aim to go beyond simple detection of patterns in the data, transmitting a deeper and more subjective meaning (Lau & Moere, 2007).

McCandless (2010) data journalist and information designer who has aimed his work 'Information is Beautiful'[7] towards the beauty of visualization, minimizing the impact of text and maximizing the combinations between the facts and their connections, their contexts and relationships, making information meaningful, fun and beautiful (Figure 11, Figure 12).

[7] Information is Beautiful: http://www.informationisbeautiful.net/

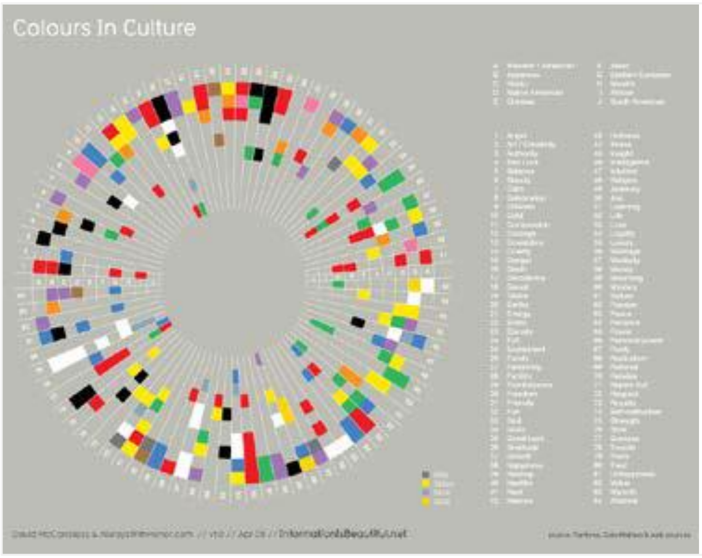

Figure 11. Colours in culture, David McCandless (2009).

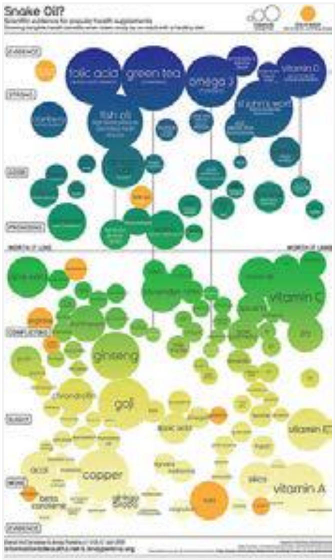

Figure 12. Snake oil David McCandless (2010).

Tufte (2006) alerts that many scientific images are published just because they are just amazing images, without any assistance in understanding it, like having a scale of measurement or relevant comparison. Therefore it is not only necessary to care about the aesthetic aspects of an image, or a graph, it is essential to contextualize when displaying data.

2.1.3. Tools and fields of application of information visualization

For just under two decades, information visualization tools suffered from a lack of existence of solutions and inaccessibility of applications to all potential users, often reusing techniques that had allowed more successful views and tailoring them to a specific domain of application (Heer, Card, & Landay, 2005). Currently the access to infovis tools has increased, allowing its users a vast choice between tools where they can interact with data and visualizations, and tools that enable them to create their own visualizations by uploading a specific dataset. A comprehensive search of infovis tools supported by the web, takes us to an appealing extensive universe in exponential growth. We will divide the tools into the category of infovis tools within which the user can interact to analyse data, and the category of tools that allow the user to create visualizations their own infovis by uploading datasets.

Infovis tools that use real time data and user generated data have become a trend since the massification of mobile devices internet connected. Flowing City[8] a project developed by Margarida Fonseca (2011) built a collection of infovis projects of cartography of the city that visualize community generated data (Figure 13). More than 400 were aggregated, ranging from visualizing

[8] Flowing City: http://flowingcity.com

daily traffic patterns with GPS data, citizens reports of several actions within their city such as heroism reports – data provided by citizens -, crime maps – data derives from police agencies, crime feeds and news outlets -, sexual harassment maps – data provided via SMS – and for example civic engagement visualizations showing real time mobile data provided by citizens in cities around the world. Maps have been included in several projects not merely as a way to visualize geographic data (Behrens, 2008), but also of varied information that can be georeferenced, as shown with the projects in Flowing City.

The result of the massive volume of data produced and stored online every day creates the big challenge, for all areas, to make sense of the data ("Manuel Lima - Visual Complexity", 2009). Manuel Limas' Visual Complexity[9] project indexes over 700 infovis projects of different fields, from biology, business, food, art, music, politics to social networks, showing the different visualization methods (Figure 14).

Figure 13. Flowing city. Margarida Fonseca (2011-2014).

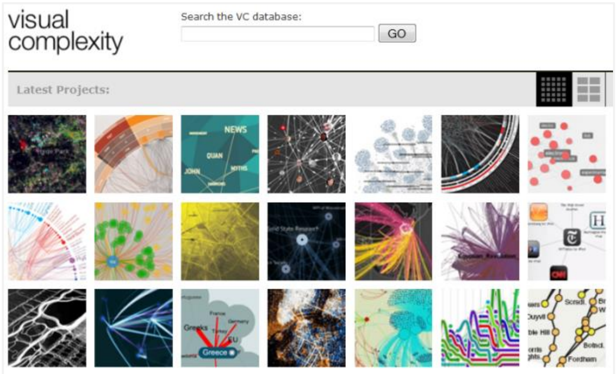

Figure 14. Visual Complexity. Manuel Lima (2009-2014).

There are also applications and tools that visually organize data hierarchies, whether using their numerical or empirical organization as regard the authors Heer, Bostock and Michael Ogievetsky (2010, p. 64): "Special visualization techniques exist to leverage hierarchical structure, allowing rapid multi scale inferences: micro-observations of individual elements and macro-observations of large groups". Example of this approach is the OECD Better Life Index[10] interactive infovis tool to compare well-being across countries, or Map your moves[11] (Figure 15) a cartogram which also maintains statistical data, distorts the shape of the map of the geographical areas so the data can encode a given variable (Heer et al., 2010): we see the exploration of movement of New Yorkers leaving the city in 2010. The map enables user interaction with the information, to search, manipulate and choose specific information of interest to access. These interaction techniques are also frequent in other applications.

[9] Visual Complexty: http://www.visualcomplexity.com/vc/
[10] OECD Better Life Index: http://www.oecdbetterlifeindex.org
[11] Map Your Moves: http://moritz.stefaner.eu/projects/map%20your%20moves/

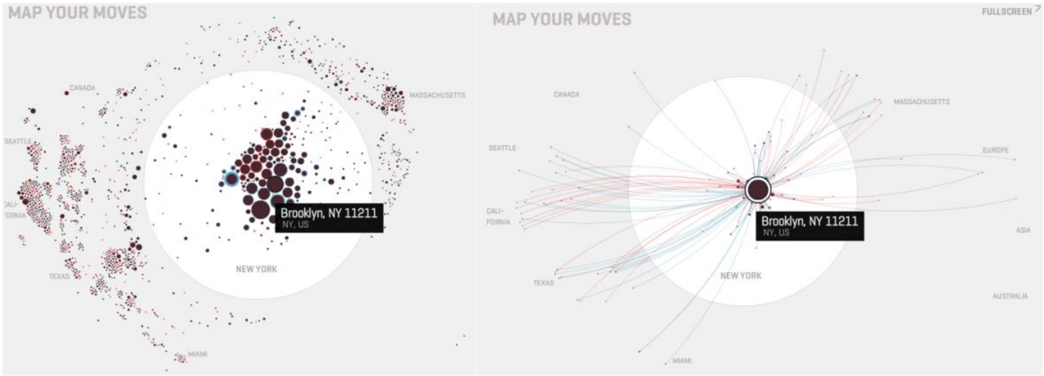

Figure 15. Map your moves. Moritz Stefaner (2010).

In applications such as Newsmap (Figure 16) and Map of the Market (Figure 17) which add-up data and latent information on the Internet, allowing for updated data views. Newsmap visually reflects the constantly changing landscape of the Google News, as the author says “Newsmap's objective is to simply demonstrate visually the relationships between data and the unseen patterns in news media” (Marumushi, 2004). While Map of the Market provides current information on the stock market values - this belongs to the digital The Wall Street Journal. Both are represented in enclosure diagram, another form of hierarchical tree view, as defined Johnson and Shneiderman (1991).

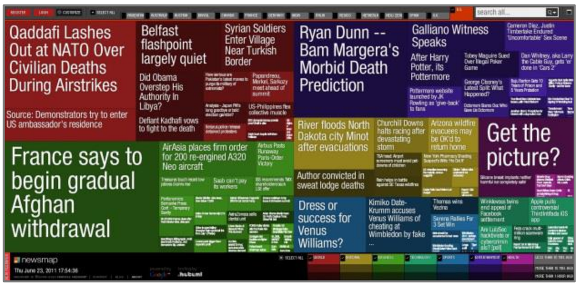

Figure 16. Newsmap.

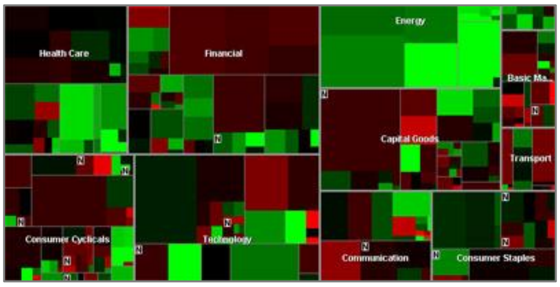

Figure 17. Map of the Market.

Visualization tools of data from the field of education vary from statistical data of countries as allowed to explore (data and visualizations9 in the Education GPS[12] an OECD project aiming to visually present OECDs’ international comparable data on education; the DUST[13] project provide a freely available, web based information visualization tool that supports parents in exploring and comparing the educational offerings from major cities in the United States; ‘Adults With College Degrees in the United States, by County’ (Figure 18) mapping census data relating to individuals school levels allowing a temporal analysis; The ‘Education Eye mapping inovations’ (project ended) (Figure 19) was an interactive visual mapping tool that aggregated the feeds of innovations from educational websites, forums and case studies; University Autonomy in Europe[14] (Figure 20) ranks and rates Higher Education systems from 28 European countries according to their

[12] Education GPS: http://gpseducation.oecd.org
[13] DUST: http://www.densitydesign.org/research/dust/
[14] University Autonomy in Europe: http://www.university-autonomy.eu/

autonomy in finance, staffing, organizational and academic; Politikatlas Schulreform[15] (Figure 21) a visualization of the German schooling structure in each of the 16 different federal states (infosthetics, 2010); Schooloscope[16] (project ended in 2012) turned official government data about over 20,000 schools in UK, into easy to read visual summaries to help parents choose the best schools.

Figure 18. Adults With College Degrees in the United States by County.


Figure 19. Education Eye mapping inovations.

Figure 20. University Autonomy in Europe.

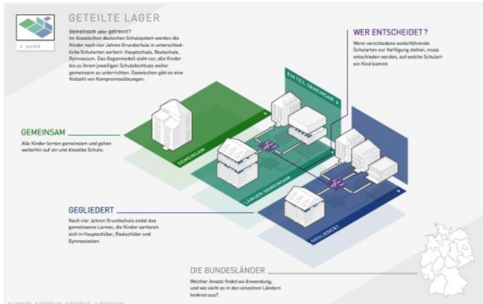

Figure 21. Schooloscope.

2.1.4. Tools for creating visualizations

Nowadays creating visualizations is both accessible to experts and non-experts. To create a visualization we need data, analytical tools and visual displays (Viégas, *et al*, 2007; Zanconato, n.d.). This section is dedicated to the analytical tools accessible to anyone who wants to manage datasets and create visualizations.

Information visualization tools that offer the possibility for any user to upload a dataset and create graphs, are becoming more user friendly. This is a growing market where the user can choose from free and open access tools, to paid tools. The free open-source software can be downloaded and used by anyone, to turn existing datasets into interactive and dynamic graphics in their computer. In web interface tools users can work and create dynamic graphics on the web browser.

[15] Politikatlas Schulreform: http://www.politikatlas.de
[16] Schoolscope: http://berglondon.com/projects/schooloscope/

There are many software options available, Protovis[17] and D3[18] (Figure 22) are two examples of JavaScript library, created in 2009 by the same author, Mike Bostock, as graphic kits, free and open-source which can be downloaded and used to represent both static or animated and interactive visualizations. Polymaps (

Figure 23) is also a free JavaScript library to create interactive and dynamic maps in web browsers, allowing the user to load geographical data from multiple scales (countries, cities, neighbourhoods, streets) and define the design of the data.

Figure 22. D3 data-driven documents.

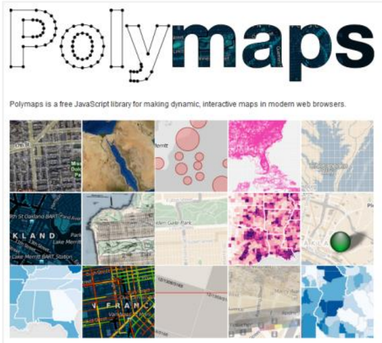

Figure 23. Polymaps.

Processing[19] founded in 2005, has a similar approach to the previous examples. It is a website that makes available for download a library of visualizations in the processing language, to assist the creation of interactive, aesthetic visualizations, graphics, videos and interactive animations, enabling the visual result to be embedded into a web page. Requires that the user knows how to code using Processing language.

User friendly software is the GapMinder, Many Eyes or Raw, all open and accessible through a web site where users may directly upload data, create interactive visualizations and share the results.

GapMinder[20] founded in 2005 by Hans Rosling, Ola Rosling and Anna Rosling Rönnlund, has two types of services freely available: analysis of countries statistical data, presentation of up-to-date data in animated and interactive statistics time series graphics in order to show major global development trends .and the software can be downloaded and used in a desktop.

Many Eyes software[21] was created in 2007 and upgraded into a second version in 2013 (Figure 24), both versions are maintained online and are open access. This web based tool allows users to upload datasets of different types of data - numeric data or tab-delimited or full text files -, and choose the type of graphics to create a visualization. Visualizations can be saved in the website or

[17] Protovis: http://vis.stanford.edu/protovis
[18] D3: http://d3js.org/
[19] Processing visualization language: http://processingjs.org/
[20] Gapminder: http://www.gapminder.org
[21] Many Eyes version2: http://www-958.ibm.com/software/analytics/labs/manyeyes/#home

shared within the website. Users can collaborate by posting asynchronous comments to the graphics created and published. As the authors of Many Eyes explain:

> "[t]he goal of the site is to support collaboration around visualizations at a large scale by fostering a social style of data analysis in which visualizations not only serve as a discovery tool for individuals but also as a medium to spur discussion among users. To support this goal, the site includes novel mechanisms for end-user creation of visualizations and around those visualizations." (Fernanda Viégas et al., 2007, p. 1)

The first version of Many Eyes did not allow a user to delete a visualization created, they became immediately public, this has been changed in the latest version giving the user the power to decide if the graph created becomes public.

A recent tool, Raw[22] (Figure 25) was created in 2013 by Giorgio Caviglia, Giorgio Uboldi, Matteo Azzi and Michele Mauri at the DensityDesign Lab, is an open web tool to create vector-based visualizations, based on D3s library (mentioned above) allowing the users to upload data files or paste datasets numerical and text, and visually represent it by choosing from seven types of visual displays, and by manipulating color, grid and labels. The visual result can be exported or embedded in html.

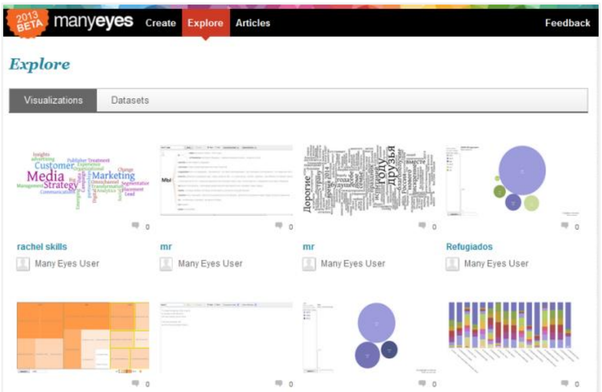

Figure 24. Many Eyes software version2 (2013).

Figure 25. Raw. Density design (2013).

Many other tools have emerged, democratizing data exploration and representation: Google Databoard to explore insights from Google research studies, create your own custom infographics and share them with others; Datamarket[23] and Q Research[24] allows users to explore datasets for enterprise use, uploading, creating a visualization and sharing. Also there have emerged tools that allow anyone to analyse their own network data created from personal social networks, generating visualizations. Fizz[25] (Figure 26) is an application that collects data on the publications of personal Facebook and Twitter accounts at users request, generating a visualization of the clusters of who

[22] Raw: http://raw.densitydesign.org
[23] Datamarket: http://datamarket.com
[24] Q Research: http://www.q-researchsoftware.com
[25] Fizz: http://fizz.bloom.io

publishes and shares content within your network, what is published and when. Also social network sites, such as LinkedIn are offering users the possibility to map and analyse their network (Figure 27).

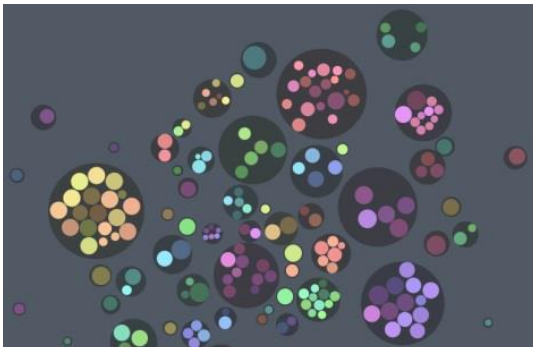

Figure 26. Fizz.

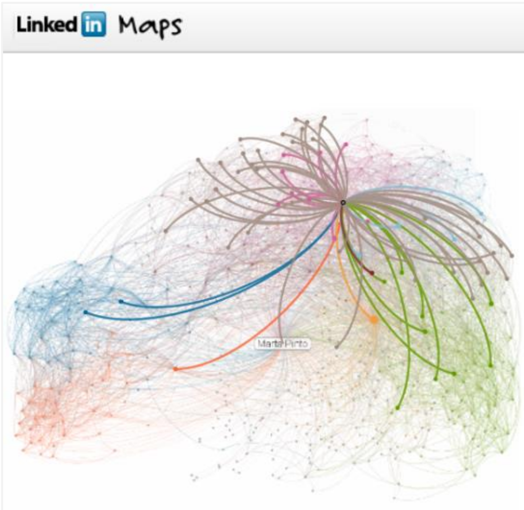

Figure 27. LinkedIn Map.

2.2. Data about Higher Education, where we are and the trends

In this section we present a historical overview of the data collection processes regarding education and higher education, and present a set of web tools that present education and HE data, highlighting the existing HE Transparency tools.

2.2.1. The historical overview of statistical data on Education

The collection of data about education contexts derives from the 19th century, when education was recognized as a statistical field. In the historical overview about the rise of data collection in education, Lawn (2013) documents the recognition that having comparative data on education was a problem because the existing statistical data up to the 1950s was presented in countries' own terms. A crucial step towards the collection of comparable data aimed to solve the need of international comparable data and having definitions, terms, classifications and tabulations of educational statistics. It was only after the 1950s that it became possible to create an international agreement built about the definitions and terms of the classification of education by UNESCO (Smyth, 2008),., and in the 1960s the network of research centres from different countries joined to develop international projects on school research through the International Association for the Evaluation of educational Achievement (IEA) ("International Association for the Evaluation of educational Achievement," 2011; Lawn, 2013). This influenced the growth of international cooperation and made the influence of education data grow (Lawn, 2013).

UNESCOs offered predominantly comparable data of a descriptive nature, because their main concern was about the diversity of the education systems and not to produce rankings (Cussó & D'Amico, 2005). This approach was criticized by organizations such as Organization for Economic Cooperation and Development (OECD) and the World Bank, who in the 1990s started to approached education towards statistical comparability in order to allow a ranking comparison of countries (Cussó & D'Amico, 2005).

The arrival of OECD intensified the European research collaborations headed for cross-national comparison studies on the performance of entire systems, engaging in collection and analysis of statistical data (Lawn, 2013). In mid 1990s the OECD created the Programme for International Student Assessment (PISA), surveying education systems from various countries - 70 countries until 2012 -, regarding public policy issues, literacy, lifelong learning ("OECD Programme for International Student Assessment (PISA),"). It was until 2003 that UNESCO published the first rankings of countries (Cussó & D'Amico, 2005).

OECDs', UNESCOs' and The World Bank organizations have been collecting statistical data about countries HE, with regularity over the years. OECD through a feasibility study for the Assessment of Higher Education Learning Outcomes (AHELO) (OECD, 2013b), has collected data by countries, regarding: private expenditure in tertiary education; attainment of tertiary education by type of program; expected completion of tertiary education, completion rates and areas; annual expenditure per student; how much tertiary education students pay and public support received; students in tertiary education, by percentage share in type of institution or mode of enrolment; expected entries of students in tertiary education; international mobility of tertiary students; structure, finances, and performance of education systems in more than 40 countries (OECD, 2013a, 2013c). UNESCO, through the UNESCO Institute for Statistics collects statistical data about national education systems worldwide, including tertiary education, regarding: entry requirements, entry age, duration and diplomas obtained (UNESCO, 2013b). This data collection begun in 2007 and has an international comparative framework. The World Bank collects data about countries tertiary education, regarding: expenditure per student; ratio of female to male enrolment; School enrolment.

Also the European University Association (EUA) has collected comparable data regarding countries universities autonomy in 29 European higher education systems, in the year 2010, focusing on four autonomy areas of autonomy: organizational; financial; staffing; academic. and ranks countries according to the level of autonomy they have in each of these (Thomas Estermann, Nokkala, & Steinel, 2011). The data was provided by the national rectors' conferences, through a survey by questionnaire process.

2.2.2. Overview of rankings of Higher Education Institutions

There is also a great demand for comparative information on international HEI, so institutions and governments can better ensure quality of HE, and students can make more informed decision when seeking to enter university (UNESCO, 2013a). But comparable data regarding HEI is more complex to gather because of countries different organizational systems and the difficulty in measuring quality issues. Also data on HE, as any other data of other area of interest, can have many strands. It can be open data presented in an accessible format or in various formats, it can be disperse or already collected, and have been collected by different entities, organizations, institutions, through different methods, measures and data sources.

Nevertheless university rankings attempt to fill that gap of HE data, namely providing HEI comparable data and information through rankings. A ranking system is when the data is fed into a scoring and weighting system, and the results appear in a hierarchical order (Thomas Estermann et al., 2011; Vercruysse & Proteasa, 2012).

Rankings or league tables, although varied in their methodologies and underlying measures, facilitate data collection about HEI (UNESCO, 2013a). Not surprisingly the data most often encountered is from a set of indicators that can be more easily measured, rather than from indicators which have to rely on correlations (Hazelkorn, 2013). Rankings about HEI are mainly supported by indicators that focus on research and performance mostly using bibliometric methods (Hazelkorn, 2013). Fewer rankings resort to survey methods, applying questionnaires to collect data in order to rank HEI, although in our research we have identified 4 of these rankings. This is evident when analysing the data sources of the top HE rankings on **Erro! A origem da referência não foi encontrada.**, composed of the top 10 rankings proposed by Hazelkorn (2013) that largely measure a vast number of institutions worldwide, to which were added 2 other rankings we considered relevant.

Table 2. Global rankings list -proposed by Hazelkorn (2013, p.3) and transparency tools, per indicators and data sources. Date indicates the date-of-origin of the ranking; (*) inacessible rankings; (**).

Academic Rankings	Data indicators	Data sources
Academic Ranking of World Universities[26] (ARWU), Shanghai Jiao Tong University, 2003.	• Alumni. • Awards. • Highly cited researchers. • Number of papers published in Nature and Science. • Publications. • Per Capita Performance.	• National Ministry of Education, National Bureau of Statistics, National Association of Universities and Colleges, National Rector's Conference. • Nobel prise list. • International Mathematical Union Fields Medallists list. • Highly cited research, Thomson Reuters. • Web of knowledge, Thomson Reuters.
Webometrics[27] (Spanish National Research Council), 2003.	• Performance of universities from all over the world based on their web presence and impact: Visibility; Activity.	• Google, Google scholar. • Institutions web pages. • Web link databases. • Web index of links. • SCImago Institutional Ranking.
Performance Ranking of Scientific Papers for Research Universities[28], 2007.	• Research productivity • Research impact • Research excellence	• ISI's ESI and Web of Science, which included SCI and SSCI, and Journal Citation Reports.
Leiden Ranking (Centre for Science & Technology Studies[29], University of Leiden), 2008.	• Scientific performance. • Fields: Biomedical and health sciences; Life and earth sciences; Mathematics and computer science; Natural sciences and engineering; Social sciences and humanities	• Web of Science bibliographic database by Thomson Reuters.
World's Best Colleges and Universities[30] (US News and World Report), 2008. (*)		
SCImago Institutional Rankings[31] , 2009.	• Bibliometric indicators: scientific impact, thematic; specialization, output size; international collaboration networks of institutions.	• Scopus database
Global University Rankings (RatER) (Rating of Educational Resources, Russia), 2009. (*)		
Top University Rankings[32] (Quacquarelli Symonds), 2010.	• Faculty student • International faculty and students • Citations per faculty • Academic reputation • Employer reputation	• Scopus database • Global survey: applied to academics and graduate employers.
Times Higher Education/Thomson Reuters - World University Ranking[33], 2010.	• Teaching • International Outlook • Industry income • Research • Citations	• Thomson Reuters' Web of Science database. • Thomson Reuters' Global Institutional profiles database • Survey: academic reputation survey. • Validation of the data by institutions
U-Multirank[34] (European Commission), 2011.	• Teaching and learning • Research • Knowledge transfer • International orientation • Regional engagement	• Bibliometric and patent indicators are analysed based on existing data bases. • Questionnaire institutional data. • Questionnaire field-based data. • Questionnaire student survey.
University autonomy in Europe[35] (European University Association) 2012 (**)	• Organizational autonomy • Financial autonomy • Staffing autonomy • Academic autonomy	• Questionnaire HE system autonomy: applied to the national rectors' conferences.
CPS International ranking[36], 2012. (**)	• Use of Information Communication Technology in teaching, enhancing quality, and for effective university education.	• Survey by interview, to 250 East African Universities

[26] Academic Ranking of World Universities: http://www.shanghairanking.com
[27] Webometrics: http://www.webometrics.info
[28] Performance Ranking of Scientific Papers for Research Universities: http://nturanking.lis.ntu.edu.tw/Default.aspx
[29] Leiden Ranking: http://www.leidenranking.com
[30] World's Best Colleges and Universities: http://www.usnews.com/usnews/store/college_compass.htm?src=bar
[31] SCImago Institutional Rankings: http://www.scimagoir.com
[32] Top University Rankings: http://www.topuniversities.com/university-rankings
[33] Times Higher Education - World University Ranking: http://www.timeshighereducation.co.uk/world-university-rankings
[34] U-Multirank: http://www.umultirank.org
[35] University Autonomy in Europe: http://www.university-autonomy.eu
[36] CPS International ranking: http://www.cps-research.com/index.php?option=com_zoo&view=frontpage&Itemid=240

From the total of the 12 rankings analysed, 9 rank institutions and 1 ranks countries HE system (University Autonomy in Europe). The data mostly conveyed in the rankings concerns HEIs performance in relation to research, citations and publications, having as data sources bibliometric data spaces such as Scopus or Thomson Reuters. Disproportionately data about teaching and learning is approached, only by two rankings, which between themselves offer distinct data. The Times Higher Education enables access to data about teaching and learning environment from an academic and students perspective, data collected by an invitation only survey and which final score is made accessible by ranking institutions.

The U-Multiranks' ranking has a multidimensional approach and enables the access to in-depth data about teaching and learning in the institutional, field based and student perspectives (Frans van Vught & Ziegele, 2011). The institutional perspective offers data for teaching and learning based on the indicators of expenditure on teaching, graduation rate, interdisciplinary programs, relative rate of graduate (un)employment and time to degree. The field based ranking is based on the indicators of Student-staff ratio, graduation rate, Investment in laboratories, Qualification of academic staff, interdisciplinary of programs, inclusion of issues relevant for employability in curricula. Finally the Student satisfaction indicators are based on the overall judgment of the program, research orientation of educational program, Evaluation of teaching, Facilities, Organization of program, Promotion of employability (inclusion of work experience), Quality of courses, social climate, Support by teachers, Opportunities for a stay abroad, Student services and University webpage.

Other rankings offer data about the number of students or of awards granted, while others offers data such as the visibility and activity of an institution on the web.

The diversity of the data is also a result of the distinct data collection methods. Four of the rankings collect quality data and validate it directly provided by HEI (U-Multirank, CPS), and in the case of U-Multirank a multidimensional data collection allowing access to comprehensive datasets, or in the case of University Autonomy in Europe directly provided by HE rectors' conferences. This evidences that digital technologies have allowed the handling, access and manipulation of data-sets, in the case of rankings to benefit HE stakeholders, and simultaneously, helping to envision how HEI compare, strengthening international communication and transparency (OECD, 2012a).

U-Multirank features an exclusive approach of data collection, differentiating itself from the other rankings. Data is collected by calling upon HEI to provide data about their own institution, and three questionnaires are applied: institutional data, field-based data and student data. This allows data about the quality of study and teaching, and services to the community (EUROASHE, 2012). This ranking makes available more detailed data on each indicator of the HEI, not simply presenting a league table result.

'Top University Rankings' also adopts the approach of applying a global survey about institutions reputation, for which there is no direct inquiry to HEI, but is made an open call to academics and graduate employers, only considering answers regarding the institutions the respondents do not belong to (Symonds, 2012).

The Times Higher Education ranking has a tangent approach, by involving HEI in part of the collection of the data, and in the validation of data.

Searching beyond the top rankings listed in **Erro! A origem da referência não foi encontrada.**, we deepened the search for rankings or HEI data tools that focus on the same topic treated by the U-TRACER®: the use of Communication Technologies in support to teaching and learning practices. We found evidence only of one existing ranking: the Centre for Public and Social Research (CPS) international ranking, (produced by a Market and Social Research Company by surveying 250 East African universities of 5 countries during the year of 2012. The data was collected by applying the method of face-to-face interviews: "[…] how the universities and higher education institutions in this region have embraced the use of Information Communication Technology in teaching and enhancing quality and for effective university education in East Africa" (CPS, 2012, p. 1). This data was used to rank the top 100 HEI in East Africa that have institutionalized the use of ICT strategically to follow worldwide university best practices of management, development and provisions (CPS, 2012).

By participating in the data collection and validation processes, institutions are able to best contribute with quality data and to detail on the diverse institutional contexts and HE systems important to consider when comparing HEI. Therefore rankings are contributions to the transparency agenda in higher education (Costes, Hopbach, Kekäläinen, van IJperen, & Walsh, 2010; UNESCO, 2013a).

2.2.3. Transparency tools of Higher Education that make use of information visualization[37]

A knowledge economy is more competitive, transparent and widens access to information relevant for all the stakeholders of any field. Higher Education is one of the fields gradually grasping the advantage of transparency and competitiveness to involve all its stakeholders, for benchmarking practices, comparing strengths through comparable data and adequate indicators (Proteasa, 2010). Result of the economic and financial crisis of the 2000s, set to the world the new challenge of restructuring the knowledge society, in which HE should be deeply involved through education and training, applied research and knew knowledge (EURASHE, 2012).

In the European context, the European Union (EU) and European Commission (EC) recommended the Bologna reform to answer to these new challenges, and this reform strived for transparency by

[37] Part of this sections content was published on the proceedings of the international conference on Information Visualization IV2012 (Pinto, Raposo, Ramos, 2012).

introducing transparency tools to help HE systems and institutions identify and compare strengths (EHEA, 2012; ENQA, 2011; EUROASHE, 2012). Also the Lisbon declaration recognizes that the evolution of universities from elite to mass systems of HE implies diversity of institutional profiles, missions and strengths (EUA, 2007). Transparency tools assist this transparency. These tools may consist of benchmarking exercises, classifications of study programs, rankings, quality profile of HEI, or comparable information (EHEA, 2012). As a result of this incentive many projects have been developed - U-Map; U-Multirank; University Autonomy in Europe (**Erro! A origem da referência não foi encontrada.**).

Table 3. European Transparency tools.

Name	Type of tool	Dimensions	Presentation type
U-Map[38]	Classification	‣ teaching and learning profile ‣ student profile ‣ research involvement ‣ regional engagement ‣ involvement in knowledge exchange ‣ international orientation	Interactive visualization: interaction through information filters.
U-Multirank	Ranking	‣ Teaching and learning ‣ Research ‣ Knowledge transfer ‣ International orientation ‣ Regional engagement	Interactive Visualization and league table: interaction through information filters.
University Autonomy in Europe[39]	Benchmarking	‣ Organizational autonomy ‣ Financial autonomy ‣ Staffing autonomy ‣ Academic autonomy	Interactive visualization: interaction through information filters and the graph. Institutional profile card: contextual information; graphical information.

Transparency tools can be reliable if they have good indicators to measure what they claim, if the data is accurate, and if the "[…] users understand where the differences in the results provided come from."(Vercruysse & Proteasa, 2012, p. 20). Rankings and classifications tools are also transparency tools, that provide comparable data about HEI and study programmes, while the first offer hierarchies according to the score of individual elements evaluated, and the second offer clusters of HEI, built around relevant indicators (Vercruysse & Proteasa, 2012).

As mentioned in the previous section, the HE sector generates and consumes a great volume of data, but which is frequently disperse and in diverse formats making it difficult to access (Yanosky & ECAR, 2009). Therefore it is useful to have data be communicated in a comprehensive way, mainly data of interest to enabling for HE stakeholders: "The great challenge of institutional content management is to provide tools that allow the right people to create, publish, find and preserve, or winnow the right content according to the needs of the institutions" (Yanosky & ECAR, 2009, p. 12). HEI and governments are also making use of the information disseminated through ranking, rating

[38] U-Map: http://www.u-map.org/
[39] University Autonomy in Europe: http://www.university-autonomy.eu/

or transparency instruments.

Ranking and transparency instruments have had a media impact, raising interest, criticisms, but above all discussions around their impact on institutions and stakeholders decisions (Kaminer, 2013; J. Morgan, 2013; U-Multirank, 2013). Two examples of this impact, are reported by The New York Times: the plan raised by the President of the United States, Obama, to rate colleges on their value and affordability and tie that to the financial aid supplied every year by the federal government (Kaminer, 2013); and also, closely followed by HEI presidents the World's Best Colleges and Universities ranking (number 5 of the list shown in **Erro! A origem da referência não foi encontrada.**) is offering an additional list of Best Value Schools[40],ranking those that offer the best value (grants, tuitions) according to ratio of quality to price, need-based aid, and average discount (Kaminer, 2013; US News) affecting students choice of institutions.

A media arousal has also generated, in 2013, heated discussions around U-Multirank launching. Entities such as the League of European Research Universities (LERU) criticized U-Multirank calling it “(…) a threat to a healthy higher education system”, and the UK HE International Unit publically criticized its’ validity because data is provided by institutions themselves, accusing it to allow a misunderstanding of the facts. Supporters of the new tool also entered the public discussion, individual professors (U-Multirank, 2013), organizations such as the European Commission’s Directorate General for Education, and the European Student Union stated that stated the usefulness of the new tool enhancing the understanding of HEI by including the social dimension of higher education (ESU, 2013).

Within the context of the massification of HE and its growing stakeholders, the positive side of rankings and transparency instruments is that they respond to the growing demand to make informed choices (UNESCO, 2013a). Being valuable to decision makers, data and its visibility on the web may give institutions prestige, help them attract students, scholars and financial investment (Butler, 2010; Ortega et al., 2008).

These instruments are presenting information relatively simply on the quality of higher education institutions, in an accessible and manageable format. The trend has been to present information organized in a league table format, but a new trend is emerging through the use of information visualization techniques to assist communication of data and easy to read and analyse institutional individual data, according to the diverse indicators of analysis.

Because the focus of this study is on data about HEI and the use of information visualization to make that data more easily perceived, we have analysed the lists of rankings and classification tools in Table 2 and Table 3, and chose to describe the four tools that adopt infovis techniques to communicate the data to the end user:

[40] World's Best Colleges and Universities, Best Value School: http://colleges.usnews.rankingsandreviews.com/best-colleges/rankings/national-universities/best-value

1. U-Map
2. U-Multirank
3. University Autonomy in Europe
4. The Times Higher Education ranking

Describing the transparency tools

The interest and need for transparency in European HE, has led to the creation of three online transparency tools, all of which have strategically adopted information visualization techniques to represent data about the profiles of European and non-European HEI. The dimensions of the data and the infovis techniques adopted will be described below.

U-Map[41] is a HEI classification tool of any type or focus of the institution (private, public, university or polytechnic). It offers the user the possibility to create a variety of comparable profiles of institutions, according to 6 dimensions: 1) teaching level and subject focus; 2) student body; 3) research intensity; 4) knowledge exchange; 5) international involvement; 6) regional involvement (Rauhvargers, 2011). The data sources are both existing European data sources to a very limited extent, and data provided by the participating HEI, to a larger extent through two country-specific online questionnaires pre-filled with information. The online questionnaires explored the relevance of the dimensions and its indicators (F.A. van Vught, 2010). Additional, in the tool, information on the dimensions will be presented by a set of context characteristics that may be useful for deeper analysis and understanding of the differences between institutions. The additional information regards country of origin, founding year of the institution, link to its website, legal status (public or private), mission, vision, goals, and graduates by educational field (F.A. van Vught, 2010) . Nonetheless, it is important to reveal that the contextualization information did not exist in the first demo of the U-Map tool[42] (Frans van Vught, File, Kaiser, Jongbloed, & Faber, 2011). As we witnessed in 2011, in a U-Map workshop developed in Portugal, the lack of contextualizing information about HEI arose a strong discussion and concern, strengthening the position about the need to include such information mainly because the tool allows comparison between institutions, and risk of misinterpretation of the data: one example of a concern of a misinterpretation considered the measurement of doctorate degrees awarded, and the need to clarify that polytechnics in Portugal cannot award such a degree.

U-Map is an interactive information visualization tool, with integrated interaction features such as filters to select a set of dimensions and indicators of information of interest of the user (Figure 28). The institutions listed can be compared between themselves, minimum of 2 HEI to unlimited number of HEI (Figure 29), according to the filters applied. To assist the users understanding of the context of each institution, the tool provides an institutional profile card (Figure 30) adding

[41] U-Map: http://www.u-map.org/
[42] First demo of the U-Map: http://www.u-map.eu

information about: Location; Founding Year; Website; Legal Status; Mission Statement; and Graduates by educational field

The visual metaphor adopted in U-Map is a sunburst chart, coded in the size of the rays to represent difference in quantification of the indicator, and with color code in the rays according to the dimensions of the data under analysis. Also in the institutional profile card is used a pie chart to present data about the number of graduates by educational field. The labels in both graphs are dynamic.

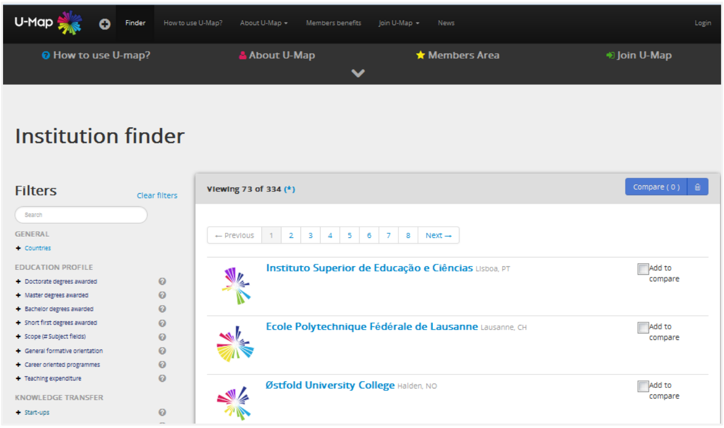

Figure 28. U-Map interaction tasks with filters.

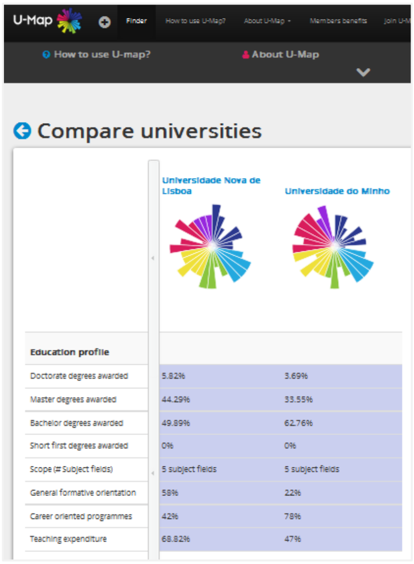

Figure 29. U-Map comparison of two institutions.

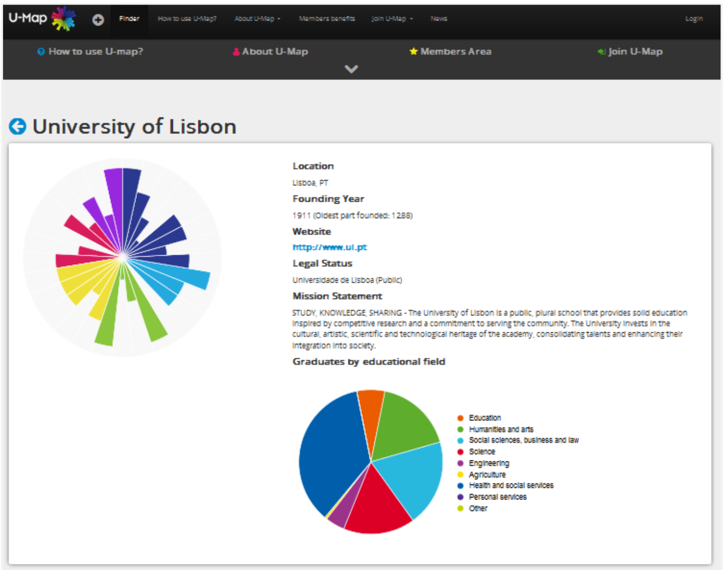

Figure 30. U-Map institutional profile card.

The main audience of this tool are HE stakeholders – students, leaders -, with the main goal of helping them support their decision-making and inform on the quality and diversity of HE and research (F.A. van Vught, 2010).

U-Multirank[43] tool is a global university multi-dimensional ranking, on the institutional and the field levels. It will offer the possibility to access information about 5 main dimensions measured by a series of indicators: 1) teaching and learning; 2) Research; 3) Knowledge transfer; 4) International orientation; 5) Regional engagement. The data sources are bibliometric and patent indicators on existing data bases, and three different questionnaires applied to institutions so they can provide the data: questionnaire institutional data; questionnaire field-based data; questionnaire student survey.

The tools' web interface will become public in the year 2014. Nevertheless we have some insights regarding the features of the interface revealed in the U-Multirank final report. The tool consists of a web interface that offers the users the possibility to filter information and select HEI performance indicators according to users preferences and priorities, and therefore define the institutional profile they are interested in and hence the sample of institutions to be compared, gaining a detailed view of institutional profiles (Frans A. van Vught & Ziegele, 2012b). HEI will be presented in a ranking order hierarchical and by user selected groups as shown in Figure 31, to compare institutions or fields that can be compared: institutional ranking is based on the five performance dimensions of an institution as whole; field-based ranking is based on the indicators in a specific field in which institutions are active. The performance is indicated by a coloured circle with diferent sizes, indicating a scale of performance (Figure 31) (van Vught & Ziegele, 2011).

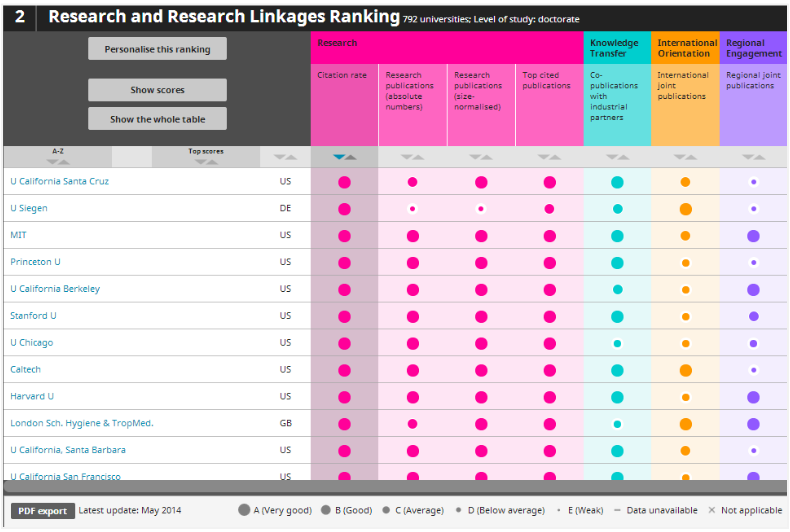

Figure 31. U-Multirank: Reserach and research linkages ranking (2014).

A profile of an institution can be consulted by indicators and by field, with the result presented in a sunburst chart, where the size of the ray indicates a higher or lower performance, and the color of the ray represents the dimension to which it belongs (Figure 32).

[43] U-Multirank: http://www.u-multirank.eu/

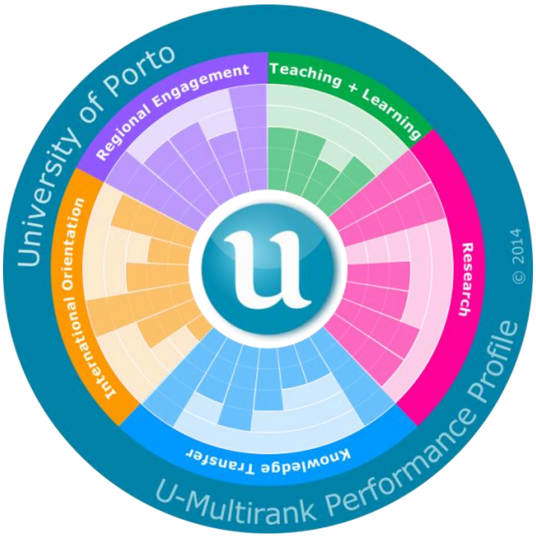

Figure 32. U-Multirank sunburst representation of an institutional performance profile (2014).

The principal audience of this tool are different HE stakeholders – students, leaders, academics, policy makers -, with the principal goal of supporting different decisions regarding HE and research institutions (Frans A. van Vught & Ziegele, 2012a; Westerheijden & Ziegele, 2013).

U-Map and U-Multirank are outcomes of the EU and EC recommendations, both serving the aim of informing and disseminating information about quality of HEI and make use of wide-ranging institutional information, provided by institutions themselves (EUROASHE, 2012). They add new highlights to the practice of well-known global rankings by taking into account, for example, quality of study and teaching (Kaiser & Jongbloed, 2010), and by offering a new approach to user-driven rankings (Frans van Vught et al., 2011). The institutional profiles of U-Multirank rely on multidimensional rankings already created in U-Map. The difference lies in the organization of the information, while U-map as a classification tool offers the possibility to create clusters of institutions to compare, U-Multirank offers the comparison between institutions in a raking hierarchical organization (Federkeil, File, Kaiser, van Vught, & Ziegele, 2012).

University Autonomy in Europe tool[44], ranks and rates HE systems from 28 European countries according to four dimensions of autonomy: organizational, financial, staffing and academic (Figure 33). The data represented was provided by the countries national rectors' conferences, the representative organisations of universities (Thomas Estermann et al., 2011).

Countries are presented in a ranked order according to the dimensions, also being possible to obtain a detailed view by country by dimension and indicator. The tool also offers a country rating, by creating clusters of countries for each indicator (Figure 35).

The graphical metaphor adopted is sunburst-like, in which the rays represent unique indicators built

[44] University Autonomy in Europe: http://www.university-autonomy.eu/

by multiple color squares that show the score of each indicator. The more autonomous the HE system is, the more color squares there are per ray (Figure 34). The graph is coded by color, representing dimensions, and by size that represents the score of a dimension and its indicator. A high score on an indicator or autonomy dimension indicates that the relevant regulations provide a legal framework without restricting universities in their freedom of action (Thomas Estermann et al., 2011).

In the year of 2012 at the conference “University Autonomy in Europe: The Autonomy Scorecard Project and the case of Portugal”, organized by *Conselho de Reitores das Universidades Portuguesas* (CRUP), we interviewed Thomas Estermann[45], coordinator of this project (Appendix 1 - Transcript of the interview made to Thomas Estermann). When questioned about the process of development of the tool, Estermann stated that the vision was to have an interactive tool, pleasant for the user by being easy to interact with and to look at:

> “Because there is an enormous amount of data which is very dry to look at it if you only have the data. So we wanted to have something that’s a bit more playful as well, and then have different layers of information, so depending on if you want to get a quick information you can get this overview, if you want more detailed information you can get it in the same way according to what you did.” (Estermann, 2012)

Figure 33. University Autonomy in Europe: homepage (2011).

Figure 34. University Autonomy in Europe: country sunburst chart (2011).

45 Thomas Estermann is Head of the Unit Governance, Autonomy and Funding with responsibilities for EUA’s work aimed at strengthening universities' autonomy, governance, management and their financial sustainability. Information retrieved from http://www.eua.be/about/who-we-are/secretariat/thomas-estermann.aspx

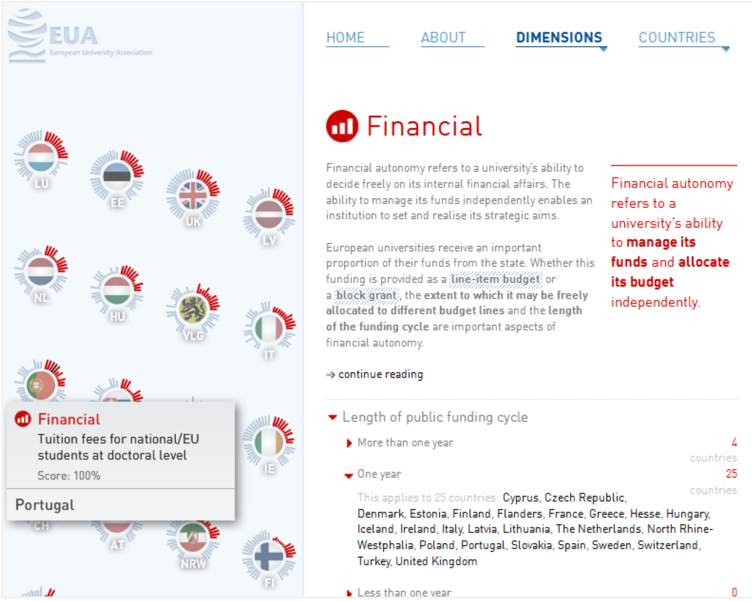

Figure 35. University Autonomy in Europe: financial dimension (2011).

The principal audience of this tool are policy makers, researchers, and its principal purposes are of benchmarking of national policies and awareness-raising among universities, and to provide comparable to establish relations between autonomy and other concepts (T. Estermann & Nokkala, 2009).

Times Higher Education World University Rankings[46], created in 2010, is a university performance ranking table based on 13 performance indicators grouped in five main categories: 1) teaching; 2) research; 3) Citations; 4) Industry income; 5) international outlook. Also rankings can be created for six broad categories: Arts & Humanities; Clinical, Pre-clinical & Health; Engineering & Technology; Life Sciences; Physical Sciences; and Social Sciences.

The data sources are, as listed previously in **Erro! A origem da referência não foi encontrada.**, are the Thomson Reuters' Web of Science database, and Global Institutional profiles database that gathers data directly from HEI through an academic reputational survey, gather of institutional data (bibliometric data, statistical data) and validation of that data by HEI. Quantitative data collection integrates the rankings backbone (Figure 36), whereby more qualitative data on the context of HEI integrate their profiles (Figure 37).

The tool offers users the possibility to generate rankings by filtering data by region or subject, and by categories. The user can also make a comparison of the data over time, by filtering the year to which the data reports on an interactive slider.

The ranking is presented in a league table list of HEI, and has chosen to add a visual

[46] The Higher Education World University Rankings: http://www.timeshighereducation.co.uk/world-university-rankings/2013-14/world-ranking

representation to show the overall score for each category. The representation is a rectangular bar for which is attributed one different color for each category, and which size varies depending on the score of the HEI (Figure 36). The same visual display and code was used on the profile card for each HEI (Figure 37), and additionally used a geographical display of the HEI, through a google map.

Figure 36. Times Higher Education World University Rankings: leaguetable (2013).

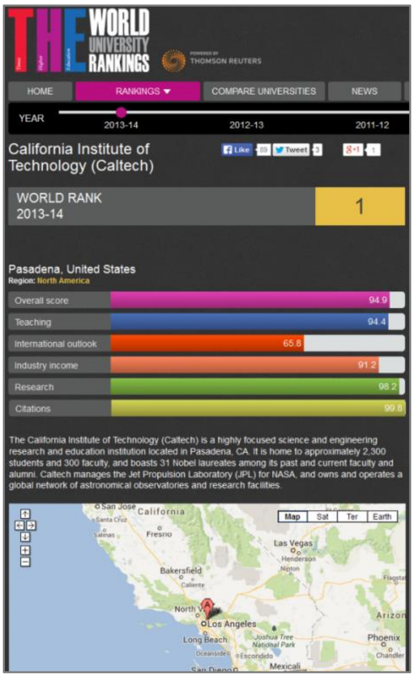

Figure 37. Times Higher Education World University Rankings: institutional profile (2013).

Additionally, this ranking tool allows the comparison of institutions within United States of America, and within United Kingdom. In this area of the tool offers 9 filters of information, from geographical to institution size, to institution type or religious affiliation, and additional information on 16 indicators related to the institutions, such as ethnic demographics, degrees offered, degree details, graduation rate, amongst others. This are is highly interactive. The first interaction is with the filters of the information that will result in a list of HEI to be compared (Figure 38). The result of the comparison between institutions has quantitative and qualitative information represented (Figure 39). Quantitative information is presented in different types of graphs – pie, ring, bar charts -, and qualitative information through lists and text. All the interaction is performed with the filters which result in different visual displays.

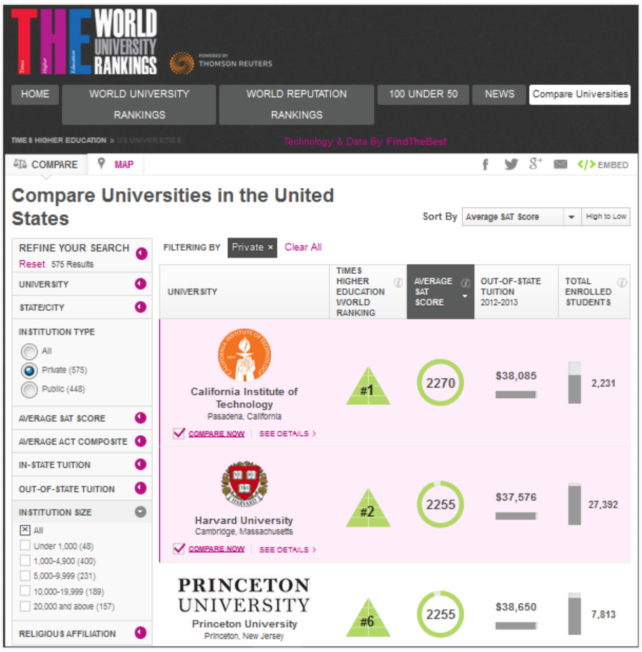

Figure 38. Comparison of Universities in the United States: list of institutions (2013).

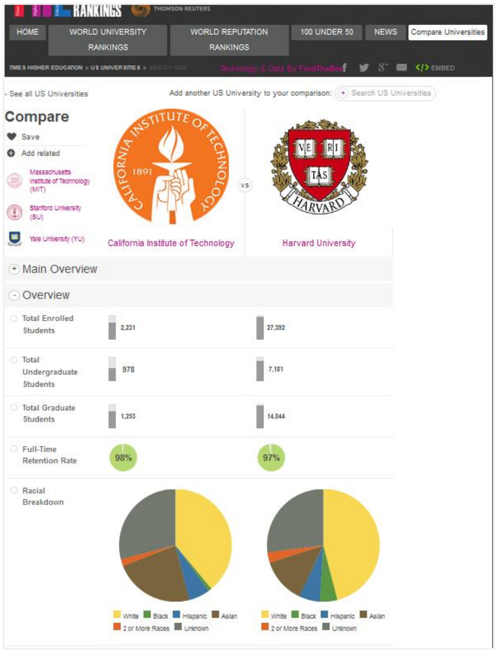

Figure 39. Comparison of Universities in the United States: two profiles compared (2013).

The principal audience of this tool are students, academics, university leaders, industry and governments (THE, 2013). The principal aim is to be a source of broad comparative performance information on universities.

2.2.3.1. Comparison of the interactive dynamics for visual analysis of the transparency tools

Described the four ranking and infovis tools, we will systematize the comparison of the visualisation methods of the 4 tools. The comparison will be based on the visualisation methods as proposed by Behrens (2008), presented previously in Table 4, by compiling the visualization methods proposed and allowing a comparison of the design patterns for interactive infovis tools, providing an overview of methods with elements of the display, behaviour and interaction patterns.

Table 4. Visualization methods, by Behrens (2008). (x) not integrated in the tool; (✓) integrated in the tool; (-) unable to verify.

		Tools			
		U-Map	**University autonomy in Europe**	**U-Multirank**	**Times Higher Education**
Display Patterns	Correlations (Scatter plots and Bubble Charts).	x	x	✓	x
	Continuous quantities (Simple Line Charts and Multiset Line Charts).	x	x	x	✓
	Discrete quantities (Simple Bar Charts, Multiset Bar Charts and Stacked Bar Charts).	✓	✓	✓	✓
	Data proportions (Nightingale's Polar Area Diagrams, Pie Charts and Ring Charts).	✓	✓	✓	✓
	Flow diagrams (Sankey's Diagrams and Thread Arcs).	x	x	x	x
	Hierarchies (Tree Diagrams and Treemaps).	x	x	x	x
	Networks (Diagram Maps and Relation Circles).	x	x	x	x
	Spatial configurations (Topographic Maps and Thematic Maps).	x	x	x	✓
Behaviour Patterns	Navigation (Simple Zoom, Local Zoom, Panning,Timeline, Linked multiples and Overview plus detail).	x	✓	-	✓
	Filtering (Layering, Active Objects, Boundary Filters, Facet Browsing and Dynamic Query).	✓	✓	✓	✓
	Arrangement (Selective Arrangement, Sortable Columns, Custom Dimensions and Isolated Comparisons).	✓	✓	✓	✓
	Exploration ("Details on Demand" and DataTips).	✓	✓	-	✓
	Animation (transition in element's color or size and element animation).	x	x	-	x
Interaction Patterns	Boolean selection (usually done with interface elements such as radio buttons, checkboxes, and dropdown menus)	✓	✓	-	✓
	Linear adjust (Sliders and double Sliders).	x	x	-	✓
	Spatial navigation (Drag and Drop and Selection Masks).	x	x	-	x

The results show that the display patterns of discreet quantities and of data proportions are a common option in all the tools. The U-Map, U-Multirank and University Autonomy in Europe tools have the Nightingale's Polar Area Diagrams, also known as sunburst, as the main display. As was described previously, all the tools, except the University Autonomy in Europe, adopt more than one type of visual display.

All the tools, allow the users to have behaviour patterns such as filtering the information to access and arranging it facilitate understanding and comparison tasks, and allowing for a deeper exploration of data and information by giving details on demand as well as data tips. The interaction patterns most common in use are the selection of elements by interacting with the checkboxes or dropdown menus of the interface. It is also common between the tools, to allow the user to make comparisons isolated or not.

Also all the tools offer the user interaction with interface elements such as list of words, checkboxes or dropdown menus all by Boolean selection, which consequently results in personalized rankings or clusters of institutions or countries presented by the visual displays mentioned above.

2.2.4. Impact of rankings and transparency tools on decision making in Higher Education Institutions

The worldwide phenomenon of HE rankings and transparency tools require us to answer the questions about the uses and outcomes of these tools by HEI. Are they used to support decision-making by institutions? The debate has many sides, recognizing the usefulness of rankings and criticizing its main approaches privileging disproportionately research over teaching (Hazelkorn, 2013; IHEP, 2009; UNESCO, 2013a) .

Rankings and transparency tools, as those described in this study, are only one way to compare or provide more transparency about HEI performance. One of our aims is to understand the impact and use of the U-TRACER® tool, which will be conceptualized in this study, on decision making process by HE decision makers, and therefore we are focusing on similar tools used for similar purposes.

Interviews with campus stakeholders at institutions in countries that have their own national ranking systems and have presence in international systems, suggests that rankings influence institutional decision making in 5 areas: "strategic positioning and planning, staffing and organization, quality assurance, resource allocation and fundraising, and admissions and financial aid" (IHEP, 2009, p. 1). Key findings of the IHEP (2009) research reveal that rankings can improve data-based decision making especially in a time when

> "Higher education institutions, especially those in the United States, are increasingly called on to use data to inform their decision making and to document student and institutional success. Rankings can prompt institutional discussions about what constitutes success and how the institution can better document and report that success." (IHEP, 2009, p. 1)

Key findings also show that rankings can improve teaching and learning practices, when "institutions that use their rankings to prompt change in areas that directly improve student learning experiences (…)" (IHEP, 2009, p.1); research also reveals that some institutions are using rankings for benchmarking, leading to identify and replicate model programs; and finally results reveal that rankings increase collaboration between institutions, helping to identify the institutions with which to collaborate through partnerships in research or student and faculty exchange programs, and alliances.

Hazelkorn (2013) supports the IHEP research, recognizing that students are using rankings to decide on an institution to choose, mainly at the post graduate level, while "[…] stakeholders use rankings to influence their own decisions about funding, sponsorship and employee recruitment", and HEI are using rankings also for benchmarking and to identify potential partners.

The actors called upon to make management decisions are the executive heads at the rectory levels, schools, departments and course levels, all potential users of rankings and transparency tools to support decisions that involve dimensions measurable by those instruments.

A decision-maker can be called upon to decide about the truth of various propositions about something and about the appropriate action about something (Scriven, 1991). Decisions can be structured, meaning they have an ideal solution but require limited support; or they can be semi-structured and based on agreed parameters yet require another person to give a response or share preferences within a specific criteria; and finally by unstructured decisions that have no solution or agreed criteria relying solely on the preferences of the decision maker (Phillips-Wren, 2013). In an organization, such as HEI, problems are more likely to be broad and complex, requiring for structured or semi-structured decisions dependent on many people at different levels of hierarchy (Shimizu, Carvalho, & Laurindo, 2006). A decision maker will need to consult others and analyse data, requiring for its collection or ability to analyse and search through the data to discover trends. In some cases this demands for decision support tools, which combined with the most up-to-data ICTs can provide a valuable assistance (Bresfelean, Ghisoiu, Lacurezeanu, & Sitar-Taut, 2009). Existing data can be used to support the decision and suggest alternative decision processes, and ICT can significantly facilitate the access and assist to manage the overloaded of information and data, provided by the institution or other sources (Bresfelean *et al.*, 2009).

As the UNESCO (2013a) stresses "There is a growing need for simple-to-use but sophisticated tools to filter out the noise and shortlist options that merit further research" (p.58) in the case of students, but alerts about the limitations of global rankings as one interpretation of the data and a guide for decision-making of all HE stakeholders:

> "global rankings will never be able to provide a complete picture regardless of how sophisticated data collection mechanisms may become. Indeed, in almost all cases, such rankings were intended for use as a guide to decision-making rather than an alternative." (UNESCO, 2013a, p. 63)

As Pratt and Palloff (2003) state, to the knowledge of how wired the HE institutions are, which may help students determine which HEI to choose to apply to and attend. It also underlines the fact that making this information available through an infovis tool is of interest and may influence decision-making by institutions and users.

2.2.5. The Portuguese Higher Education data panorama

Data on Portuguese HE systems or institutions faces the same challenges of other countries data. The challenges of having comparable data, in open data and accessible formats. Data collection at national level by survey or by collection of already existing disperse data, are both costly and time consuming tasks that require strategic plan and overtime support by policy and HE decision makers.

As referred in section 2.2.1, organizations such as OECD, UNESCO or the World Bank have collected comparable statistical data about HE systems by country. There is also an effort of each countries governments and institutions to collect data for policies or research purposes.

In Portugal, data regarding HE is collected by *Direção Geral de Estatísticas da Educação e Ciência* (DGEEC) a governmental organization, and the *Instituto Nacional de Estatística* (INE) the national statistical institute. Both DGEEC and INE have the data public and in accessible formats (ODS, XLS, PDF), which is used by other organizations such as CRUP or A3ES.

DGEEC data about HE regards: Global statistics; jobs and enrolments that includes vacancies, new registrants and enrolments; graduates; unemployment of graduates Teachers; PhD; other statistics/transversal statistics, that includes demand and offer of ICT training in HE, and contributions to the characterization of ICT in HE. The datasets regarding ICT in HE relates to the interest area focus of this study, the use of CT in HE.

INE data about HE regards demographic and territorial data: enrolments; graduates; expenditure; territorial statistics of HEI.

The profile of Portuguese HE system, today, indicates that universities and polytechnics (binary system), both public and private provide this level of education. Following the Bologna reform, degrees are divided in three cycles, 1st cycle is undergraduate degree, 2nd cycle is Master degree and 3rd cycle for PhD degree only granted by universities. Integrated masters are also possible in universities (A3ES, 2013).

With a total number of 328 HEI in Portugal (public and private sector), 203 are public institutions (university, polytechnic, police and military) and 125 private (university, polytechnic) (CRUP, 2013). Student enrolment in HE in Portugal, were in the academic year 2011, 396.268 having been the highest ever with 33 years of consecutive growth (Figure 40). Nevertheless since then a small decrease was felt in student enrolment, falling to 370.587 in 2013 (PORDATA, 2013). The trend is for an increase over the years, and the decrease identified can be a consequence of the economic crises Portugal is facing.

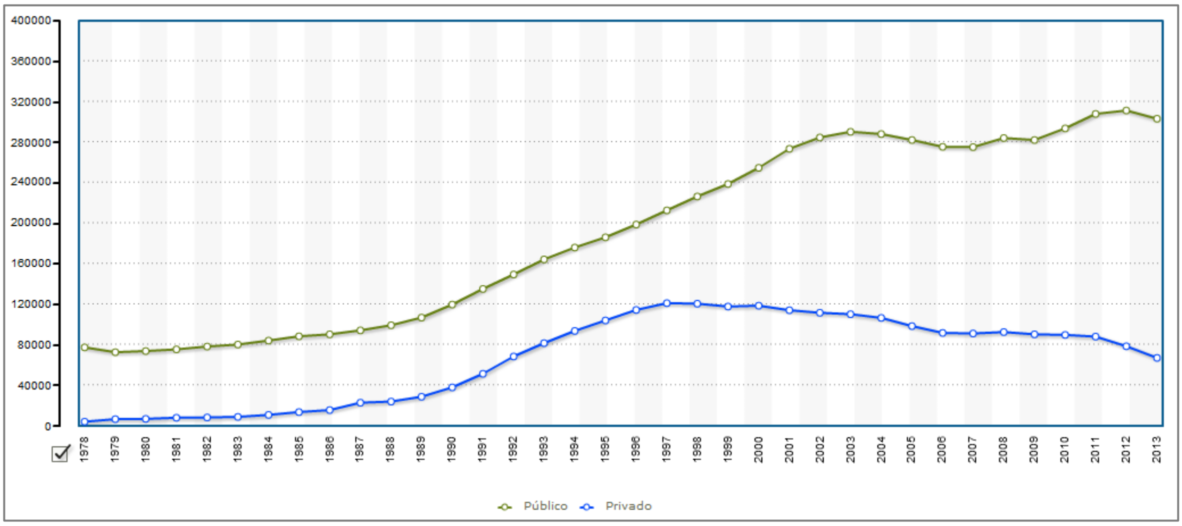

Figure 40. Students enrolled in Higher Education: total and by teaching subsystem. Data sources: DGEEC/MEC, PORDATA. Retrieved from (PORDATA, 2013)

A great effort has been made at policy and institutional levels to raise the number of HE teachers with highest training level, being successful in achieving a high number of teachers with PhD degrees, consequently lowering the number of teachers with other degree levels (Figure 41) (CRUP, 2013).

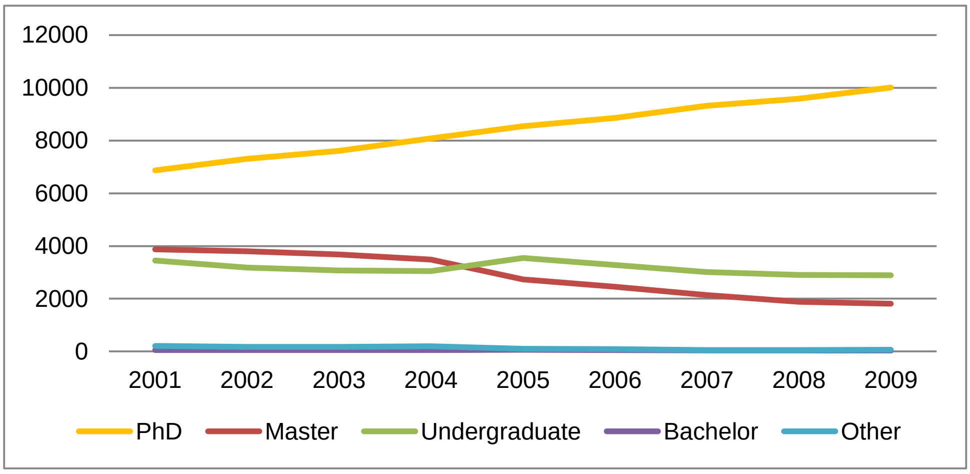

Figure 41. Teachers of public university education, by level of education. Source of the data: GPEARI-MEC. Retrieved from (CRUP, 2013)

There is evidence of a consistent growth of the Portuguese HE system also a consequence of Bologna process within European HEI, of programs such as i2010 that prompt investment and innovation in CT research. This new field of innovation, Communication Technology use in HE, has not yet been measured and therefore there is no data available, which in itself identifies a need for research. Nevertheless organizations such as UNESCO and the OECD, report that overall students are using the Internet to interact, communicate, and produce content, and that countries overall use of CT is growing exponentially.

A vast number of academic research studies focus on studying the diversity and type of use of CT in the context of the HE system, attempting to understand how are HEI are taking advantage of its use, what impact it has had on teaching and learning. Attempting to analyse the trends in the types of CT used and if institutions are training their professionals to integrate CT in their professional practice. But there is a gap in the collection of comparative data that could allow the comparison of institutions concerning their use of CT.

International literature analysis revealed to us the difficulty to access statistical data that could help answer the questions posed, both for the Portuguese or international context of HE. Evidence showed that statistical data relating to ICT in HE and provided by Portuguese governmental organizations, focus only on ICT training degrees offered by institutions, and relate to data about the student enrolment, number of courses offered and graduation earned (DGEEC, 2013). Although the information relevant given the requirements of the labour market, this type of information does not build the wider view of a transversal use of CT within HEI, the use of technology-rich and connected environments which is transforming education as we knew it in the twentieth century.

Reports published by the European Commission, have early predicted the impact of CT in learning, particularly when learning content is made available through the Internet to support teaching learning practices (European Commission, 2001). This impact is a fact, and HE is making a faster progression in the use of ICT in teaching and learning when compared to schools, and the OECD reinforces the need to locate technology in HE pedagogy, by observing its use by students (OECD, 2012b), and evidently by teachers as active players in the pedagogical process. HEI have been increasing investments on computer infrastructures attempting to integrate CT into all moments of the educational experience, as Selwyn (2007, p. 83) early stated, CT may be becoming “an icon of early 21st century higher education provision” in developed and developing countries. New learning environments and methodologies are emerging consequence of the impact of the use of CT in education: e-learning[47], blended learning[48], mobile learning[49] and cloud learning[50], (European Commission, 2001; A. Masud et al., 2012; Mikroyannidis, 2012; Sharples et al., 2007). A vast number of studies have reported how HE students, teachers and institutions are using CT in support of pedagogical practices (Pinto et al., 2012), describing processes, contexts, tools used and reflecting on good practices (Collis & Wende, 2002; Conole & Alevizou, 2010; CRUE, 2010; Dahlstrom, Boor, Grunwald, & Vockley, 2011; Li & Li, 2011; Roblyer, McDaniel, Webb, Herman, &

47 E-learning: “the use of new multimedia technologies and Internet, to improve the quality of learning by facilitating access to resources and services, as well as remote exchanges and collaboration”(European Commission, 2001).

48 Blended learning: considered to be a mix of face-to-face and online learning (Ellis, Ginns, & Piggott, 2009; Garrison & Vaughan, 2008).

49 Mobile learning: learning characterized by the mobility of people and knowledge, supported by mobile devices, application software and networking technologies(Sharples, Taylor, & Vavoula, 2007).

50 Cloud learning: facilitates individual or collaborative study of content and courses, provided by on-demand resources and services from heterogeneous sources over a network (usually the Internet) (A. Masud, Huang, & Yong, 2012; Mikroyannidis, 2012).

Witty, 2010; Santos, Pedro, Ramos, & Moreira, 2011).

2.2.6. Data about the use of Communication Technologies in Portuguese Higher Education

Data about the use of CT in Portuguese HE context has found some expression in two PhD studies that attempted to collect data at a national level and understand how CT where being used by HE teachers in support of teaching and learning practices, and to characterize its use focused on the institutional perspective (Batista, 2011; Dias, 2010; Morais, 2013). Within the Portuguese HE context, research about the use of CT focuses majorly on the perspective of its use by students, and lesser on the use by teachers or institutions (Pombo et al., 2013). The existing data is disperse and in varied formats, and although existent it is not comparable, revealing the need to have a national comparable data collection to enable a comparative overview of the use of CT in Portuguese HEI.

Consequently, project TRACER[51] a research project entitled “The use of Communication Technologies in Portuguese Public Higher Education Institutions”, undergone at University of Aveiro between year 2011 and 2014, attempted to fill that gap of comparable data regarding Portuguese HE. The first stage of data collection focused on the institutional perspective of the use of CT, inviting the decision makers at the rectory level to provide data by filling an online questionnaire consisting of seven parts: 1) profile of the institution; 2) resources and functionalities of CT; 3) Infrastructures to support the use of CT; 4) equipment and supports for the use of CT; 5) Training for CT use. From the total of 35 Portuguese Public HEI, 9 provided data for one school year (2011/2012). The second stage of data collection focused on the teachers’ perspective of the use of CT, data provided by teachers of Portuguese Public HEI by completing an online questionnaire. The questionnaire was composed of 5 parts: 1) teachers’ profile; 2) CT used in teaching practice; 3) resources used in teaching practice; 4) equipment and supports for the use of CT; 5) Training. A total of 185 teachers from 19 Portuguese Public HEI provided data for one school year (2012/2013). The third phase of data collection focused on the good practices of the use of CT from the teachers’ and institutions’ perspective. Institutional data was collected by asking decision pivots who participated in the first stage of data collection, to complete a questionnaire. Data about teachers perspective was collected by interview with teachers identified as proficient in the use of CT in their pedagogical practice.

The two main goals of TRACER were to collect data at a national level, and to disseminate the data through an online information visualization tool, the U-TRACER®. The conceptualization of the tools infovis features is the core work developed within the present study and which will be described in the further chapters. The tool aims towards the sustainability of the data collection and presentation, foreseeing analysis of comparable data of HEI over time.

[51] TRACER project http://cms.ua.pt/TRACER/

U-TRACER® is not a ranking tool, but connects to the need of transparency advocated for HE by the EC and EHEA.

2.3. Exploring the missing link between Information Visualization and support to decision making in Higher Education

With the transformative impact of CT in HE worldwide institutions are facing an increased demand to strengthen their capacities to support teaching, research and innovation, a demand to continuously process collect and analyse data to compare how well a policy is being implemented for the purpose of a defined objective (Tsolakidis, Sgouropoulou, Papageorgiou, Terraz, & Miaoulis, 2013). HEI need to analyse their own performance and compare their performance with other institutions. HE decision makers need the support data and tools to meet the need to decide quickly and well and rankings tools have contributed to highlighting the importance of quality in HEI and supported decision-making towards excellence of an institution in a competitive world (UNESCO, 2013a). Within these support tool there can be Information visualization tools, providing methods and instruments to analyse and show data and information, supporting a decision maker in the process of reporting data in alternative ways with the purpose of achieving a goal (Tsolakidis et al., 2013): "[…]information visualization techniques can be used to rebuild the support information, and solve the problems of "information thirsty" and "information anxiety" (Zheng, Wang, Luo, Cao, & Qing, 2011, p. 781).

An example of the initiative promoted by of University of Aveiro, that in 2013 revealed to have built a portal of indicators, a management tool and decision support to organic units of the institution that also makes use of information visualization features. At this time the Portal has indicators regarding academic fields, but in the near future will integrate employability, human resources and research indicators, as well as institutional performance of the Organic Units. It is interesting to highlight that the aim is to promote transparency and knowledge sharing necessary for informed decision processes within the institution. Additionally university of Aveiro has strengthened the continuity of participation in the international rankings Times Higher Education World University Rankings, Global Research University Profile and U-Multirank, because they allow comparison of indicators considered important for the positioning of the institution at a national and international level (Universidade de Aveiro, 2013).

HEI nee useful comparative information (UNESCO, 2013a).supported by tools that make the processes of accessing and communicating that information an easier process, supporting all stakeholders in their decisions: "We need databases, analytical tools, and information visualizations to work together." (Zanconato, n.d., p. 2), and this is the area in which this study and the U-TRACER® tool can contribute.

Chapter 3. Methodological approach for the conceptualization and validation of the U-TRACER®

3.1. Methodological Framework

The methodology that supports the development of the present study, was framed by the processes of conceptualization and validation of the U-TRACER® tool, an information visualization tool with the aim of disseminating the dataset collected by project TRACER, by the means of infovis features.

We opted for the development of a qualitative research considered to best meet the aims of this study. Therefore we can define this study as a qualitative research, developed to achieve a richer understanding of the processes of conceptualization and evaluation of U-TRACER®, enabling full descriptions of the data collected (Carmo & Ferreira, 1998; Carpendale, 2008).

Table 5 presents the tasks that structure project TRACER, identifying the tasks that were developed within this study.

Table 5. Project TRACER tasks developed within the present PhD study. (n/a): not applicable; (CT): Communication Technologies; (HEI): Higher Education Institutions

TRACER tasks	Tasks developed within the present study
Task 1: Literature review.	n/a
Task 2: Phase I: Survey development and validation.	n/a
Task 3: Phase I: Survey implementation and data analysis.	n/a
Task 4: U-TRACER® tool: conception, specification and prototyping.	Developed
Objectives • Develop the U-TRACER® according to both state-of-the-art information visualization techniques and Web 2.0 structural concepts.	Developed
• Develop a review of similar projects, in order to establish some technological and methodological reference points.	Developed
• Conceptualize the tool, taking into consideration graphic, interaction and technical design of the U-TRACER® Tool.	Developed
• Evaluate the U-TRACER®, besides other matters, with usability and accessibility, which will be tested with a sample of users and with a group of peer experts.	Developed a usability test, and interviews with HE decision makers.
Expected results • The development of a technological tool that renders possible the visualization of information based on the correlation of collected data using filters. According to specific needs of the users, the tool will, for example, allow to: obtain geo-referenced representation of the use of CT in all the HEI included in the study; display, according to metaphors negotiated by the team members, the correlation of data established in accordance with the filters selected by the user.	Achieved in this study
• The tool will also allow using the HEI results for studies at a national level.	n/a
Task 5: Phase II: Survey development and validation.	n/a
Task 6: Phase II: Survey implementation and data analysis.	n/a
Task 7: HEI-CT U-TRACER® tool delivery.	Developed
Objectives: • To finish HEI-CT U-TRACER® tool development.	Developed
• To disseminate and promote the use of HEI-CT U-TRACER® tool.	n/a
• To evaluate the HEI-CT U-TRACER® tool.	n/a
Expected results: • Comprehensive visualization of collected data.	n/a
• The final version of the Tracer.	Achieved in this study
• Promotion of the Tracer.	Achieved in this study
• Dissemination of the study inside the several HEI.	n/a
Task 8: CT use in public Portuguese HEI – Best practices	n/a

It is important to highlight that this study conceptualizes the tool, but the development and interface design was done by a company whose services were hired by project TRACER. This is relevant specifically regarding task 4 - U-TRACER® tool: conception, specification and prototyping - developed within this study, but which different phases of the development of the prototyping depended on the effective possibilities of development by the company. In this work relation, potentials and limitations were identified and described in chapter 4 - Conceptualization of the U-TRACER® an Information Visualization tool.

The process of conceptualization of U-TRACER® followed principles of Development Research (DR), involving participants in the different moments of the conceptualization, including the evaluation through usability testing. These are empirical evaluation methods that involve real users, allowing the researcher to obtain qualitative data to design the tool (Mazza & Berre, 2007).

According to van den Akker (1999), the choice of a development research may result from the inadequacy of ‘traditional’ approaches which don’t always provide the answers or the solid information needed to design or improve a product. With DR approach, interactions with participants constitute essential moments:

> “The ultimate aim is not to test whether theory, when applied to practice, is a good predictor of events. The interrelation between theory and practice is more complex and dynamic: is it possible to create a practical and effective intervention for an existing problem or intended change in the real world? The innovative challenge is usually quite substantial, otherwise the research would not be initiated at all. Interaction with practitioners is needed to gradually clarify both the problem at stake and the characteristics of its potential solution. An iterative process of ‘successive approximation’ or ‘evolutionary prototyping’ of the ‘ideal’ intervention is desirable. Direct application of theory is not sufficient to solve those complicated problems.” (van den Akker, 1999, pp. 8, 9)

The authors Richey, Klein and Nelson (2004), classify DR as a study that focuses on a process, with interest in identifying the general principles of development or specific recommendations of a contextualized situation. The work stages can be organized into two types: the first refers to “(...) an analysis phase, design phase, the development phase, and a try-out and evaluation phase”, while the second type of organization refers to “(...) phases directed toward first analysis, then prototype development and testing, and, finally, prototype revision and retesting” (Richey et al., 2004, p. 1114). The conceptualization and evaluation of the U-TRACER® fits in the first phase of research projects involving the analysis and design phases of the product that a particular situation is described and the prototype testing (Richey et al., 2004) (Table 6).

Table 6. Development research phases vs the tasks developed within the study. (n/a) not applicable.

Phases of Development Research	Tasks
Analysis phase	Analyse existing infovis tools for Higher Education and by comparison define the main infovis features for U-TRACER®.
Design phase	Involve end-users in the definition of the interaction features, through the focus group sessions.
	Design various proposals of graph displays to represent U-TRACER®s dataset.
	Involve end-users in the selection of the graph displays to represent U-TRACER®s dataset.
	Analysis of the focus groups sessions and definition of the interaction features to integrate the prototype.
	Analysis of the test to the Reading effectiveness of the graphs, and define the graph displays that are to integrate the prototype.
Prototype development	n/a (work developed by the company hired by project TRACER)
Prototype testing	Usability test to the prototype.
prototype revision	n/a
Prototype retesting	n/a

Taking into account the moments of iteration of users - testers and interviewees - with the U-TRACER®, and description of those different moments of conceptualization, it is possible to situate the method under the category of a case study. A case study which was approached and not surprised as it unfolded in its natural context, because the conditions of interaction of the users in the different moments of process of conceptualization and evaluation of the U-TRACER® were motivated by the researcher (Martins, 2006). As Martins (2006, p. 10) states:

> "Contrary to the traditional model of research, where there is a well-defined phase to analyse the results, in the case study, analysis and reflections are present during the various stages of the research, particularly when gathering information, in situations where partial results suggest changes, course corrections, as well as require additional queries to other works of bibliographic reference".[52]

Stake (1995) also stresses that a researcher in a qualitative study does not merely collect data, identify and interpret variables, yet puts the observer in the field unfolding the activity being studied, searching and interpreting. The researcher seeks to know and understand the uniqueness of the case and its particular context.

Strategies for data collection were applied by means of different techniques, such as: focus groups, in-depth interviews, questionnaires, document analysis. The different techniques ensured the study a high degree of reliability, allowing for triangulation of data using multiple sources of evidence (Martins, 2006).

[52] Translation of the quote, from Portuguese to English, is responsibility of the researcher.

3.2. Research questions and goals

The research questions that drive this study relate to the need to communicate data provided by Portuguese Public HE institution decision makers - rectors' team; presidents team; directors of organizational and research units; coordinators of courses - regarding the institutional use of Communication Technologies that support teaching and learning practices, by making use of information visualization features that comprise the U-TRACER® tool. The research questions and goals that frame this study integrate this context.

Question 1: What information visualization proposal is most adequate, to represent the dataset concerning the use of Communication Technologies that support teaching and learning practices in Portuguese Public Higher Education institutions?

Question 2: What is the perception of Portuguese Public Higher Education decision makers, regarding the usefulness of the U-TRACER®?

Research goals for question 1:

- Conceptualize the U-TRACER® tool, with information visualization features, considering the dataset and profile users as the stakeholders of Higher Education.
- Understand how information visualization is being used to represent data concerning Higher Education institutions.
- Critically reflect on the challenges of information visualization in the context of the higher education data.
- Understand the concepts of information visualization and adapt them to the dataset about "The use of Communication Technologies to support teaching and learning practices, in Portuguese Public Higher Education Institutions.

Research goals for question 2:

- Understand decision makers' perceptions towards the usefulness a U-TRACER®.
- Understand the possible relation between the use of the information visualization tool U-TRACER® by Higher Education decision makers, and its use to support decision making processes.
- Understand the advantages, disadvantages and concerns decision makers identify in the U-TRACER®.
- Critically analyse the acceptance of information visualization tools within the European context of Higher Education.

3.3. Research phases

The work is divided in four phases of data collection and has two object studies that reflect the two perspectives from which information visualization can be perceived: the development perspective, and the users perspective (Colin Ware, 2013). The first object of study is the development perspective, the conceptualization process of the tool which happens through phases 1 to 3 (Figure 42). The second object study is the users' perspective, understanding the perceived usefulness of the tool by HE decision makers in phase 4 (Figure 42).

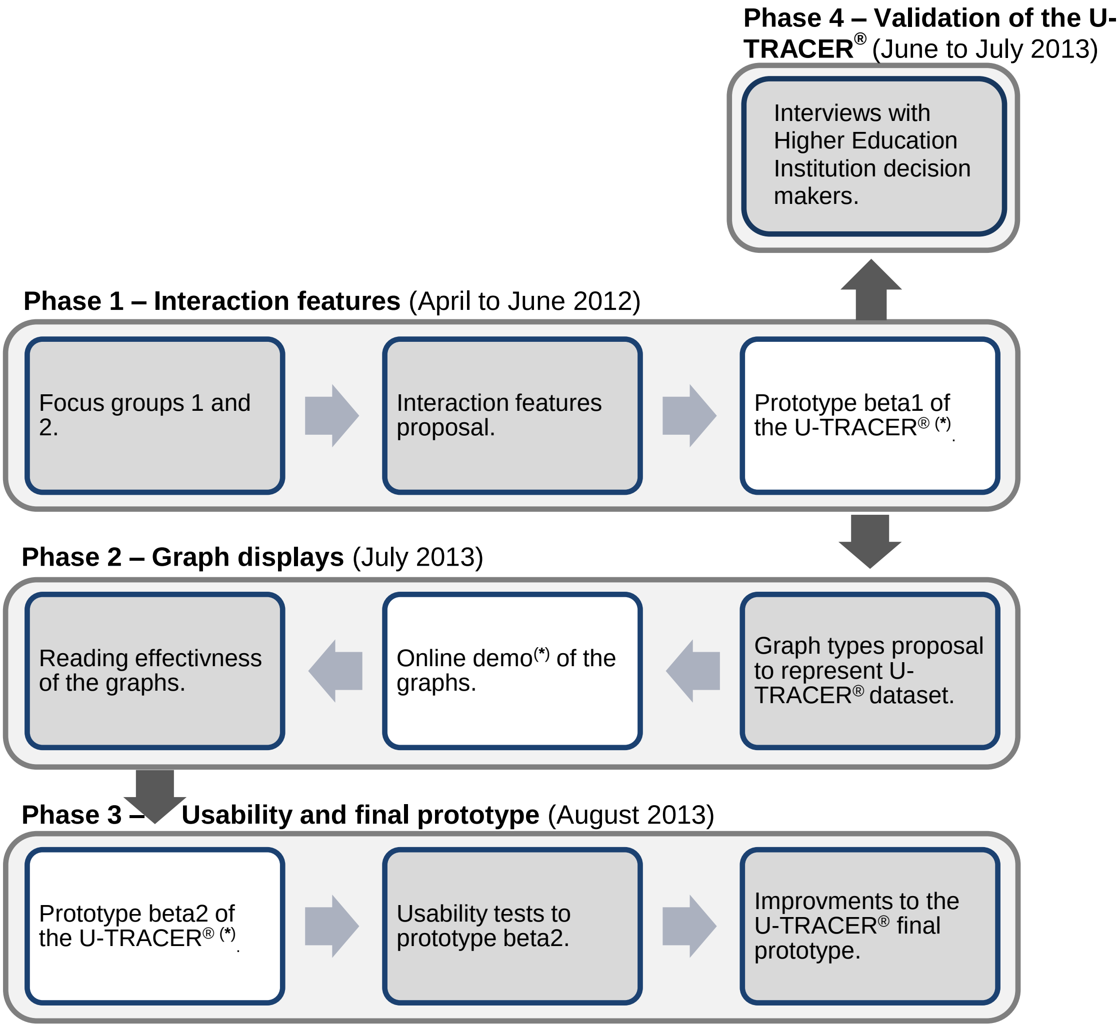

Figure 42. Research phases. (*) Developed by the company hired by project TRACER.

Phase One - Interaction features

The first phase of the study served the purpose of developing a proposal of interaction features for the U-TRACER® (Table 7). To achieve this, a first moment of data collection happened with two focus groups sessions with participants framed within the target audience of the U-TRACER®. The focus groups explored the opinions, expectations and suggestions of potential users of U-TRACER® (Richey et al., 2004) regarding the infovis features, contributing to the conceptualization process.

Phase Two - Graph displays

The second phase of data collection served the purpose of proposing the graphical displays to represent the dataset of the U-TRACER®, and test the reading effectiveness of the graphs with end-users. This phase involved work developed in collaboration with the company hired by project TRACER, responsible for the development of an online demo version of the graphics tested by the users. This phase contributed to the process of conceptualization of the tool (Table 7).

Phase Three - Usability and final prototype

This phase involved the implementation of a usability test by end-users to the online version of the prototype of the U-TRACER® tool. The results of the analysis of the usability tests led to the development of the final proposal of the infovis features for the U-TRACER® (Table 7).

Phase Four - Validation of the U-TRACER®

This phase aimed to answer the second research question (Table 7) about the usefulness HEI decision makers perceive for the U-TRACER®. To achieve this we conducted in-depth interviews with HE decision makers from the institutions that provided data to project TRACER, meaning that their institutions data will be represented by the U-TRACER®.

Table 7. Research questions and corresponding research phases.

Research question	Research phase
Question 1	Phase One - Interaction features.
	Phase Two - Graph displays.
	Phase Three - Usability and final prototype.
Question 2	Phase Four - Validation of the U-TRACER®.

3.4. Analysis Model

The analysis model serves as a reference model, clarifying the concepts which guided the researcher in building the instruments for data collection and the data analysis process. The concepts were retrieved from the research questions, defined and from which were derived the main dimensions of analysis and its indicators (Quivy & Campehnoudt, 1995). The dimensions of analysis which can be more evident the more evident can be measured or observed by indicators or less evident; or less evident when conveyed by opinions or expressions that inform about the dimension (Quivy & Campehnoudt, 1995).

The analysis model was built following two stages. The first stage accomplished a systematization of the main concepts related to the research questions. The second depended on a first attempt to code both focus groups transcripts, attempting to identify concepts that were not predicted before, and included the new concept as part of the analysis model. The analysis model and all its theoretical grounds can be consulted in Appendix 6 - Analysis Model. Finally, the analysis model was structured by three main concepts: Information Visualization; Acceptance of a web platform (the U-TRACER®); and Higher Education decision maker.

3.4.1. Concept of Information Visualization

The concept of information visualization guides an important part of this research, essential to answer the first research question which leads to the conceptualization process of the U-TRACER® tool.

In the attempt to define Information Visualization (infovis) we found that there are commonalities in the definitions of various authors. Spence (2007, p. 5), defines infovis as “data - in whatever form - is transformed into pictures, and the pictures are interpreted by a human being”, regardless of it being static or interactive representations, having or not a computational support. Other authors such as Shneiderman & Plaisant (1998-2010), Card et al (1999) and Ware (2004), having a similar definition to the one stressed by Spence, added the concept of interaction and knowledge. Therefore the authors stated that infovis uses interactive visual representations of abstract data, with the aim of amplifying cognition.

Interaction features in infovis involve the transformation of data’s visual display by manipulating controls or changing parameters, simultaneously changing the process of understanding data and retrieving information. Interaction may potentiate cognition, allowing the user to reduce the memory requirements, accelerating the process of searching for information, enhancing the detection of patterns in the data, working or exploring parameters of the information stored in the visualizations (Card et al., 1999). Cognition arises framed by visual representation and interaction in infovis (Liu, Nersessian, & Stasko, 2008).In this study, we adopt the definition of infovis that integrates interaction features to enhance cognition. The foremost reason relates to the fact that the U-

TRACER® is a web tool and therefore grasps the possibility of enabling its future users the possibility to interact within this enhanced context.t Therefore, when designing the U-TRACER® we should consider the infovis principles that integrate the model of analysis. Divided into 3 dimensions (A, B, C) (Table 8**Erro! A origem da referência não foi encontrada.**), the model encompasses: visual display, interaction, and data.

Table 8. Analysis model: Concept of Information Visualization

Research question 1: What information visualization proposal is most adequate, to represent the dataset concerning the use of Communication Technologies that support teaching and learning practices in Portuguese Public Higher Education institutions?			
CONCEPT: Information visualization			
Dimension	**Category**	**Sub-category**	**Indicator**
A. Visual Display	A.1. Visual Representation	A.1.1. Correlations	‣ Scatterplot chart ‣ Bubble Chart ‣ Stem-and-Leaf Plots chart ‣ Q-Q plots chart ‣ Scatter Plot Matrix chart ‣ Parallel Coordinates chart
		A.1.2. Continuous quantities	‣ Line chart ‣ stacked chart ‣ Sparklines chart ‣ Index chart ‣ Small multiples chart ‣ Horizon graph chart
		A.1.3. Discrete quantities	‣ Bar chart ‣ Multiple Bar chart ‣ Dot matrix chart ‣ Stacked bar chart ‣ Isometric bar chart ‣ Span chart
		A.1.4. Proportions	‣ Pie chart ‣ Ring chart
		A.1.5. Hierarchies	‣ Tree diagrams chart ‣ Tree map chart ‣ Sunburst chart ‣ Enclosure Diagrams (treemap/bubble map) chart ‣ Node-link diagrams chart ‣ Adjacency diagrams chart

		A.1.5. Spatial configurations	‣ Topographic map ‣ Thematic map ‣ Flow map ‣ Colorpleth map ‣ Graduated Symbol map ‣ Cartogram
	A.2. Visual Encoding		‣ Size ‣ Value ‣ Texture ‣ Color ‣ Orientation ‣ Shape
B. Interaction	B.1. Tasks		‣ Overview: gain an overview of the entire collection; ‣ Zoom: zoom in on items of interest. ‣ Filter. ‣ Details on demand: Select item or group and get details when needed. ‣ Relate: view relationships among items; ‣ History: keep a history of actions to support undo, replay and progressive refinement. ‣ Extract: Allow extractions of sub collections and of query parameters. ‣ Scroll.
	B.2. Process and provenance		‣ Record: Record analysis histories for revisitation, review and sharing. ‣ Annotate: Annotate patterns to document findings. ‣ Share views: Share views and annotations to enable collaboration. ‣ Guide: Guide users through analysis tasks or stories. ‣ Alternative representation.
C. Data	C.1. Attribute dimensions		‣ 1D ‣ 2D ‣ 3D ‣ Multidimensional ‣ Temporal ‣ Tree ‣ Network ‣ Geographic
	C.2. Attribute quality		‣ Nominal ‣ Ordinal ‣ Interval ‣ Ratio

A) Visual Display - Dimension

The first dimension of analysis is Visual Display, which integrates both the visual representation that defines the types of graphics that will be used to represent the chosen dataset, and the visual encodings that relate to the graphical features.

A.1) Visual Representation - Category

This first category, regards the ways in which data can be represented visually through different techniques (R. Spence, 2007). The category results from the effort to compile the categorizations proposed by Behrens (2008) and Heer, Bostock & Ogievetsky (2010), who proposed 8 and 5 that aggregate a specific set of design patterns related to different types of datasets. The authors proposed common sub-categories - Correlations, Continuous quantities, Discrete quantities, Proportions, Hierarchies, Spatial configurations - but suggesting different types of graphical representations that we merged in order to create a more complete list of sub-categories.

A.2) Visual Encoding - Category

Visual displays use similar visual encodings, which are methods that guide the user through common tasks of infovis (R. Spence, 2007). Visual encoding methods that integrate this model result from the review of visual encodings proposed by Tidwell (2005), Bertin (2011) and Mackinlay (1986), detailed in the second chapter (section 2.1.2, page 19). To integrate the model we propose Tidwells' encoding categorization: Color hue, Position, Color brightness, Color saturation, Texture, Orientation, Size, Shape.

B) Interaction - Dimension

Graphical perception can be enhanced with an appropriate balance with interaction design and aesthetics (Heer et al., 2010), promote simultaneously an output, and an input through the visual representation, recording ideas or actions performed by the user (Ware, 2004).

B.1) Tasks of interaction - Category

We propose to integrate the model the six interaction tasks proposed by Shneiderman and Plaisant (1996): Overview task, Zoom task, Filter task, Details on demand task, History task, Extract task. (detailed definition in chapter 2, section2.1.2. page 21).

B.2) Process and provenance - Category

Process and provenance is a category defined by the diversity of interaction operations performed by anyone who seeks to understand a dataset: Record, annotate, share, guide Heer and Shneiderman (Heer & Shneiderman, 2012). A feature that creates new approaches towards inforvis supported by the web (Rohrer & Swing, 1997).

The subcategory of ‘alternative representation’ was added to the list of sub-categories as a result of the first phase of coding the focus groups transcripts. This feature was mentioned by participants in the focus group, justifying its inclusion. Spence (2007) also refers to alternative visual representation of the data, as a task of interaction, meaning that more than one type of visual representation of the data is offered. It is possible to see this option being offered in several web infovis tools, such as are examples Pordata (2009), or The Observatory of Economic Complexity (Simoes, 2010).

C) Data type - Dimension

The dimension data type is divided into two attributes: data attribute of dimension, and attribute of quality.

C.1) Data attributes of dimension - Category

The attribute of dimension, we considered the seven data types defined by Shneiderman (1996) (1996) and Shneiderman & Plaisant (1998-2010): 1 dimension, 2 dimensions, 3 dimensions, multidimensional, temporal, tree and network data.

C.2) Data attribute of quality - Category

The characterization of the data types is important because it determines the type of visual representations possible to represent the dataset with. The attribute of quality, relates to the levels of measurement of the data. There are four scales of measurement of the data: nominal, ordinal, interval and ratio (Stevens, 1946; Tuckman, 2000).

3.4.2. Concept of acceptance of the U-TRACER®

The second concept relates to the acceptance of the U-TRACER® tool by its target users, defined in this study to be the decision makers of the HE institutions, who provided the data which will be represented through the U-TRACER®. Understanding this group’s acceptance of the tool is crucial for its sustainability, dependent on the continuous providing of up-to-date data. This concept will help to answer the second research question. Table 9 presents the dimensions, categories and indicators of the concept acceptance of the U-TRACER®.

Table 9. Concept usefulness of U-TRACER®: dimensions, categories and indicators.

Research Question 2: What is the perception of Portuguese Public Higher Education decision makers, regarding the usefulness of the U-TRACER®?		
CONCEPT: Usefulness of the U-TRACER®		
Dimension	**Category**	**Indicator**
A. Usefulness	A.1.Perceived usefulness (TAM)	‣ Information for support activities ‣ Information quality ‣ Information for primary activities ‣ Information for management ‣ Information for research and development ‣ Information for support activities
B. Convenience	B.1. Advantages	‣ Inform decision makers (Query and information retrieval) ‣ Maps newly emerging areas ‣ Comparable information on other HEI ‣ Customization tool ‣ Gain knowledge ‣ Gain insights from the data to help improve decision processes ‣ Assist decision making process
	B.2. Disadvantages	‣ Lack of contextual factors when comparing HEI ‣ Lack of data regularly provided by other institutions ‣ Reinforce competition between HEI
	B.3. Concerns	‣ Data: Methodological ground/collection of data ‣ Impact on stratification rather than on diversification of institutions

A) Usefulness

The concept of perceived usefulness firstly defined by Davis (1989, p. 320) as "Perceived usefulness is defined as the prospective users' subjective belief that using a specific application system will increase his or her job performance within an organizational context." This definition was later adopted by authors such as Lederer (2000) and Teoa (1999, p. 25) that advanced to the proposal of models to measure the technology acceptance, which included the perceived usefulness towards the use of a specific technology in the context of job performance.

We have chosen to adopt the categories proposed by Lederer et al (2000) for the Technology Acceptance Model (TAM) concerning web tools, adds to Davis (1989) proposal by focusing on the World Wide Web technology. The TAM proposes to understand the ease of use and usefulness to predict the attitudes towards the usage of a technology. In this study we will only focus on the usefulness, result of the fact that the U-TRACER® was at an demo version, and could not be used at the time, disabling the focus on the ease of use of the TAM model (Figure 43) contemplating the aspects of usefulness and ease of use. Because within the time scope of this study, it will not be possible to have a finished version of the U-TRACER® to test with the target group, we will focus only on the usefulness (i):

- Usefulness antecedents.
- Perceived usefulness consists of: characteristics of useful information; task environment information; strategic areas for corporate decisions; functional area information.

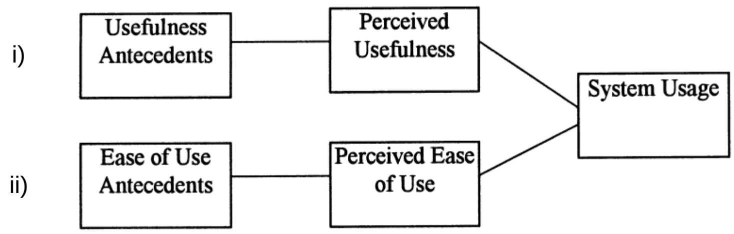

Figure 43. Technology Acceptance Model and web usage model (Lederer et al., 2000).

B) Convenience

Additionally from the analysis to the reports of the transparency tools for European HE, U-Map and U-Multirank, emerged issues related to the advantages, disadvantages and concerns perceived expressed by the opinions of those decision makers who provided data about their institution (Frans van Vught & Ziegele, 2011; F.A. van Vught, 2010). This emphasized the motivations of the higher education stakeholders to participate and perceive usefulness of these tools, or not to participate. Therefore we saw as relevant the inclusion in the analysis model, the perceived advantages, disadvantages and concerns, complementary towards a more complete understanding of the context under study.

B.1) Advantages - category is composed of eight indicators:

- Inform decision makers (U-Multirank, U-Map)
- Map newly emerging areas (U-multirank, U-Map)
- Compare information on other Higher education institutions (U-Multirank, U-Map)
- Personalize/customize information (U-Multirank, U-Map)
- Gain knowledge (U-Multirank, U-Map)
- Gain insights from the data to help improve decision processes

- Query and information retrieval
- Assist decision making process

B.2) Disadvantages - category is composed by three indicators:

- Lack of contextual factors when comparing HEI
- Lack of data regularly provided by other institutions
- Reinforce competition between HEI

B.3) Concerns - category is composed of two indicators:

- lack of contextual factors when comparing HEI;
- lack of data regularly provided by other institutions; reinforce competition between HEI.

3.4.3. Concept of Higher Education decision maker

The concept of HE decision maker enables us to understand and identify the organizational level in which the decision maker who participated in this study, is integrated in the HE institution, and the type of decisions they are called upon to make. Additionally we deepened the understanding of the types of decisions made by the decision makers, related to the institutional adoption of CT (Table 10).

Table 10. Concept of Higher Education decision maker

Research Question2: What is the perception of decision makers of PPHEI, as to the usefulness of the U-TRACER® tool?		
Concept: Higher education decision-maker		
Dimension	**Category**	**Indicator**
A.Decision maker	A.1.Institutional level of decision making	‣ Institutional decision at the Rectory level ‣ Institutional decision at the presidency ‣ Institutional decision at the Institute ‣ Institutional decision at the department ‣ Institutional decision at the school ‣ Institutional decision at the level of faculties/other academic structures are listed in the law
	A.2.Types of decision	‣ Other ‣ Structured ‣ Semi-structured ‣ Unstructured

A1) Institutional level of decision making - category

The first category is the institutional level of decision making, which in this study relates to the adoption and use of TC, at an institutional level.

As is stated in the U-Multirank report, to understand the information need of the users, it is necessary to understand their decision situation (Frans A. van Vught & Ziegele, 2012a). In this study we attempt to understand the decision situation of the decision makers who will be interviewed: situation and work position within which they have decision responsibilities – at the levels of rectory, organizational units, support services.

A2) Type of decisions - category

The second category presents the type of decision, categorized by Phillips-Wren (2013), in three types, necessary to understand in order to be able to effectively assist in a decision process, when creating an intelligent decision support system (IDSS). Although we inspire in IDSS, this study does not develop a IDSS, but rather a tool which will be used by HE decision makers through an interface with information visualization features.

Three types of decisions were presented by Phillips-Wren (2013, p. 25):

1) Structured decisions: “have a known optimal solution and, thus, require limited decision support”.
2) Semi-structured decisions: “have some agreed-upon parameters and yet require human input or preferences within a specific set of criteria”.
3) Unstructured decisions: “have no agreed-upon criteria or solution and rely on the preferences of the decision maker”.

3.5. Data collection instruments

Following we will present the four instruments built to collect data: the focus group interview, questionnaire, in-depth interview (Table 11). Both instruments of focus group interview and questionnaire, in qualitative studies, allow the evaluation of infovis features and tools, in comparison with other methods such as observations, more appropriate to identify the users direct opinions, formulating questions that the users didn’t anticipate having before looking at the visualization (Mazza & Berre, 2007; Plaisant, 2004).

Table 11. Data collection instruments.

Data collection instruments	Options	Contribution to research
Focus group	‣ Face-to-face focus group interview with participants. ‣ Sound recording of the discussion.	Define the interaction features of the U-TRACER®.
Interview	‣ Online interview using video-conference call. ‣ Face-to-face interview. ‣ Computer screen and sound recording.	Understand the perceived usefulness HEI decision makers have of the U-TRACER®.
Questionnaire to test the reading effectiveness of graphs	‣ Face-to-face with participants. ‣ Interaction with graphs in online demo. ‣ Think aloud. ‣ Researcher takes notes.	Choose the graph types to develop in the tool
Questionnaire to test the usability of the tool	‣ Face-to-face interview. ‣ Interaction with the tool inn online demo. ‣ Think aloud. ‣ Computer screen and sound recording.	Evaluate the tools prototype and identify improvements to integrate the final version of U-TRACER®

3.5.1. Focus Groups

The focus group (FG) as an instrument of data collection was used in phase one – Interaction features. The aim was to collect the opinions, in greater depth, of the participants regarding the interaction features they would prefer to see implemented in an information visualization tool such as the U-TRACER® tool. The set of opinions of the participants after analysed and systematized, were part of the process of conceptualization of the tool.

Two focus group sessions, face-to-face, were organized following the same script of questions to arouse discussion. Participants were asked to participate and interact freely with each other to give their opinion. However, to ensure a rich discussion, participants were encouraged to manifest their views on all matters.

The focus group question script was supported by the ‘analysis model’ and the concept of Information Visualization, for the dimension of ‘interaction features’. The questions focused on the research goals, some of which posed questions on the usefulness of the tool, and others towards exploring the types of visual and interactive displays to represent the data. We opted to present semi-structured questions, to allow a richer discussion between the participants and obtain greater depth overview of the problems discussed.

The FG question script was divided into 3 sets of question groups (Appendix 2 - Focus group guide):

- First group was composed of two questions, regarding the usefulness and interest of the U-TRACER®, with questions about the expectations of the user towards the use of U-TRACER®.
- The second group was composed three main questions, regarding interaction features of information visualization. One of the questions was sub-divided into 10 examples of infovis discussed by the participants.
- The third group of questions section was composed of one question about the usefulness of the U-TRACER® to support decision making processes related to the adoption of Communication Technologies.

The first and third group of questions contribute to answering the second research question regarding the usefulness of the U-TRACER®, by gathering the participants opinions about their expectations as to the actions the U-TRACER® will allow them to perform, and their opinion concerning the usefulness of the tool as a support of decision making processes in HE.

The second group of questions focus entirely o contributing to answer the first research question, concerning the interaction features of infovis that would the participants would prefer to see offered by the U-TRACER®.

Both focus group sessions were conducted following the same question route. Using a focus group as an instrument of data collection in the field of Information Visualization allow researchers to obtain unexpected opinions and discussions related to solutions or problems that cannot be identified through more structured analytics.

A focus group is a research led group discussion to generate data about a topic proposed by the researcher, used in a more exploratory or structured way. The researcher poses a set of questions to a group of participants, moderating the discussion and encouraging interaction between the group members (Savin-Baden & Major, 2013).

The advantages of using the focus group as one of the qualitative data collection methods, relates to allowing interaction between participants who react to each other views, which allows to generate new ideas (Mazza & Berre, 2007). It is important that the users are familiarized with the information, and it is useful to them. The moderator also has the opportunity to interact and clarify answers given by the participants to the posed questions (Mazza & Berre, 2007). Gaining insight into a new area that have not been proved yet (Savin-Baden & Major, 2013). Provides in depth information (Morgan, 1997).

There are also limitations pointed to the use of this method, such as: the responses from the participants may not be independent, suffering influence in the opinions exposed by others (Mazza & Berre, 2007), and the presence of a dominant member within the group can make others hesitate to talk (Mazza & Berre, 2007). This may difficult moderation.

Data recording procedures

The focus group sessions were sound recorded and had the previous consent of all the participants. The recordings were afterwards transcribed to enable the analysis.

3.5.2. Questionnaires

In this study, two questionnaire instruments were created and used in different phases, phase two - Graph displays - and phase 3 - Usability and final prototype of the U-TRACER®.

Questionnaire "Reading effectiveness of the graphs"

The first questionnaire was applied to test the reading effectiveness of the graphics that were chosen to represent the dataset we are working with in this study – The use of CT by Portuguese Public HEI. The aim was to select the type of graph display to implement in the U-TRACER®, therefore contributing to answer the first research question.

The questionnaire was divided into 3 sections (Appendix 3 - Questionnaire "Reading effectiveness of the graphs"):

- First section was composed of seven questions regarding the overall profile of the participant: age, gender, academic background, professional activity, and experience in using online data platforms.
- Second section was composed of three questions regarding the reading effectiveness of the graphs to retrieve information. For each question there was a graph with which the participant had to interact with online in a demo built for this purpose and then was asked to order them according to their reading effectiveness.
- Third section was composed by a set of three questions regarding the variations in the design of the graphics, and indicating their preferred graphical display.

There were three types of questions types: closed; closed with multiple requiring the respondent to order a set of graphs; and with Likert scale (Martins, 2006).

The interaction with the graphs on the online demo and the completion of the questionnaire was with the presence of the researcher.

The questionnaire script underwent validation by two team members of project TRACER, who commented and on the structure and content of the questionnaire. The changes recommended were made, and the final version of the questionnaire applied (Appendix 3- Questionnaire "Reading effectiveness of the graphs").

The test was applied in an office at the University of Aveiro, were the participants had access to a laptop computer connected to the internet, the survey in a document Word format and with the online demo open on a web browser where the participants could interact with the graphics.

Participants were asked to comment aloud on the interaction with the graphics. The completion of the questionnaire was accompanied by the researcher, as an observer, only intervening when needed to clarify doubts related to the questions.

The researcher took notes of the comments of the participants.

Questionnaire "Usability test to the front-office of the U-TRACER®"

The second questionnaire was applied in phase three - Usability and final prototype - to test the usability of the front-office of the U-TRACER®, identify the problems of interaction with the interface and propose improvements. The test was applied in a face-to-face moment between the researcher and participants.

The questionnaire was composed of three sections and a total of nine questions and 14 tasks, presented to the participant in an online google questionnaire format. The tasks were also given to the participant in a printed format so there would be no need to navigate between different tabs in the web browser. The questionnaire was filled by the participants, although in the presence of the researcher (Munn & Drever, 2004) (Appendix4 - Usability test to the front-office of U-TRACER®).

The limitations identified in using a questionnaire is that it can be used to collect information that tends to describe rather than explain what is being studied, the information can be superficial, and to build a pilot questionnaire is a time consuming task (Munn & Drever, 2004). The main advantages identified, particularly adequate in the present study, are "the efficient use of time, anonymity for the respondent and standardized questions" (Munn & Drever, 2004). Both questionnaires applied were anonymous. The main advantages for this study is the standardized questions with which all the participants were presented with, because the aim was to obtain their response to the same stimulus.

The researcher asked the participants to think aloud during the completion of the tasks. The sessions were audio recorded and the screen of the computer was recorded using Debut video capture software[53].

The recording of the participants comments and interactions performed in the web interface of U-TRACER®.

[53] Debute vídeo capture software http://www.nchsoftware.com/capture/

An instrument of observation was built by the researcher, by specifying an indicator of task completion for each task the participants were asked to complete I the usability test. We integrated this as part of the usability test guide that can be consulted in Appendix 4 - Usability test to the front-office of U-TRACER®.

Previous to all interviews, the interviewees consented to the recording of the sessions. The recordings were afterwards transcribed to enable analysis.

3.5.3. Semi-structured interview

The in-depth interview is the data collecting method for the fourth phase of this study, contributing to answer the second research question of this study: What is the perception of usefulness of higher education decision makers, concerning the U-TRACER® tool?

The interview was divided into six sections and a total of nine questions (Appendix 5 - Interview guide to Higher Education Decision Makers.):

- First section served the purpose of making a demonstration of the web interface of the U-TRACER® tool, yet in its first initial prototype version.
- The second section was composed of two questions to assist in the ccharacterization of the interviewee role as an institutional decision-maker and decision-making processes he or she is involved in at the HE institution.
- The third section was composed of one question regarding the interest of the information disseminated through the U-TRACER®.
- The fourth section was composed of two questions regarding information visualization features of the U-TRACER®.
- The fifth section was composed of one question regarding concerns related to the U-TRACER®.
- The sixth section was composed of three questions focused on the advantages, disadvantages and future use of the U-TRACER®.

We opted for a semi-structured interview because of it is a strong approach to draw information about the interviewees impressions and general comments (Mazza & Berre, 2007) regarding the usefulness of the U-TRACER®.

In depth interviews are frequently referred to as semi-structured interviews due to the interviewers' some control over the direction of the interview, and the participants freedom to elaborate in one or more directions related to the content (Given, 2008). The one-to-one communication in interviews allow the exploration of data through understandings and peoples' opinions (Arksey & Knight, 1999) and inquires deeply into the participant's experiences, especially in this case that we want to gain understanding of information that is sensitive.

The weaknesses of a semi-structured interview are related to the lower opportunity the person interviewed has of giving their own opinion when compared to the unstructured interview process (Savin-Baden & Major, 2013), it may limit the researchers opportunity for interpretation because the interviews depend on the recall of actions which does not substitute observations, and also depends on "the ability of the participant to articulate his or her experiences within the timeframe of the interview, and the ability of the researcher to ask the "right" questions to prompt more detailed discussion and aid the analysis (Given, 2008). An interview takes time to apply, and also to process (Drever, 2003). This method of data collection is commonly used in small-scaled research, and case studies (Drever, 2003).

The nature of the U-TRACER® tool as a web and information visualization tool, determined our choice to create the interview script integrating questions specific to the context of the use of U-TRACER® tool, based on the Technology Acceptance Model (TAM) described ahead in section 3.7 as part of the analysis model. of this research. TAM contemplates Lederers' et al (2000) model for usefulness antecedents, and perceived usefulness: 1) characteristics of useful information; 2) task environment information; 3) strategic areas for corporate decisions; 4) functional area information.

The interviews were conducted through online video conference and in presence. From the total number of 10 interviews, eight were conducted via online video conference due to the distance between the interviewer and interviewee, using skype or google hangout. Two interviews were conducted face-to-face on the request of the interviewees due to the geographical proximity.

The online sessions were recorded using a Debut Video Capture Software[54] which simultaneously records sound and the computer screen. The face-to-face interviews were sound recorded using an audio recorder.

Previous to all interviews, the interviewees consented to the recording of the sessions. The recordings were afterwards transcribed to enable analysis.

3.6. Participants in the study

Participants of focus group 1 were team members of project TRACER, all Higher Education professionals teaching or researching in areas related to the use of Communication Technologies in educational contexts. The common characteristics of the participants, related to their involvement in the project and as professionals, helped the conversation to flow in a more open way (D. L. Morgan, 1997).

[54] Debut Video Capture Software http://www.nchsoftware.com/capture/

The participants in the study were suited to small sample sizes, selected according to each work phase and its aim in data collection and the interest in different types of participants. As Munn and Drever (2004) state, the “effort should go into defining clearly the group or groups of people that the research is interested in, after which a purely random sample can be taken from each group”. The samples in this study were not random, but rather drawn from convenience, meaning that we had a some type of professional contact with the participants, involving the same scientific fields of Education and Communication and Information Technologies. Therefore they were directly invited to participate in this study. Further on in the text, ‘Participants’ will be denominated by the letter (P) and each person will be given a number (e.g. P1 as participant one). We have chosen to number each participant from number one to 16, including participants from both FG.

3.6.1. Participants of the Focus Groups

Inquired by the method of focus group discussions, were a total of 16 participants, all of which were Higher Education professionals with whom we had some type of professional connection: team members of project TRACER; HE decision makers at the rectory level, teachers and researchers. The sampling strategy was both comprehensive and reputational, meaning that the choice followed the criteria: being HE professionals, with work related to the field of Education, Communication and Information Technologies, and Information Visualization; being knowledgeable experts in the areas of the criteria (Savin-Baden & Major, 2013).

Two focus groups took place in this study. In focus group 1 (FG1), there were a total of nine participants, two of the female gender and 7 of male gender, HE experts in the following fields:

- Communication Technologies: P1, P2, P3, P4, P5
- Education: P2, P7, P8, P9, P6, P5
- Chemistry: P7
- Literature: P6

In focus group 2 (FG2), there were a total of seven participants, three of the female gender and four of male gender, all Higher Education professionals being six from University of Aveiro and 1 from University of Minho, experts in the following fields:

- Communication Technologies: P10, P11, P12, P13, P14, P15, P16
- Education: P13
- Information Visualization: P12

The focus groups were conducted with professionals working at University of Aveiro, framed the profile of the target audience of the tool: higher education professionals, students and researchers (Table 12). The names of the participants were substituted by a code composed of the letter P (meaning participant) and a number. The participants of both focus groups have academic backgrounds related to education, communication technologies, information visualization. This allows the combination of their interests with the information needed to be obtained (Given, 2008). The opinions, ideas and suggestions that emerge from the different perspectives of the participants, will contribute to answer the first research question.

Table 12. Number of Participants in the focus groups, per professional role in HE. P: Participant.

Professional role	Focus Group 1	Focus Group 2
PhD student	P8, P9	P16
Researcher	P7	n/a
Professor	P1, P2, P3, P4, P5, P6	P11, P12, P13, P14
ICT technician	n/a	P15
Pro-rector	n/a	P10
	Total 9	**Total 7**

3.6.2. Participants of the questionnaires

For the questionnaires and usability test the sampling strategy was homogeneous, choosing a small sample of individuals with similar and defining characteristics (Savin-Baden & Major, 2013): higher education professionals and PhD students, with work activity related to communication technology, computers, education and design.

3.6.2.1. Participants of questionnaire “Reading effectiveness of the graphs”

With a total of 12 participants, with the average age of 32 years, being 5 of female gender and 7 of male gender. All participants are higher education professionals from University of Aveiro (Table 10), 8 doctoral/postdoctoral fellows of whom 4 are additionally higher education teachers, 2 specialists in information technology and communication, and 2 scientific research fellows. Table 13 identifies the participants and their professional role in HE. We have chosen to number each participant from number one to 12.

Table 13. Number of Participants who completed the questionnaire “reading effectiveness of the graphs”; (P): Participant.

Professional role	Participants
Postdoctoral/PhD student	P2, P5, P6, P7, P8, P10, P11, P12
Research fellow	P1, P3
Professor	P4, P5, P9, P11
Expert in information and communication technologies	P4, P11

The professional areas of participants are divided between computer informatics (2), Arts and Humanities (3) specifically Design, Information and Journalism (2), Education (2), and other areas are covered by Sciences Communication and Information (1), Sciences and Communication Technologies (2).

In the first section of the questionnaire, participants were asked about the frequency with which they used online infovis data portals. From the total of 12 participants, all HE professionals, 9 confirmed making a monthly use of online infovis data portals and 3 participants never used infovis data portals (Figure 44), 10 participants consider to be experienced users of data portals and 2 non-experienced.

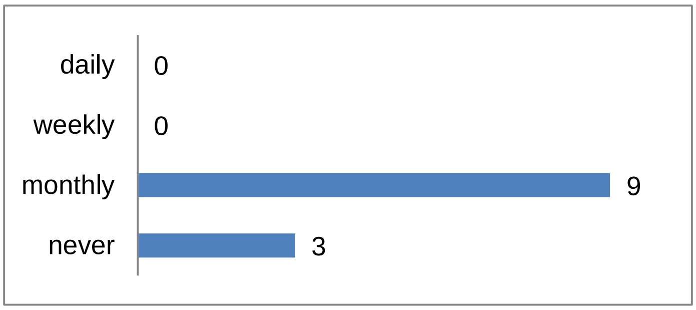

Figure 44. frequency of use online infovis data portals, indicated by the participants who completed the questionnaire "reading effectiveness of the graphs".

3.6.2.2. Participants of questionnaire "Usability test to the front-office of U-TRACER®"

The profile of the total of 7 participants was identified according to: age, gender, academic training completed; scientific area of professional activity; professional area; experience and frequency of use of online infovis data portals.

The participants average age is 27 years, 2 female and 5 male. All are higher education professionals (Table 14) 3 PhD/doctoral students, 1 Design professor and 3 research fellows. Six of the seven participants have a completed master's degree. The professional areas of participants are divided between computer informatics (3 participants), Arts and Humanities (3 participants) and Social Sciences (1 participant). In Table 14 the 'Participants' are coded with the letter (P) and each person will be given a number (e.g. P1 as participant one). We have chosen to number each participant from number one to five.

Table 14. Participants and professional role in Higher Education. (P): Participant.

Professional role	**Participants**
Postdoctoral/PhD student	P1, P2, P7
Research fellow	P3, P4, P6
Professor	P5
	Total 7

The participants were asked about the frequency with which they use infovis online data portals, 6 of the participants confirmed using these portals, 3 in a monthly use, 3 using less than once a month, and only 1 participant indicated never to use online data portals. Subsequently, regarding the experience of the participants in using data portals, 1 participant indicated to be a non-experienced user, 3 consider to be somewhat experienced, 1 participant as an experienced user, and 2 participants as very experienced (Figure 45).

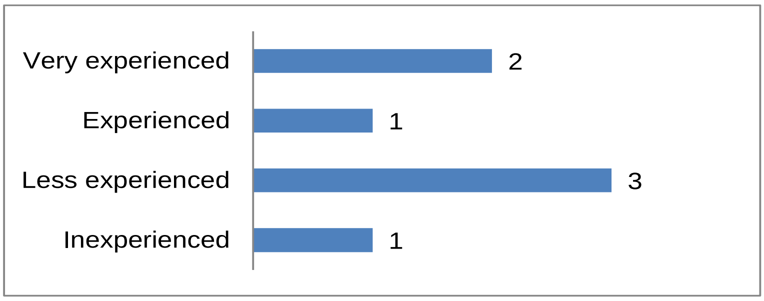

Figure 45. Participants experience of use of online data portals.

3.6.3. Participants of the interviews

For the interviews, the sampling strategy was comprehensive, choosing by criteria (Savin-Baden & Major, 2013) of: Higher Education decision makers who provided data in project TRACER. In semi-structured interviews the sample is usually small, which in small-scale studies it is not seen as a restriction because the aim is to understand the opinions and expectations of that specific group within a local context (Drever, 2003). The participants selected to be interviewed were the people – rectors, pro-rector, president, vice-president – who had been in charge of providing the data requested by project TRACER regarding the use of Communication Technologies in their HE institution. The same data that feeds the U-TRACER® tool. The approach was to invite all the decision makers from the total number of 9 Portuguese Public HEI that provided data, and recognizing the full agenda of the people invited, we proposed that in the event of being impossible to ensure a participation, to delegated this to another decision maker who either was involved in the data collection process, and who could represent the institution. This specific group people are part of U-TRACER® target audience, familiar with the data, and are the stakeholders who can contribute to the sustainability of the tool.

Therefore the aim of the interviews was to understand the perceived usefulness of the tool by the HEI decision makers, contributing to answer the second research question of this study.

From the total number of nine HEI invited to participate in the interviews, both to the University and Polytechnic subsystems eight accepted to participate:

- Open University.
- University of Açores.

- University of Aveiro.
- University of Évora.
- University of Trás-os-Montes e Alto Douro.
- Institute Polytechnic of Beja.
- Institute Polytechnic of Tomar.
- Institute Polytechnic of Viseu.

The profile of the interviewees reveals that three are of the female gender and seven male gender, four are decision makers at the rectory or presidency levels, and four are decision makers at the Information and Computer Services (Table 15).

Table 15. Number of intervewees and professional role per Higher Education subsystem. (n/a): not applicable

	Higher Education subsystem	
Professional role	**University**	**Polytechnic**
Pro-rector/ pro-president	2	1
Vice president	n/a	1
Director of Computer Services	2	2
Responsible for information systems	1	
Chief of Communications office	1	0
Total	**6**	**4**

From the two pro-rectors (university subsystem) interviewed all were pro-rectors for Information Communication Technologies, and one pro-president (polytechnic subsystem) for Planning and Strategic Development.

3.7. Data analysis

The data analysis focused on the procedure of content analysis, much used in social science studies, offering the possibility of treating information and testimonies that present some level of depth in a descriptive and interpretative way (Guerra, 2010; Quivy & Campehnoudt, 1995).

There are two methods of content analysis: quantitative and qualitative. The quantitative method of content analysis focuses on the frequency with which certain characteristics of the discourse appear, or the correlation between them; the qualitative method analysis the presence or not of a characteristic, or the way elements of the discourse articulate (Quivy & Campehnoudt, 1995). We will adopt both types. The analysis was be made to the transcripts of the focus groups and interviews, through qualitative description based on a categorical content analysis, supported by the qualitative analysis software webQDA. The content of the transcripts were set through categorical analysis, by grouping text units according to the categories proposed in the reference model. The process of categorizing is iterative process for the researcher, revisiting the text units that may be relevant to more than one category, and resolving contradictions (Given, 2008).

During the focus group sessions, the participants were given instructions to comment on any question to which they wanted to share their opinion or enter a discussion, but the participation was not mandatory. Therefore we did not make a quantitative content analysis. The empirical data was confronted with the referential framework built by the researcher and detailed in section 3.7 (Guerra, 2010). Through this technique it was possible to give a descriptive dimension of the data, and an interpretative dimension which stems from the questions and reflection process, of the researcher, regarding the object under study (Guerra, 2010).

The questionnaires were subject to quantitative analysis for the closed questions, and for the open questions were subject to categorical content analysis.

Chapter 4. Conceptualization of the U-TRACER® an Information Visualization tool

“The design of an information visualization tool (…) is very much a craft activity” (Spence, 2007). The design process of the U-TRACER® information visualization tool draws upon concepts, techniques, previous designs and the discussion of ideas. As Spence (2007) states, a process with a craft nature, where all the work phases developed and analysed, led the conceptualization of the U-TRACER®.

The implementation of phases one, two and three was part of the conceptualization process of the U-TRACER®, phases which will be detailed in this chapter. Conceptualization of the U-TRACER®®, in Figure 46, will describe the data collection and analysis and discussion, attempting to answer the first research question: What information visualization proposal is most adequate to represent the dataset concerning Communication Technology use in Portuguese public Higher Education institutions?

- **Phase 1 - Interaction features:** Data collection by conducing two focus groups sessions and its analysis, leading in phase one, to the outcome in the proposal of the interaction features for the U-TRACER®.
- **Phase 2 - Graphic displays:** Analysis of the dataset to be represented in U-TRACER® leading to the outcome of the graph type proposals. Test the graphs with participants, analyse the data and propose the final types of graphs to be implemented in the tool.
- **Phase 3 - Usability and final prototype:** Usability tests to the U-TRACER®, with users, data analysis and the final proposal of the conceptual model for the tool.

The implementation moments of each phase were responsibility of a company hired by project TRACER for the purpose of development of the U-TRACER® tool, and responsibility of the project team. A summary of these moments of each phase will be made in each section, to situate the reader and related to choices made that were impacted by the outcomes of the implementation moments.

The process of weaving all the different phases of data collection and analysis attempts to answer the first research question: "What information visualization features are most adequate to represent the dataset concerning CT use in Portuguese Public Higher Education Institutions?"

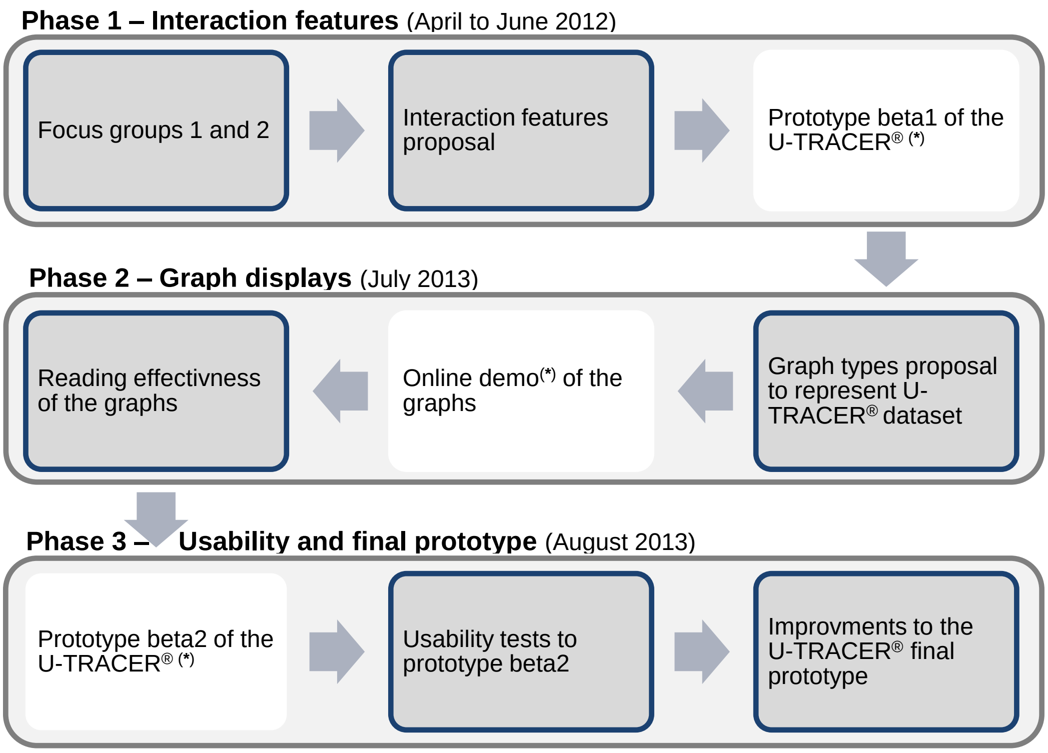

Figure 46. Conceptualization of the U-TRACER®. (*) implementation developed by the company contracted by project TRACER.

4.1. Phase One - Interaction features

The study conducted in the first phase of this research project was supported by the data collected by thetwo focus groups (1 and 2) conducted, which aimed to collect the opinions of the participants regarding the interaction features they would prefer to have in the U-TRACER® tool. The content analysis to the discussions aroused in the focus groups provided a deeper understanding of the expectations and preferences of interaction features for the tool. The following section presents:

1) content analysis of the focus groups.

2) synthesis relating the analysis to the research goals.

The full transcripts of the focus groups 1 and 2 can be found in Appendix 7 and 8 (Transcription of the session Focus group 1; Transcription of the session Focus group 2). The Analysis to the focus groups sessions will be presented in the following way: question from the script; content analysis; quotes of the answers given by participants (the quotes will be labelled by adding the related codification that substituted the participants mane (e.g.: P1, meaning Participant1) – for more detail see Table 12 in page 66. The content analysis is qualitative and not quantitative, because the participation in the discussions was not mandatory, rather the participants could choose when and if they participated in the discussion.

4.1.1. Interest in the Information Visualization tool

The first question set to the focus groups participants was about their interest in having access to an information visualization tool such as the U-TRACER®.

All the participants in both focus groups agreed on the interest of the U-TRACER® tool and the information disseminated through infovis features. Participants of FG1 - project TRACER team members – considered that the infovis features will allow future users of the tool to make a faster and easier analysis of the dataset (P2, P3, P4, P7, P8), being most useful for overtime data analysis assisting in the identification of trends related to the use of CT in HEI.

> P3: "Relating to interest, I have no doubt, especially because data visualization allows one thing that I think is essential: a quick qualitative perception of the data available. That is where I see people using this type of tool. In general the interest is for people building a quick opinion, qualitative and not necessarily detailed, on a set of aspects they have interest in understanding."

Moreover, the interest the tool may have for HEI that provided the data that feeds the tool was also highlighted (P9), enabling their access to the data and systematized information of all the institutions that also provided data about the use of CT in the institution. This can be a very relevant asset, because as identified in the U-Map tool report, HEI are many times "serious survey fatigue" as result of the administrative burden to respond to information requests (van Vught *et al.*, 2010, p. 32) and in return of the effort to answer surveys and provide information, it is important to guarantee a return that compensates the effort made by the institution.

> P9: "Universities are very used to being requested information for several studies, but maybe they do not have the opportunity to see the information systematized in an interesting way. And what we can offer is to some extent also that, it is putting in a distributed online solution the product of their collaboration, and the information which was provided."

In **FG2** participants expressed interest in the infovis features that allow customization of information, but also saw interest in having access to the full report for an in depth analysis of the data.

Besides the recognized interest of the participants, two main concerns were manifested. The first relates to the rigor of the data presented in U-TRACER® assuring that it does not induce its user in an erroneous analysis.

> P10: “When you ask me if it is interesting to study new techniques and uses of information visualization, I say yes. However I consider myself old school in the sense that such reports which are said to be dense, with graphics well built, but synthetic in explaining the content and how they arrived to that content. I continue to consider them very interesting. Now the dynamic of changing the questions and building a report about what I'm searching, a bit like what I can do with PORDATA, which I think is a beautiful example of information extraction in a gigantic database which I think I a wonderful exercise... and I also appreciate that possibility. Now all the information that is in the background that originated it, I want to know it, I want to read the full report.”

> P12: “Data or information visualization can be very interesting in an analysis process, it can be a great help in research. But there are two things to which we need to pay attention: first is what I call "garbage in, garbage out", if the data is neither complete nor accurate, what you will see is of no interest. Worst yet, it may be dangerous because it can provide a false sense of security to those who are analyzing the data: I have some very intuitive views, I then look at them and see a series errors that have no groundings! So I'd say you have to know very well to what users, to do what, in what context, and ensure that the data is actually accurate and complete, and only then from there can I sit down, realize what kind of methods I will use to visualize, and if it's worth it...”

The second concern related to the willingness of HEI to have their data compared with the data of other institutions. These concerns also met those expressed in the U-Map and U-Multirank reports (F van Vught et al., 2010; Frans van Vught & Ziegele, 2011), where the HE participants pilot study revealed concern in the comparisons between the data of the institutions, mainly because the comparison lacks contextual information about the institution, but also because of the conceptual and methodological foundations of the data collection process, behind the infovis tools.

> P13: “My question is if the higher education institutions want to be compared and if they are open enough to provide this data, knowing that it will serve be for a tool that will essentially allow the comparison between institutions scenarios.”

4.1.2. Interaction features

Filters of the information

Regarding the interaction features, based on the definition by Shneiderman and Plaisant (2010), to understand which interaction tasks – overview, zoom, filter, details on demand, relate, history, extract - the participants would prefer to perform in the U-TRACER® tool, they were shown examples of infovis tools (these examples are illustrated in Appendix 2 - Focus Group Guide).

Given the method of filtering information, participants were asked to observe two figures below (Figure 47, Figure 48).

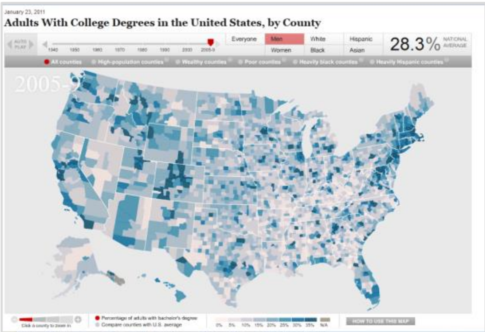

Figure 47. Adults with college degrees in the United States by county (January 23, 2011)[55].

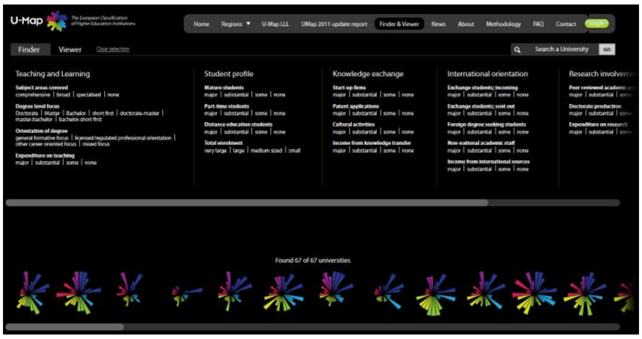

Figure 48. U-Map European classification of higher education institutions (prototype version)[56].

Participants from **FG1**, P2 and P4 stated that the method of filtering information should allow an iterative and cumulative process, having a geographical filter of the information or others types of filters. The geographical filter of information was consensual among participants as a filter of interest for the U-TRACER®, although they envisaged problems with the representation of HEI on a map, concerned that a specific region of Portugal might be visually overloaded with the representation of institutions (P8). P3 stressed that the visual representation of all HEI that provided data to the U-TRACER®, should be valued in a map visual representation, because it could raise the interest of non-participant institutions.

The concern over the visual result of mapping institutions, that could create a visual overload of a specific region in a map, could be solved by adding the interaction task of zooming in on items of interest (Ben Shneiderman & Plaisant, 2010). Although this solution was not proposed by the participants, we will consider proposing it to integrate the U-TRACER®.

Participants P3, P5 and P6 added the need to filter information by HEI and by the main topics of 'Communication Technology'.

[55] Figure 47: retrieved from http://chronicle.com/article/Adults-With-College-Degrees-in/125995/
[56] Figure 48: retrieved from http://www.u-map.eu/

The variable of time was seen as one of the most valuable filters for the U-TRACER® by participants in **both FGs** (P3, P5, P13 and P16), arguing that this would enable analysis of the evolution of the use of CT and identification of the trends regarding each HEI and at a national level.

> P5: "I think by that the temporal data may be one of the capital gains of the tool, to see the evolution. Although there are all those sustainability challenges. But having this, and after 3 or 4 years we see the trends, in fact that has a much greater value than seeing data year by year."

> P16: "(…) having access to filters that would allow me to choose only what I want to see, compare institutions and data, and the evolution over time, having access to that is an asset."

Despite the interest, P13 (FG2) called upon his professional experience to warn that the temporal analysis depends on the regularity with which data is collected. The same concern identified the U-Map and U-Multirank reports (F van Vught et al., 2010; Frans van Vught & Ziegele, 2011), described previously, regarding HEI "serious survey fatigue".

Participants in **FG2**, observed the examples shown and commented on the different methods of selection of variables rom the dataset, comparing the quantity of variables the user would have to select in order to generate a graph. P13 made the suggestion that the high number of variables of the U-TRACER® dataset should not all be listed, such as happened in the U-Map tool (Figure 48) being observed. Rather, variables of the dataset should appear to the user in a segmented way:

> P13: "If there are 4 or 5 different variables, it is a very easy thing to fit into the interface. In the other example (U-Map tool) there are too many variables."

Summary: The macro filters of information proposed to integrate U-TRACER® are filtering by: Higher Education Institution; filter by the main theme of "the use of CT"; filter by time, which in the context of the data the time frame should be 'academic year'. Filtering with dynamic queries as Shneiderman (1996) indicates, helps users to answer specific questions by allowing OR combinations as well as AND combinations of attributes, to allow the users information needs. These combinations will need to be added.

Details on demand

In information visualization, **'details on demand'** is defined as the action of selecting an item or group of items and obtaining their details when needed, which implies that a detail aggregates different features of an object (B. Shneiderman, 1996, p. 337).

Given this interaction task, the comments of the participants from both FG 1 and FG2 revealed an overall agreement regarding the usefulness of this task. Arguing about the usefulness of this task, P9 recalled that as a user of other infovis tools that represented data about HEI, he felt the need to require details on demand as well as information that contextualized the data. Participant P11 considered the possibility of having details on demand while interacting with graphs as a very relevant feature assisting the contextualization of the data represented:

> P11: "It is called details on demand, you ask for a timeframe between 1920 and 1925 and it gives what you ask for"

A discussion arouse between participants of FG2, P10, P12 and P14, who highlighted that for them the most important was to have access to the detailed information through the access to the full reports that describe the data and its' analysis process:

> P14: "In abstract terms, whenever I see something, I always want more details."

> P12: "Or at least to know that you can have more detail."

> P14: "Exactly, I want to know that it is there but I do not want the information to appear all in the same place. For example, I want: if there's that yellow area on the map, I want to be able to click with the mouse and appear alongside that information that is there for me to know in more detail what are do the percentage mean.... Now this implies the construction of additional information to the one available, that may not even be visualized by anyone, but that is there. I think that is essential in an interactive tool, if it does not have that than there is not usefulness. Otherwise we might as well jump through the pdf pages. The interest is in narrowing the information."

Summary: The interaction task details on demand should be integrated as a feature of the U-TRACER®, allowing the user to obtain details of the data while interacting with the graphsto which should be added the possibility of the user to access the full report of the analysis of the same dataset.

Relation among items

Regarding the interaction task **'relation among items'** participants were asked about the need to relate variables of the dataset in order to visualize the relation between them, according to their commonalities and their differences. The relation of items to visualize their differences was linked to the direct question "Should the U-TRACER® enabled the direct comparison of data of different HEI, similarly to what happens in U-Map?" The opinions varied in both FG.

Participants of **FG1** were questioned about which type of comparison the U-TRACER® should enable the user to perform. The opinions found consensus in two aspects: (i) not to enable comparison between HEI as a graphical result; (ii) enable comparison of one HEI in relation to the national average of all HEI (P2, P3, P6). The main argument for (i) was that enabling a comparison between HEI to result in a graph could be understood as an attempt to rank institutions, and that is not the aim for the U-TRACER®. Nevertheless, despite P8 agreeing about the difficulty, regarding the context of the data, of having a graph outcome of the comparison between more than one institution, stated that this could generate very interesting visualizations. In fact a visual comparison should not necessarily aim to position institutions in a ranking order, because for that the data would have to be treated and measured in a different way than it would in the U-TRACER®. In **FG2**, P13 reminded that the visual comparison between two institutions, if done as in the example of the U-Map tool (Figure 48) by putting two graphs side by side, requires from the user the same type of effort as if the analysis is made by looking at one graph at a time without being displayed side by side on the interface. P13 justification is that the user of U-TRACER® when analyzing the data is automatically comparing institutions because he is filtering the same information for more than one HEI, and whether you are visualizing the graphs one by one, or to seeing two or more side by side (as shows

Figure 49), a comparison will always exist.

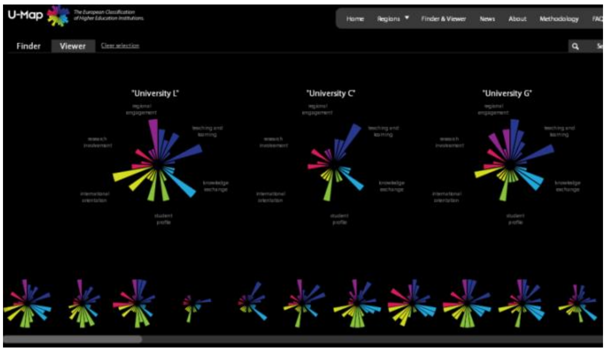

Figure 49. U-Map: comparison between three higher Education Institutions.

FG2 participants opinions ranged from considering comparison as an added value to the tool (P13, P14, P16), to recalling a previously mentioned concern about the need of ensuring accuracy of the data in order for a comparison to be made (P10 pro-rector). P13 (professor) and P16 (PhD student), were of the opinion that as users of the tool, being able to perform a visual comparison between HEI would be of great interest to them as users, and the inexistence of that visual comparison could make the U-TRACER® loose its interest:

> P13: "As a teacher and researcher it is obvious that it interest me compare."

> P16: "If there is no comparison it loses interest."

Based on previous experience of as a user of infovis tools P14 (professor), was also of the opinion that the feature of graphical comparison of HEI would facilitate the interpretation of the data:

> "The direct comparisons we typically see on many platforms, those I am honest, and occasionally I access those comparisons but don't retrieve understanding from them. Why? Because we are automatically doing the mental process: I will see Portugal and then Spain, and I am automatically comparing (…) Sure there are details of comparison that can become facilitated if they are put side by side." (P14)

Nevertheless concerns were emphasized on the need of having rigorous data to properly assure a comparison between institutions without misleading interpretations (P10, P14, P15). P10 (pro-rector) who asserts institutions openness to benchmarking and open data, advised that in order to allow direct comparisons with graphical results, there has to be a rigorous normalization of the data, to assure what data can and cannot be comparable.

> "There is much to be careful in comparison. (…) If I compare the number of publications between University 1 and University 2, it is immediately absurd. They are 4000 people and we in 1000 or 1500 and 5000/6000. This should not be allowed to be compared. The ratio of researchers or teachers it's ok (...) the comparison has to be intelligent because if it is not I am misleading people." (P10)

Summary: The opinions were divided between the participants of both FG. In FG1 participants agreed on two aspects: (i) not to allow comparison between HEI as a graphical result; (ii) to allow comparison between one institution related to the national average of institutions. In FG2 three participants agree in enabling a visual comparison of HEI, and other three participants manifested their concern about the need to assure a rigorous treatment of data to enable a comparison between institutions without misleading interpretations.

Process and provenance

For a more direct identification of the **interactive features for dynamic visual analysis** the participants were questioned about interaction features of **process and provenance**, defined by Heer and Shneiderman (2012) as related to four types of tasks: to **record** analysis histories for re-visitation, review and sharing; to **annotate** patterns to document findings; to **share** views and annotations to enable collaboration; and to **guide** users through analysis tasks or stories.

In **FG1** participants considered as a disadvantage any type of public **annotations** made by the users in U-TRACER®, stating that a careful and ongoing moderation would be needed (P1, P2, P4). It was considered best to allow the user of the U-TRACER® to **share views**, and therefore any comments would be made outside the tool. Sharing was understood as the action of sharing on social networks the generated graphs, and also sharing by enabling the user to download the graphs and the datasets in print formats (P3, P4, P5, P6).

> P2: "I think that to comment in tool is highly dangerous. It would implicate having a system to create an engine of comments which had to be moderate, and that would need someone to revise the comments. Now to do what we have discussed in other meetings, to share it on social networks and then comment there, it is common ground."

> P3: "(...) also to have a parallel means to export the data, more traditional, conventional, more excel (…)."

As participant P4 detailed on the advantages of enabling a user to share, which may contribute towards the dissemination of the U-TRACER®.

> P4: "Sharing some parts of the database, yes. (…) It is important that the format allows you to share, share one image that resulted from any analysis that I did on the site which resulted in a chart that I want to share, and this image goes to facebook, or somewhere else. It would be important to the success of the tool."

The **FG2** participants shared FG1 concerns related to the need for moderation if the system was to have public **annotations**. Participant P16 (PhD student), alerted that annotations available to the public had either to be moderated by the administrators of U-TRACER®, or self-regulated within the community, finding this last option not a safe one.

> P16: "Commenting would require moderation, which will only bring you extra work. Being the case of official institutions having comments could bring doubtful reviews, and it would only bring you extra work to moderate this, or you could trust the community to regulate themselves. Opening it up to the general public seems to me as not safe."

Participant P14 (a professor), recalls the example of the popular online tool PORDATA[57] (infovis of statistical data about Portugal) which does not allow users to annotate or comment within the tool, otherwise they would have to have dedicated more time and human resources just to moderate comments.

> P14: "For example PORDATA doesn't allow comments. And people discuss PORDATA quite a lot in networks. It is one this less they have to worry about."

Nevertheless opinions were divided as to the advantages. For P12 (professor and infovis specialist), allowing annotation and data export were two essential features that should be offered to the user of the tool, letting them use data elsewhere. Nevertheless P12 did not specify whether the annotation should be public or private.

[57] PODATA: http://www.pordata.pt/

> P12: “I would continue to say, annotate and export are basic things. And if I have a visual display or create one, for me it is very important in any situation can write it down and export it to be able to use it elsewhere.”

For P10 (pro-rector), sharing results in social networks raises concerns related to loss of control and misuses of the information. The concern over misuse of institutions information is common, such as the raising discussions about HE ranking tools and the misuse of that information by academics, universities, policy-makers and students, as a consequence of open access to “manageably packaged and relatively simple information on the ‘quality of higher education institutions’” (UNESCO, 2013a, p. 13).

Although P13 agrees with this view, added the issue of the power of social networks to attract visitors and generate discussions.

> P10: “When sharing on social networks, you lose control. I think this is the type of information that should not be easily sharable with the world. (...) We see today as has been demonstrated that governments and political parties, companies have opinion makers in social networks to counter the first trends (....) We Portuguese, at this time we're wasting time with social networks if you ask me, because it's just noise, noise.”

> P13: “Social networks are important mainly if we want to create noise and attract visitors. (...) But in reality this website has different characteristics. It is not something that someone who is participating with it and funding it, will have the goal of attracting people to it.”

Summary: Opinions of both FG were convergent relating to allow share in social networks the visual display generated by the user of U-TRACE®, and allow the same to be downloaded along with the dataset, for further use. The annotation feature was considered a disadvantage if public, and only one participant enhanced the idea that annotation was important for the user, although not specifying the public or private character of the annotation feature.

Guide users through analysis tasks or stories

Given the features of ‘**guide users through analysis tasks’** which can include guiding through visual analysis systems and incorporate *guided* analytics, or processes that allow analysts to take excursions while keeping track of what they have done (Heer & Shneiderman, 2012). To illustrate this feature it were shown images of the webpage OECD Better Life Index[58] that guides the user through different type of content (graphic and text) that assists the user through in depth data analysis (Figure 50, Figure 51).

[58] OECD Better Life Index: http://www.oecdbetterlifeindex.org

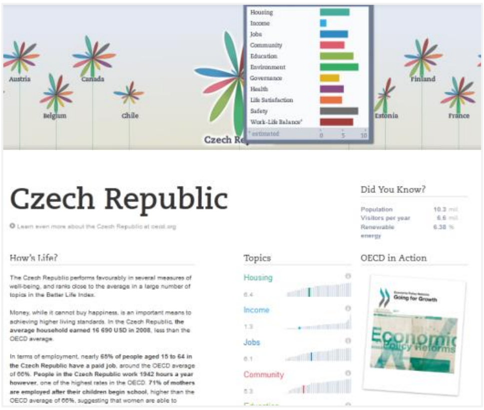

Figure 50. Better Life Index for Czech Republic

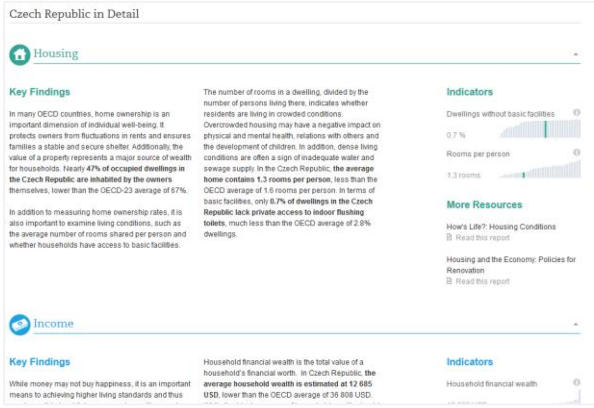

Figure 51. Better Life Index for Czech Republic, in detail and key findings

In the **FG1** session participants considered useful to integrate into the U-TRACER® guide features, a user manual (in pdf or video format) and a frequent asked question (FAQ) section. Additionally P4 and P5 (professors) proposed also to add icons of contextualized help distributed in the website to guide the user through the tasks and the analysis of the data.

> P4: "One solution is to have a commitment of contextualized help, which are the question marks nearby one or another question that may arise. (…) Having a handbook that explains how it's used, to be downloaded."

Participants of **FG2** also agreed that contextualized guides should be integrated into the U-TRACER®, and also integrate guides such as a handbook, video tutorial and a FAQ section (P10, P12, P14).

> P12: "It has to have the complete package."

Although looking to focus the discussion on interaction features, during the session of FG1 participants made unexpected comments and suggestions identified in the content analysis, leading to add a new category to the analysis model presented in section 3.7 Table 13 (page 74): multiple visual representation displays of the dataset. This would be offered to the user of the U-TRACER® as a filter meeting the users preference and type of data being analysed (P3, P4).

> P3: "I think about the possibility of offering a set of limited visualization techniques, which each user can possibly use, depending on their own preferences or possibly depending on the type of data you are analyzing. This can eventually make sense, and worth thinking about."

This discussion raised in reaction to the U-Map visual display of the data, that in the opinion of P4 offered difficulty reading the data. Moreover, in the opinion of P8 offering multiple visual displays of the dataset, although a relevant suggestion, could also create confusion if the displays were not adequate.

> P4: "I think these graphs (U-Map graphs) are extremely opaque, and a graphic must be immediately seen. If you need a label, if need to pass over the computer mouse, I think it doesn't make sense. (...) you need to have a visual display that is clear, some will be by maps, other bar charts, others will be by more complex views."

In FG2 in the discussions about the visual displays did not emerge.

Summary: Regarding the features to guide users through analysis tasks, in both FG sessions there was consensus between the participants relating to offer the user of U-TRACER® a guide through a user manual (in pdf or video format), a frequent asked question section, a guide through contextualized help distributed in the website, and finally multiple visual displays to represent the dataset.

4.1.2.1. Towards the proposal of interaction features

In a scenario of interaction, a higher education stakeholder accesses the U-TRACER®, encountering a space of continuous interaction, through the selection of different filters of information which output is generate a visual display of the datasets. The goal is to gain insights into the dataset about the use of CT in Portuguese Public HEI. To begin the interaction the user may ask the following questions:

- Which CT are being used in a HEI?
- How are CT being used at a national level?
- Is there a trend in the use of CT?
- Which institutions have differentiated uses of CT?
- How does one institution compare to another?
- How does one institution compare to the national average?

A summary of the interaction features that were proposed by the FG participants, to integrate the U-TRACER® is systematized and presented in Table 16. Nevertheless it seemed useful to present in a table format the synthesis of the interaction features that prevailed to integrate the conceptualization, and the participants who proposed those features to be integrated. It is relevant to notice that there is a balance between the both focus groups results of the discussions regarding the interaction features to integrate the U-TRACER®.

Table 16. Synthesis of the interaction features that prevailed to integrate the U-TRACER®. (P): Participant; (n/a): not applicable

		Interaction features proposed to integrate the U-TRACER®	
	Interaction features	**Focus Group 1**	**Focus Group 2**
Interaction Tasks:	Overview	n/a	n/a
	Zoom	n/a	n/a
	Filter	P1,P2,P3,P4,P5,P6,P8	P11,P3,P14,P16
	Details on demand	P3,P4,P7,P8,P9	P14,P12,P11
	Relate	n/a	n/a
	History	n/a	n/a
	Extract	n/a	n/a
	Scroll	n/a	n/a
Process and Provenance:	Record	n/a	n/a
	Annotate	P1,P2,P4	P10,P12
	Share views	P2,P3,P4,P5,P6	P10,P11,P12,P16
	Guide	P1,P2,P4,P5,P6,P8	P10,P11,P12,P14
	Alternative representation	P3,P4,P8	n/a
	Comparison of data	P2,P3,P6,P8	P12,P13,P16,P10,P14,P15

The interaction features presented above will therefore be part of the conceptual model for the U-TRACER® proposed in this study.

Explaining the filters

Looking at the dataset and the proposed macro filters to feature in the tool as result of the focus groups analysis, result the following filters with dynamic queries (AND, OR):

a) Context of the data

- Higher Education Institution: filter per institution, and one institution versus the national average;

  (OR)

- Geographical: filter by regions of Portugal (regions according to the division of the territory of NUTS II).

b) Temporal

- Filter by one academic year

  (OR)

- Filter by a period of time between academic years

c) Theme: Use of Communication Technologies

- Filter by dimensions of analysis that measure the types of CT use.

Given the task of ‘**details on demand**’ the majority of the participants of the FG chose the following to integrate the U-TRACER®:

a) interact with the visual display to obtain more details on the data, which includes from the aggregated data of the regions of Portugal to obtain individual data on each HEI;

b) access the full report of the data analysis.

Given process and provenance interaction, majority of participants consider important to integrate the following tasks:

a) share in social networks the graphs generated from their data query;

b) download graphs generated from their data query and its dataset in tabular display and *pdf* and *excel* digital formats, for further exploration or use of the data.

Regarding the feature **guide,** the participants of the focus groups agreed it is relevant to assist the user in exploring the workflow to visual analysis, both for newcomers or experienced users. The guides should not be invasive of the interaction space, and the user should have access to it whenever needed. The features proposed were:

a) give users pre-generated graphs as demonstrations of which types of information can be obtained;

b) tutorials in video and book;

c) contextualized help;

d) frequent asked questions (FAQ).

Additionally was proposed to offer the user of U-TRACER®, more than one type of visual representation of the data, attempting to meet a users’ need to choose a type of graph more suitable.

Table 17. Interaction features to integrate the U-TRACER®: results of the focus groups sessions analysis.

Interaction features	Element
1. Filters	**1.1.** Context of the data: a) Higher Education Institution: filter per institution, and one institution versus the national average. b) Geographical: filter by regions of Portugal (regions according to the division of the territory of NUTS II).
	1.2. Temporal: a) One academic year. b) A period of time between academic years.
	1.3. Theme 'Use of Communication Technologies': a) Dimensions of analysis that measure the types of CT use.
2. Details on demand	**2.1.** Interact with the visual display to obtain more details on the data.
	2.2. Access the full report of the data analysis.
3. Process and provenance	**3.1.** Share the graphs in social networks.
	3.2. Download graphs generated and its dataset in tabular display: format *pdf* and *excel*.
4. Guide Users	**4.1.** Existing pre-generated graphs as demonstrations of which types of information can be obtained.
	4.2. Tutorials in video and book.
	4.3. Contextualized help.
	4.4. Frequent asked questions (FAQ).

4.2. Phase 2 – Graphic displays

As was mentioned in the previous section, the dataset we are working with in this study results from the data collected within project TRACER, where all 35 Portuguese Public Higher Education Institutions were invited to answer an online questionnaire entitled "The use of Communication Technologies in Portuguese Higher Education Institutions – Institutional perspective" (Appendix 9 - Project TRACER Questionnaire about "Use of Communication Technologies in Portuguese Public Higher Education"). A total of 9 Higher Education Institutions provided data. Within project TRACER the data was treated and transformed into a table format, it was this data we worked with in this study to explore the types of graphs that could represent it. The first step was to understand the data that would drive the visual representation.

We based our analysis of the dataset on three parameters often used by creators of information visualization tools (F. Viégas, 2005):

1) To understand all the dimensions and to choose the ones which to represent;
2) Define the questions that interest exploring;
3) The theoretical findings concerning the use of Communication Technologies in Higher Education teaching and learning practices.

4.2.1. Understanding the data type

The data type and the relation between its items directly influences the visual display (R. Spence, 2007). We are using the term of data type as similar to the term of data measurement scale (ordinal, nominal, interval). The first step of the work was to identify the data types to represent. The data is composed of a total of 63 datasets (each question of the questionnaire that supported the data collection is considered a dataset). Each dataset was analysed and identified as quantitative or non-quantitative data, with nominal, ordinal measurement scales, or simple data (yes or no answers), and text. Additionally we categorised each dataset by the number of variables it has and which will be visually represented (Table 18).

Table 18. Dataset type per number of variables of datasets

	Quantitative datasets	Non-quantitative datasets		
	Nominal	Simple	Ordinal	Text
One variable	11	25	17	2
Two variables	4	3	0	0
Three variables	1	0	0	0
TOTAL nº	16	28	17	2

From the total number of 63 datasets, of which 16 are quantitative and 47 non-quantitative datasets, we selected 49 datasets to be visually represented and met the following criteria: non text datasets; non interdependent datasets to avoid repetition of information (see explanation in the example below). This process of selection led us to have the final 49 datasets to represent (for detail se Appendix 10 - 49 Datasets retrieved from TRACER Questionnaire “Use of Communication Technologies in Portuguese Public Higher Education”):

a) 41 datasets of 1 variable;
b) 7 datasets of 2 variables;
c) 1 dataset of 3 variables.

Understanding each dataset type was the first phase, followed by the second phase that is to understand the datasets when the filters 'Higher Education Institution' and 'Regions of the Portuguese territory' are applied. To cover the

Often may be realized that datasets[59] can have several more variables than can be legibly represented in a single visualization (F. Viégas, 2005). Therefore in Table 19, are identified the number of variables of all the datasets to which we added the number of indicators within each variable – example: the variable 'study cycles of Bologna' have 3 indicators 'first cycle, second cycle, third cycle' – to support us on the choices of the visual metaphors to apply to represent them in a graph. In Table 19Table 18 the lines highlighted in color grey – 1.4.1; 1.5; 2.3.1; 6.1.3; 7.4.1 - indicate the datasets that are representative of each type of datasets per type of data, variables and indicators. The datasets chosen will to support the attempts to create the visual display most adequate for each dataset, which will be presented in the next section 4.2.2.1.

Table 19. Data types per filter applied. (Q) Quantitative data; (NQ) Non-quantitative data; (S) simple; (O) Ordinal.

	Filter: one Higher Education Institution			Filter: Region		
Dataset	Type of data	Nº of variables	Nº of indicators	Type of data	Nº of variables	Nº of indicators
1.2	**Q**	**1**	**3**	**Q**	**1**	**3**
1.3	Q	1	2	Q	1	2
1.4	NQ: S	1	3	Q	1	3
1.4.1	**Q**	**2**	**6**	**Q**	**2**	**6**
1.5	**Q**	**3**	**7**	**Q**	**3**	**7**
1.6	Q	2	6	Q	2	6
1.7	Q	1	2	Q	1	2
2.1	Q	2	6	Q	2	6
2.2	Q	1	3	Q	1	3
2.3.1	**NQ: S**	**1**	**7**	**Q**	**1**	**7**
2.3.2	Q	2	9	Q	2	9
2.3.3	Q	1	7	Q	1	7
2.3.4	Q	1	7	Q	1	7
2.4.1	NQ: S	1	5	Q	1	5
2.4.2	Q	1	9	Q	1	9
2.4.3	Q	1	2	Q	1	2
2.5.1	NQ: S	1	4	Q	1	4
2.6.1	NQ: S	1	4	Q	1	4
3.1	NQ: S	1	2	Q	1	2
3.1.2	Q	1	0	Q	1	0
3.2	NQ: S	1	2	Q	1	2
3.2.2	Q	1	0	Q	1	0
3.2.2.1	Q	1	0	Q	1	0
4.1.1	NQ: S	1	16	Q	1	16
5.1	NQ: S	1	14	Q	1	14
6.1.1	NQ: O	2	8	Q	2	8
6.1.2	NQ: O	2	7	Q	2	7
6.1.3	**NQ: O**	**2**	**12**	**Q**	**2**	**12**
6.1.4	NQ: O	2	10	Q	2	10
6.1.5	NQ: O	2	8	Q	2	8

59 One dataset corresponds to one questions of the questionnaire used by project TRACER collect data from the Portuguese Public HEI (Appendix 9 - Project TRACER Questionnaire about "Use of Communication Technologies in Portuguese Public Higher Education")

7.1.1	NQ: O	2	10	Q	2	10
7.1.2	NQ: O	2	10	Q	2	10
7.2.1	NQ: O	2	13	Q	2	13
7.2.2	NQ: O	2	13	Q	2	13
7.3.1	NQ: S	1	7	Q	1	7
7.3.2.1	NQ: O	2	9	Q	2	9
7.3.2.2	NQ: O	2	9	Q	2	9
7.3.2.3	NQ: O	2	9	Q	2	9
7.3.2.4	NQ: O	2	9	Q	2	9
7.3.2.5	NQ: O	2	9	Q	2	9
7.3.2.6	NQ: O	2	9	Q	2	9
7.4.1	**NQ: S**	**2**	**10**	**Q**	**2**	**10**
7.5.1	NQ: S	2	10	Q	2	10
7.6.1	NQ: S	2	10	Q	2	10
7.7	NQ: S	1	0	Q	1	0
7.8.1	NQ: S	1	4	Q	1	4
7.9	NQ: O	2	11	Q	2	11
7.9.1	NQ: S	1	6	Q	1	6
7.10	NQ: O	2	10	Q	2	10
7.10.1	NQ: S	1	9	Q	1	9

In Table 19 the lines that are highlighted in dark grey will be detailed below to serve as examples for each type of datasets with 1, 2 and 3 variables.

Example of dataset 2.3 and 2.3.1 demonstrates the type of datasets that are interdependent, and which we chose to not to represent visually. In this example, we chose not to represent dataset 2.3, and only represent the dataset 2.3.1, with a simple measurement of yes or no answer.

Dataset 2.3:The institution has online platforms to support teaching and learning practices (totally online or blended):

Yes: ____; No:_____

2.3.1:Type of online teaching and learning platforms:

Online teaching and learning platforms	**X**
a. Moodle.	
b. Sakai.	
c. WebCT.	
d. BlackBoard.	
e. Desire2Learn.	
f. Instructure Canvas.	
g. Other.	

Example of dataset 1.2: Quantitative data, nominal, 1 variable (Organizational units).

Dataset 1.2: Number of organizational units.

Organizational units	**Nº**
a. Schools/colleges.	
b. Departments.	
c. Other.	

Example of dataset 1.4.1: Quantitative numerical data, 2 variables (study cycles of Bologna; teaching, and learning practices).

Dataset 1.4.1: Number of courses per teaching and learning methodologies and Bologna study cycles.

Teaching and learning methodologies	Bologna study cycles		
	1st Cycle	2nd Cycle	3rd Cycle
a. Presencial.			
b. Totally online.			
c. Blended.			

Example of dataset 1.5: Quantitative numerical data, 3 variables (type of partnership, study cycles of Bologna, teaching and learning methodologies).

Dataset 1.5: Number of courses made available online (totally online or blended), per bologna study cycle, and partnership with other institutions.

Type of courses	Totally Online			Blended		
	1st Cycle	2nd Cycle	3rd Cycle	1st Cycle	2nd Cycle	3rd Cycle
a. Courses made available in partnership with other national institutions.						
b. Courses made available in partnership with other international institutions.						

Example of dataset 6.1.3.: non quantitative data, ordinal scale.

Dataset 6.1.3: Frequency with which training focuses on the topic: (1 - never, 2 - rarely, 3 - sometimes, 4 – Many times).

	Frequency			
Training topics	**Never**	**Rarely**	**Sometimes**	**Many times**
a. Use of institutional platforms.				
b. Use of data bases and scientific digital repositories.				
c. Use of office tools.				
d. Use of software.				
e. Use of teaching and learning strategies, based on Communication Technologies.				
f. Use of Web2.0 tool in educational context.				
g. Use of hardware.				

Example of dataset 7.4.1, non-quantitative data, simple yes/no answer.

Dataset 7.4.1: Web spaces in which the Organizational Units have a presence.						
	Web spaces					
Organizational units	**Institutional portal**	**Social networks**	**Image sharing channels**	**Video sharing channels**	**Virtual worlds**	**Mash-up channels**
a. Schools.						
b. Departments						
c. Other.						

Dimensions and indicators

The data was initially divided into seven dimensions corresponding to the sections in which the main dataset (see footnote 54) was divided (Figure 52):

- Dimension 1: Profile of the institution;
- Dimension 2: Features and functionality of Communication Technologies;
- Dimension 3: Support infrastructures to implement and use of Communication Technologies;
- Dimension 4: Institutional policy regarding Communication Technologies;
- Dimension 5: Areas of concern and future perspectives regarding Communication Technologies;
- Dimension 6: Training for the use of Communication Technologies in teaching practice;
- Dimension 7: Use of Communication Technologies.

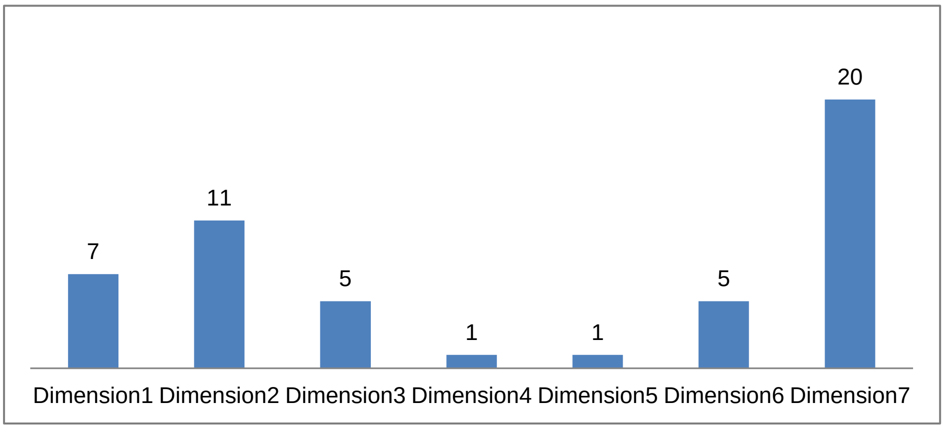

Figure 52. Number of datasets per dimension os analysis, from the raw dataset

The number of datasets per dimension varies between 1 and 20 datasets (Figure 52) corresponding to the number of questions in each section of the questionnaire. The content of the dimensions and of each dataset was subject to a careful analysis, to understand the type of content, and if exists the need to reorganize them. The aim was to obtain the final list of dimensions and datasets to interacted with and explore the data.

Analysed dimension1 - Profile of the institution - and based on theoretical ground concerning the use of CT in the context of higher education (Pinto et al., 2012), we highlighted the fact that datasets regarding “teaching and learning methodologies supported by CT” were under the scope of the dimension1. In our understanding it is a significant topic of research and an emerging area of knowledge, and therefore a ‘hot topic’ for those who will use the U-TRACER®, deserving greater highlight as a dimension in itself.

Further analysis led us to the content of dimensions 4 and 5 - Institutional policy regarding Communication Technologies; Areas of concern and future perspectives regarding Communication Technologies. Because areas of concern and future perspectives can also be understood within institutional policy, we propose to merge both under the title of dimension4 ‘Institutional policy regarding Communication Technologies’.

No further changes were considered, and thereby the final proposal of dimensions was redrawn to the following list, and the correspondent number of datasets shown in (Figure 53):

- Dimension 1: Profile of the institution;
- Dimension 2: Teaching and learning methodologies;
- Dimension 3: Features and functionality of Communication Technologies;
- Dimension 4: Support infrastructures to implement and use of Communication Technologies;
- Dimension 5: Institutional policy regarding Communication Technologies;
- Dimension 6: Training for the use of Communication Technologies in teaching practice;
- Dimension 7: Use of Communication Technologies.

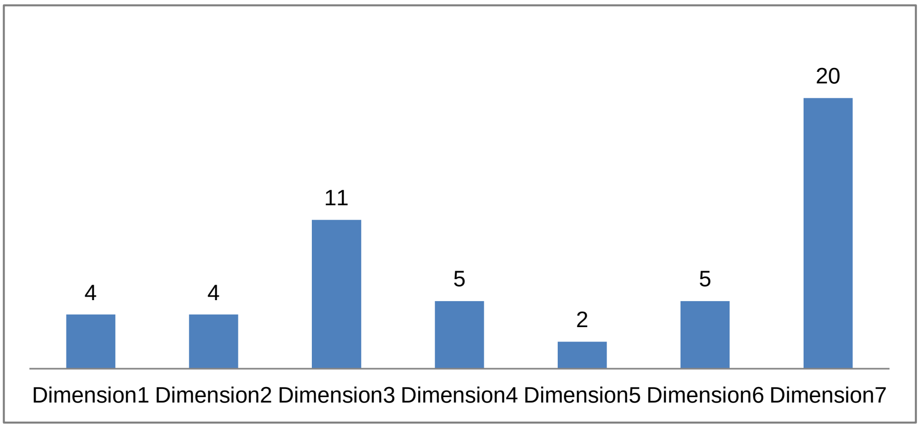

Figure 53. Number of datasets per dimension os analysis, from the treated dataset

4.2.2. Towards the exploration of visualization displays

Information visualization is used as a way to explore and communicate the data meaningfully and to be easily perceived by those who want to obtain information.

Having presented the details of the type of datasets we will work with (Table 19), relating the number of variables and type of data to the filters that will be applied in the interaction features summarized in section 4.21; and having organized all the datasets into tabular display, the next step is to choose the most adequate visual metaphor to represent the data.

To explore different visual metaphors, we chose to firstly use the excel spread sheet, and other graph generating tools, mainly motivated by the need to better represent the non-quantitative and multivariate datasets. From the search previously performed (listed in section 21.4) for open online tools to create visual representations of different types of datasets, we chose a free tool, for non-experts in programming languages (like Java, HTML, SVG or CSS), which would allow us to upload the datasets and explore diverse data metaphors. The tool of choice was **Many Eyes**[60] , which allows anyone to upload datasets in the table format, explore and create different types of visualizations. At the time when we began to work with Many Eyes, there was only available its version1 which has the specific feature that any data uploaded is automatically made public on the website as well as its visualization result. Because the data we were working with was not public, it required us to code all the data before uploading into Many Eyes, guaranteeing in this way the confidentiality of the data.

Supported by the literature review, mainly Bertins' (2011) work, we were able to draw different types of graphs tailored to the type of data, and to analyse if the graph could be easily perceived, for every graph to be created we posed the same questions Bertin (2011, p. xiv) posed:

[60] Many Eyes (version 1) http://many-eyes.com

> "One does not 'read' a graphic; one asks three questions of it. What are the *x* and *y* indicators of the data table? What are the groups in *x* and in *y* that are constructed by the data in *z*? What are the exceptions to these groups?"

These are the answers that we want the reader of the graph to perceive. And these were the questions that preceded the creation of graphs with excel spread sheet and with Many Eyes.

4.2.2.1. Visualizing datasets under the filter 'Higher Education Institution'

In this section we present the six datasets (Table 20) and the visual displays with which they can be represented in a graph. Each dataset presents real data provided by one random HEI, for which will be identified the data type, number of variables, number of indicators and to which axis - *X* and *Y* - the indicator belongs This follows by the different types of visual displays and its discussion.

Table 20. Filter Higher Education Institution: representative datasets per type of data. (Q) Quantitative data; (NQ) Non-quantitative data; (S) simple; (O) Ordinal.

Dataset	Data type	Nº of variables	Nº of indicators
1.2	Q	1	3
1.4.1	Q	2	6
1.5	Q	3	7
2.3.1	NQ: S	1	7
6.1.3	NQ: O	2	12
7.4.1	NQ: S	2	10

Visual displays options for each dataset

- **Dataset 1.2.**

Elementary question: "How many organizational units does the institution have?"

Data type: quantitative

Number of variables: 1

In X: the organizational units

In the Y: number of organizational units

Organizational units	Nº
a. Schools	5
b. Departments	20
c. Other	0

Dataset 1.2, has one variable 'Organizational units' with three indicators (schools; departments; other) with a quantitative measurement. With three indicators, the information can be perceived in a single graph for comparing individual values. The graphs bar, bubble, pie, and ring. In the bar and

bubble graphs the numbers are read individually, while in the pie or ring graph is more commonly used to compare numerical proportions, and more difficult to read part-to-whole relationships of the values. In the 4 types of graphs the null bins are ignored in the visual display. To encode the graphs we used color hue and size.

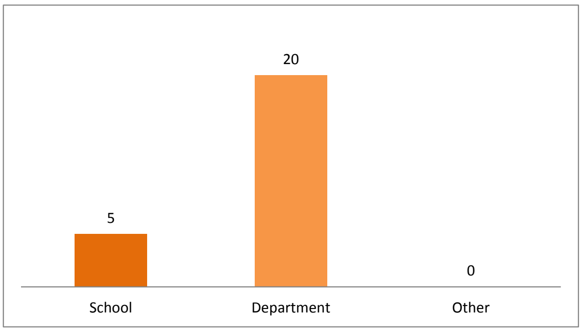

Figure 54. Dataset 1.2: Vertical bar graph.

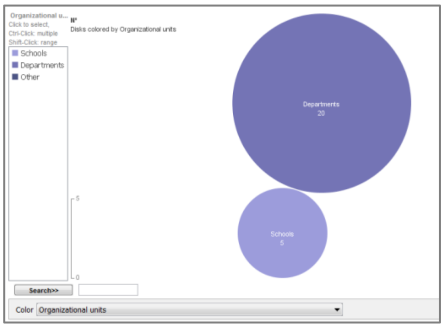

Figure 55. Dataset 1.2: Circular Bubble graph created using Many Eyes software.

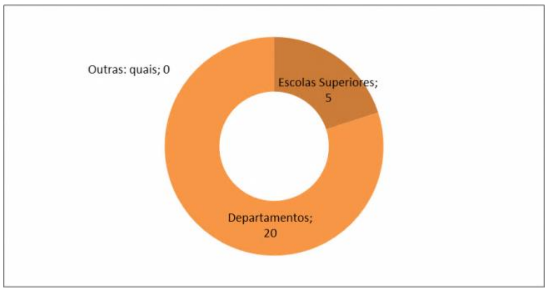

Figure 56. Dataset 1.2: Circular ring graph.

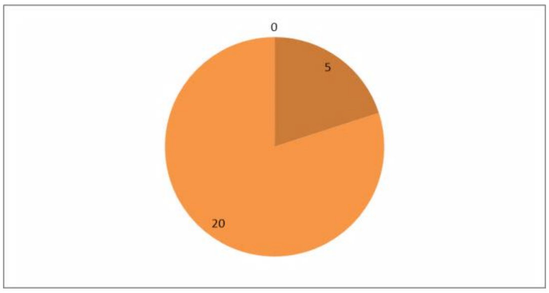

Figure 57. Dataset 1.2: Circular Pie graph.

- **Dataset 1.4.1.**

Elementary question: "How many courses does the institution have, per Bologna study cycle and teaching and learning methodology?"

Data type: quantitative

Number of variables: 2

In X: Teaching and learning methodologies

In the Y: Bologna study cycles

	Bologna study cycles		
Teaching and learning methodologies	**1st Cycle**	**2nd Cycle**	**3rd Cycle**
Presential	60	60	41
Totally Online	1	0	0
Blended	0	1	1

This dataset has two variables (Bologna study cycles; Teaching and learning methodologies) with quantitative measurement of the number of courses offered by the institution, which is the first piece of information, and six indicators (three from each variable). The information can be perceived in a graph that compares individual values: bar, stacked bar, matrix bubble, matrix bar.

In the **bar** (Figure 58) a whole set of values are represented in one bar parallel to each other and under the indicator to which they belong. In the **stacked bar** graphs (Figure 59) a whole set of values are represented in a box of a single bar (Few, 2009). The **matrix graph** (Figure 60, Figure 61) maps a table of quantitative data into a single graphical presentation, representing each number in a separate cell of a grid structure maintaining its tabular organization (Marsh, 1992). The matrix allows to present 2, 3 or more variables, if one is common to all the data (Bertin, 2011), and in the dataset we are representing there are 2 variables, one common to the other, showing that the information is distributed across different study cycles and teaching and learning methodologies. All types of graphs were encoded using color and size.

Figure 58 and Figure 59 require readers to look at each set of three bars for every methodology type, comparing within them its values, but taking more time to read and compare the values between methodologies for all study cycles. The same information represented in the matrix graph (Figure 61) the relation between cycles and methodologies are immediately shown.

In all graphs the qualitative indicators - presential, totally online, blended -, which do not have a universal manner of being ordered, were ordered from the highest number to the lower numbers, but can be reordered for purposes of information processing (Bertin, 2011).

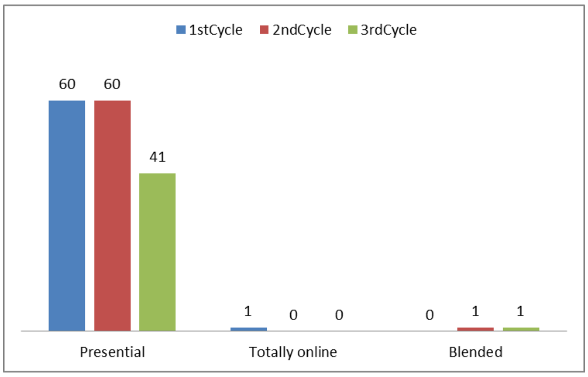

Figure 58. Dataset 1.4.1: Vertical bar graph.

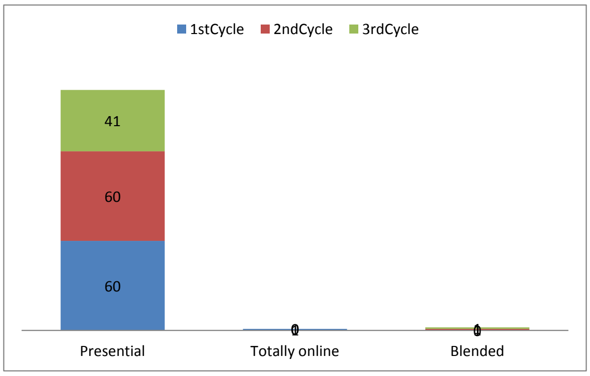

Figure 59. Dataset 1.4.1: Vertical stacked bar graph.

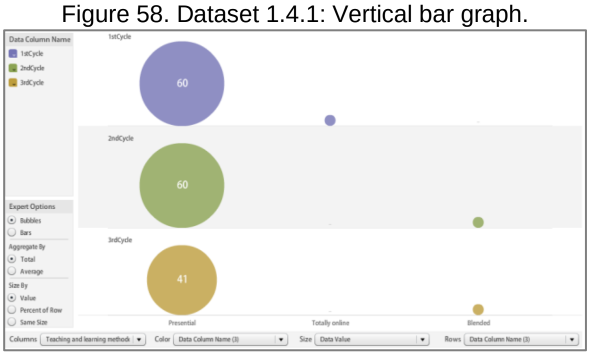

Figure 60. Dataset 1.4.1: matrix bubble graph, created using Many Eyes software.

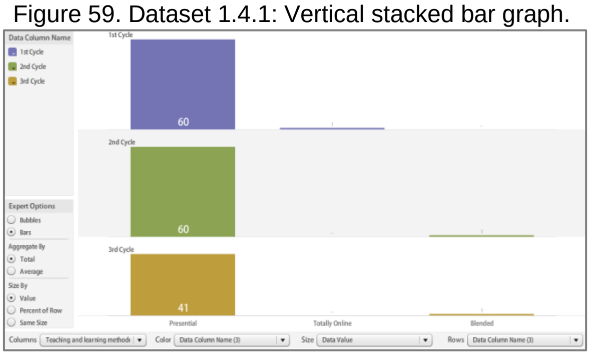

Figure 61. Dataset 1.4.1: matrix bar graph, created using Many Eyes software.

- **Dataset 1.5**

Elementary question: "How many courses does the institution have in partnership with other Institutions, per Bologna study cycle and teaching and learning methodology?"

Data type: quantitative

Number of variables: 3

In X: Institutional partnership

In the Y: Teaching and learning methodologies per Bologna study cycles

In the Z: number of courses

	Totally online			**Blended**		
Institutional partnership	1st Cycle	2nd Cycle	3rd Cycle	1st Cycle	2nd Cycle	3rd Cycle
National	1	0	0	0	1	0
International	0	0	0	0	0	0

This dataset has three variables (Bologna study cycles; Teaching and learning methodologies - totally online and blended -; Institutional partnership) with quantitative data measuring the number of courses offered by the HEI. The first piece of information is the number of courses per type of partnership, and the second piece is the teaching and learning methodology and Bologna study cycle to which the course belongs. With 3 variables and 10 indicators, the information can be represented in a graph that compares individual values, such as: bar, stacked bar, matrix bubble, matrix bar.

This requires the reader of the graph to read carefully the size of the bar or bubble which indicates the quantity of courses per type of partnership, adding the information in labels that indicate what is being quantifiable. The labels represent the Y and are composed by two indicators of two different variables:

- Totally online (indicator): Teaching and learning methodology (variable)
- 1st cycle (indicator): Bologna study cycle (variable)

Figure 62 and Figure 63 show the representation of the dataset using the parallel bar graph and the stacked bar graph.

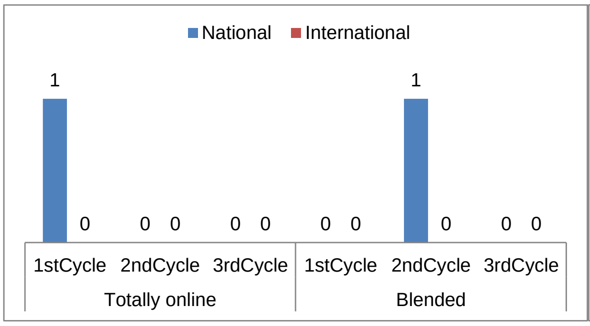

Figure 62. Dataset 1.5: Vertical bar chart.

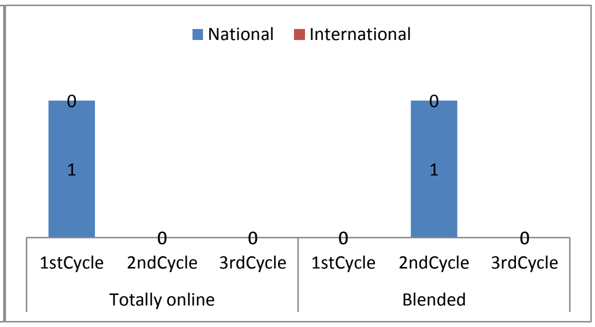

Figure 63. Dataset 1.5: Vertical stacked bar chart.

The matrix graphs show that the information is distributed across a grid or data table with an independent set of quantitative data, showing columns or rows as a series of dimensions which each contain the data. size and color are encoded into the graph. In the case of this dataset, there are more null values that are not represented, which makes it difficult to fully realize the possibilities of a matrix graph.

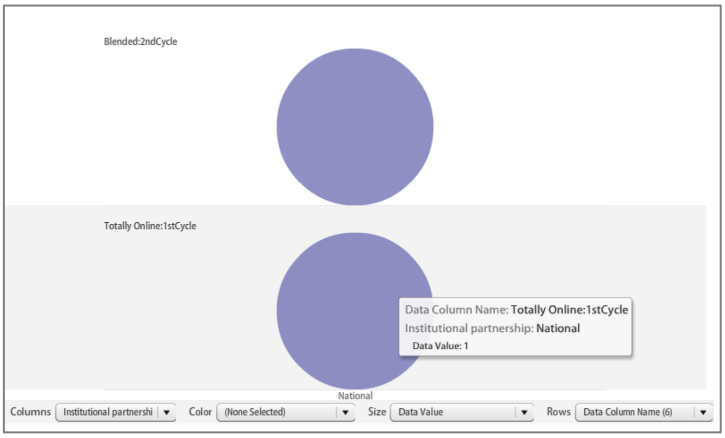

Figure 64. Dataset 1.5: Matrix bubble chart, created with Many Eyes software.

The specificity of this dataset is that for the total universe of 9 HEI, only one institution has some type of partnership with other HEI, meaning that it can be represented, but there will be no data to represent visually for the other 8 HEI.

- **Dataset 2.3.1**

Elementary question: “What web platforms to support online teaching does the institution have?”

Data type: non-quantitative; simple (yes/no answer)

Number of variables: 1

Web platforms						
Moodle	**Sakai**	**WebCT**	**Black Board**	**Desire2 Learn**	**Instructur e Canvas**	**Other**
x						x

This dataset is non-quantitative and has one variable (web platforms) and the measurement of that variable is through yes/no answers indicating the web platforms that the institution has to support teaching practice. That is the first piece of information.

With qualitative indicators that do not have a universal order and that have equal importance between its indicators, the reordering of the indicators can be made for purposes of information processing (Bertin, 2011). Therefore the indicators as shown in Figure 65 were rearranged in Figure 66 and Figure 67 so the information could be processed by groups of yes (existing) or no (non-existing) answers related to the web platforms. To enhance the process of reading the graph we added color encoding to clearly indicate the ‘yes’ or ‘no’. The tone of the color is constant.

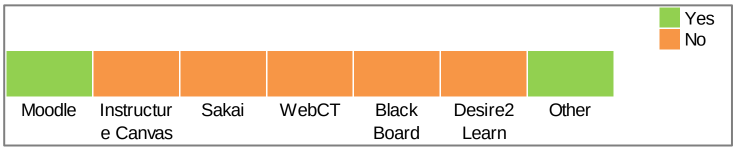

Figure 65. Clor grid for dataset 2.3.1.

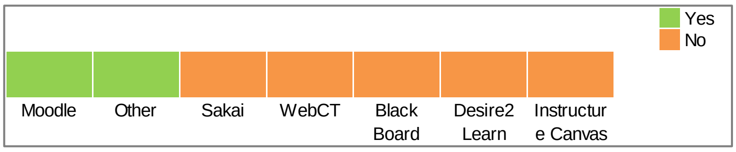

Figure 66. Horizontal ordered color grid, for dataset 2.3.1

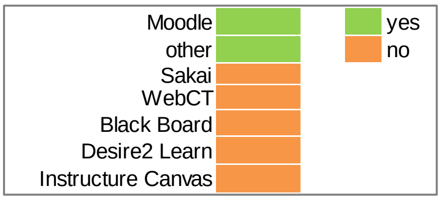

Figure 67. Vertical ordered color grid, for dataset 2.3.1

- **Dataset 6.1.3**

Elementary question: "How frequently does the institution offer teacher training by topic?"

Data type: non-quantitative; ordinal

Number of variables: 2

	Frequency			
Training topics	**Never**	**Rarely**	**Sometimes**	**Many times**
Use of institutional platforms				
Use of data bases and scientific digital repositories		X		
Use of office tools				X
Use of software			X	
Use of teaching and learning strategies, based on Communication Technologies				X
Use of Web2.0 tool in educational context		X		
Use of hardware			X	

This dataset has two variables (training topics; frequency scale). The overall question is "with what frequency are training topic approached? which is the first piece of information. The qualitative indicators (training topics) have no specific order allowing to order them as more convenient for the enhanced display (Bertin, 2011). The indicators were initially represented in a grid (Figure 68) and then reordered and grouped by frequency as shows Figure 69, in a grid with X and Y axis to which was added color hue to represent the frequency scale, leading to enhanced insight (Bertin, 2011; R. Spence, 2007). To simplify the observation of correspondences Because the frequency scale has a specific order, it was not permuted, and the hue of the color constant.

Figure 69 and Figure 70 order variables according to their frequency facilitating its perception, contrary to Figure 68 that makes more difficult to perceive the topics most frequently and less frequently addressed in teacher training offered by the institution.

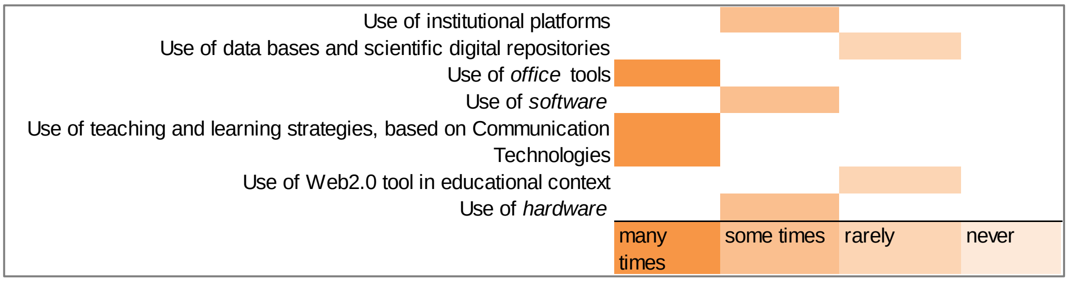

Figure 68. Color plot grid for dataset 6.3.1.

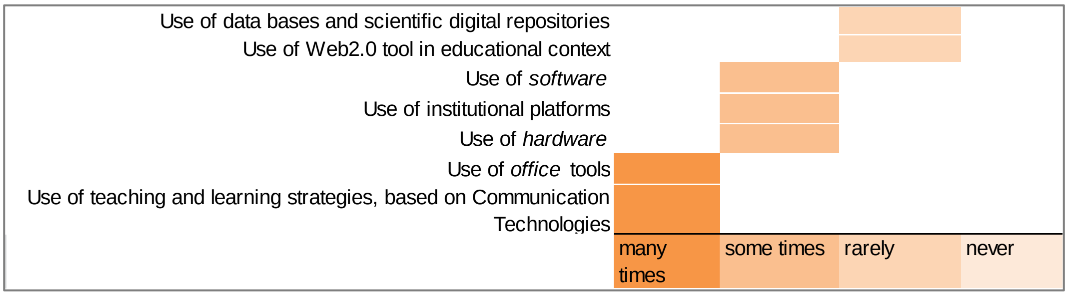

Figure 69. Color plot grid, ordered by frequence scale, for dataset 6.3.1.

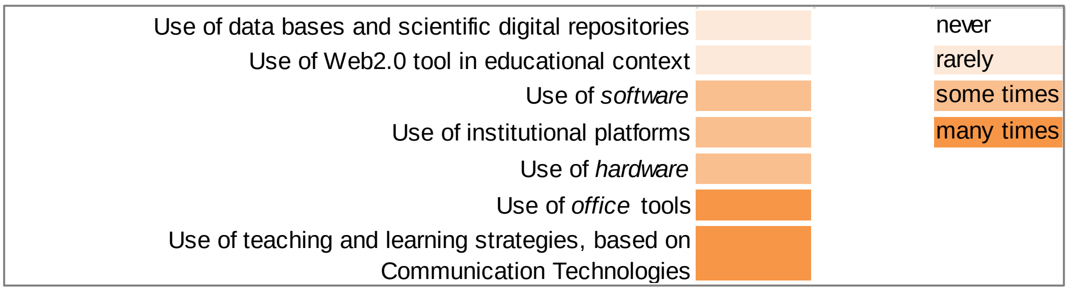

Figure 70. Color plot grid, ordered by frequence scale, for dataset 6.3.1.

- **Dataset 7.4.1**

Elementary question: "The organizational units have an official presence in which web spaces?"

Data type: quantitative

Number of variables: 2

In the X: Organizational units

In the Y: Web spaces

	Web spaces					
Organizational units	**Institutional portal**	**Social networks**	**Image sharing channels**	**Video sharing channels**	**Virtual worlds**	**Mash-up channels**
Schools	x	x				
Departments	x	x	x			
Other	x	x	x			

This dataset has two variables (organizational units; web spaces) measured by yes/no answers meaning the web spaces within which organizational units have an official presence. This is the first piece of information. The variables and its indicators were organized in a grid, and because they do not have a specific order, we chose to order them by types of answers, grouping the yes and the no answers and color encoding by type of answer. If necessary the *Y* axis (web spaces) may be rearranged to allow representation of the data by groups (Figure 71).

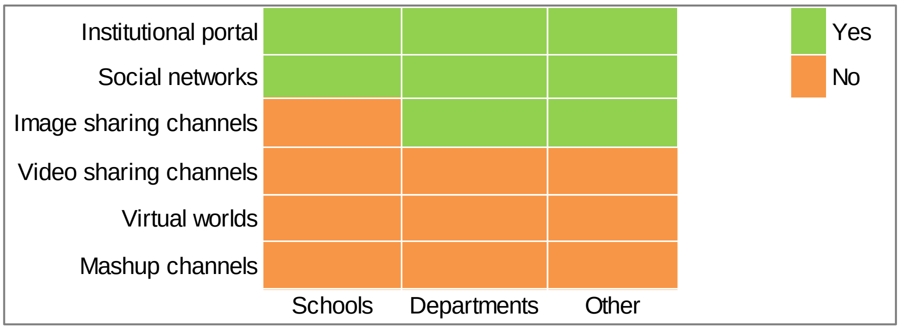

Figure 71. Color plot grid for dataset 7.4.1.

4.2.2.2. Visualizing datasets under the filter ‘Regions of the Portuguese territory’

This section presents the exploration of several types of visual representations for each dataset, according to the filter Region of the Portuguese territory – filter which resulted from the focus groups analysis. These datasets are now composed by the aggregated data of all the HEI that belong to one region. The regions are organized following the Nomenclature of Territorial Units for Statistics (NUTS II) in Figure 72. To overview the group of datasets (Table 21), were listed all the regions of the Portuguese territory, indicating the total number of HEI per region and the total number of HEI from which we have data to work with. Although the representativeness of the regions is clearly unbalanced, having only 2 regions composed of more than one institution with data, we have chosen to meet focus groups analysis results. Therefore the datasets and visual representations in this section, respect the region ‘Center’ with the highest number of HEI with data.

Table 21. Number of Higher Education Institutions by region, who provided TRACER with data

Region	Total nº of Higher Education Institutions per Region	Total nº of Higher Education Institutions with data, per Region
North	8	1
Center	10	4
Lisbon	9	1
Alentejo	4	2
Algarve	1	0
Autonomous Region of Açores	1	1
Autonomous Region of Madeira	1	0

Figure 72. Map of the Portuguese territory divided by regions NUTS II.

The presentation of each dataset follows the same structure of the previous section, showing its elementary question, data type, number of variables, indicators, *X* and *Y* axis, the data in tabular display, and finally the different types of visual representations of the dataset. The six datasets that will be used are the same used for the visualization under the filter HEI in section 4.2.2.1 (page 104).

The particularity of these datasets under this new filter is that all the data becomes quantitative (Table 22), because we are now counting the number of HEI in a region that make use of CTs.

Table 22. Filter Region: representative datasets per type of data. Q: quantitative data

Nº of the Dataset	Data type	Nº of variables	Nº of indicators
1.2	Q	1	3
1.4.1	Q	2	6
1.5	Q	3	7
2.3.1	Q	1	7
6.1.3	Q	2	12
7.4.1	Q	2	10

- **Dataset 1.2**

Elementary question: “How many higher education institutions have schools or departments, in the region?”

Data type: quantitative

Number of variables: 1

In X: the organizational units, departments and schools

In the Y: number of organizational units (Schools, Departments)

Organizational units	**Nº**
School	4
Department	4
Other	3

Dataset 1.2, has one variable (organizational units) with three indicators (schools; departments; other) and the quantitative measurement is of the number of HEI in the region that have organizational units. With three indicators with individual values to be compared, the graphs to explore are: bar, pie, and ring.

In the bar graphs the numbers are read individually, while the pie and ring graphs quantities are compared within the whole. The pie and ring graphs are a circular version of the rectilinear representation. In the 4 types of graphs if there are null bins, they will be ignored from the representation. To encode the graphs, color hue value and size were used.

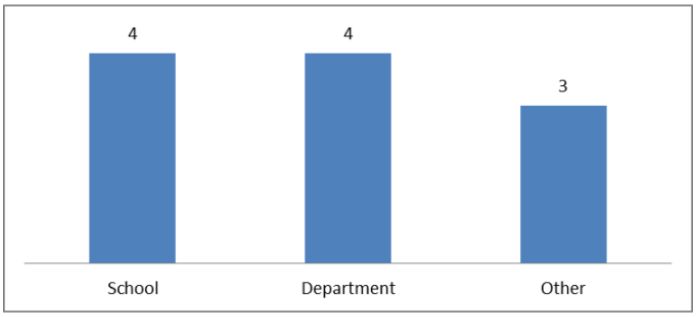

Figure 73. Rectangular bar graph, of the number of institutions per organizational unit.

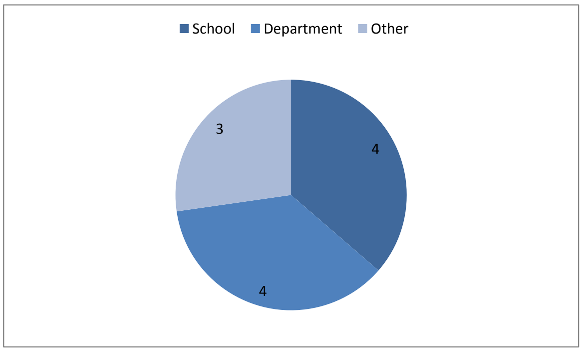

Figure 74. Circular pie graph, of the number of institutions per organizational unit.

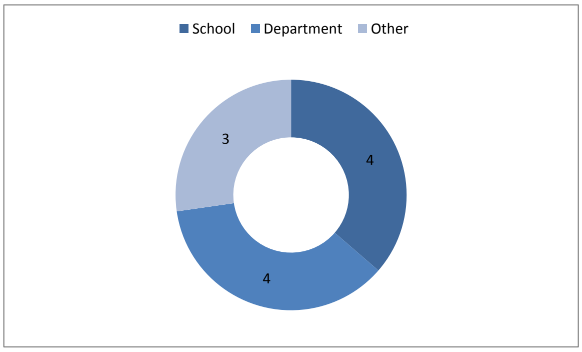

Figure 75. Circular ring graph, of the number of institutions per organizational unit.

Dataset 1.4.1

Elementary question: "How many courses per Bologna study cycle and teaching and learning methodologies, are offered in the region?"

Data type: quantitative

Number of variables: 2 – Bologna study cycles; Teaching and learning methodologies

In X: Teaching and learning methodologies

In the Y: Bologna study cycles

	Bologna study cycles		
Teaching and learning methodologies	**1st Cycle**	**2nd Cycle**	**3rd Cycle**
Presential	4	4	1
Totally online	2	0	0
Blended	0	1	1

This dataset has two variables (Bologna study cycles; Teaching and learning methodologies) and measures the number of HEI, in the region, that offer courses per teaching and learning methodologies and Bologna study cycles. That is the first piece of information. With six indicators with individual values to be perceived, the dataset can be represented in graph types: bar, stacked bar, matrix bubble, matrix bar.

In the bar graph the whole set of values can be both represented in separate bars parallel to each other and grouped under a single indicator (Figure 76), or can be represented in a stacked bar graph (Figure 77) the whole set of values are represented in a box (stacked graph is composed of what we will call boxes as Few (2009), enabling to have one bar with different size boxes per Y variable.

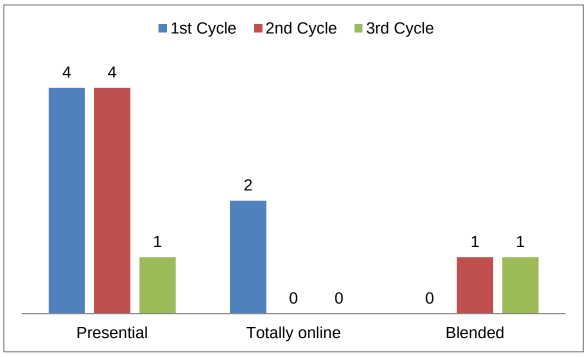

Figure 76. Rectangular bar graph

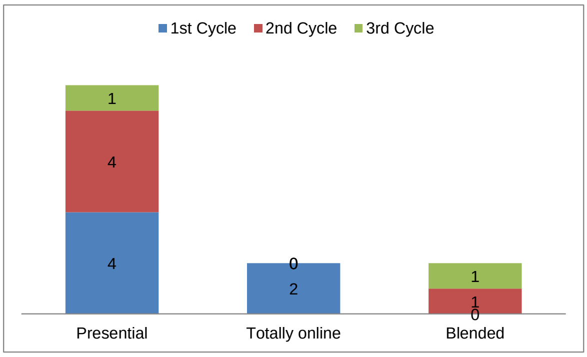

Figure 77. Rectangular stacked bar graph

In the matrix bubble and bar graph (Figure 78, Figure 79) each number is represented in a separate cell of a grid structure, by a circle or a bar which size varies according to the data value.

The matrix graph allows to represent 2, 3 or more variables when one is common to all the data, as happens in this dataset. It shows that the information is distributed across different study cycles and methodologies. The matrix graph is both represented with circles and rectangular bars. To encode the graphs, color and size were used.

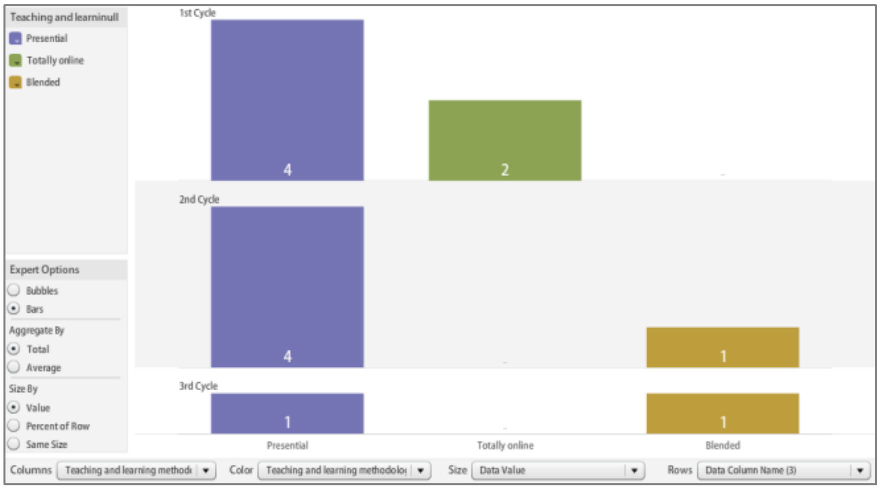

Figure 78. Matrix bar graph, created with Many Eyes software.

Figure 79. Matrix bubble graph, created with many Eyes software.

- **Dataset 1.5**

Elementary question: "How many courses in in partnership with other Institutions, per Bologna study cycle and teaching and learning methodology, are offered in the region?"

Data type: quantitative

Number of variables: 3

In X: Partnership with other institutions

In the Y: Bologna study cycle per teaching and learning methodology.

	Totally online			Blended		
Institutional partnership	**1st Cycle**	**2nd Cycle**	**3rd Cycle**	**1st Cycle**	**2nd Cycle**	**3rd Cycle**
National	1	0	0	0	1	0
International	0	0	0	0	0	0

This dataset has three variables (Bologna study cycles; Teaching and learning methodologies; Institutional partnership) and it measures the number of HEI in the region that offer courses. With ten indicators, the information can be perceived in a graph that compares individual values: bar, stacked bar, matrix bubble, matrix bar.

The graphs are the same under filter 'HEI' (section 4.2.2.1, page104) or "Region", therefore we will not repeat the explanation in this section.

For the total universe of the 7 regions only one region has an institution with data regarding this question.

- **Dataset 2.3.1**

Elementary question: "How many institutions offer web platforms to support online teaching, in the region?"

Data type: quantitative

Number of variables: 1

In the X: web platforms

In the Y: number of institutions

Web platforms	Nº
Moodle	4
Sakai	0
WebCT	0
Black Board	0
Desire2 Learn	0
Instructure Canvas	0
Other	1

Dataset 2.3.1, has one attribute representing one variable – the organizational units – with three indicators – schools; departments; other – and the number represents the number of higher education institutions in the region, per organizational unit. With three indicators with individual values to compare, the graphs to explore are: bar, bubble, pie, and ring.

In the bar graph (Figure 80) the numbers are read individually, while in the pie and ring graphs it is more commonly used to see the part of a whole, and more difficult to read part-to-whole relationships of the values. In the 4 types of graphs if there are null bins, they will be ignored from the representation.

To encode the graphs, color hue value and size were used.

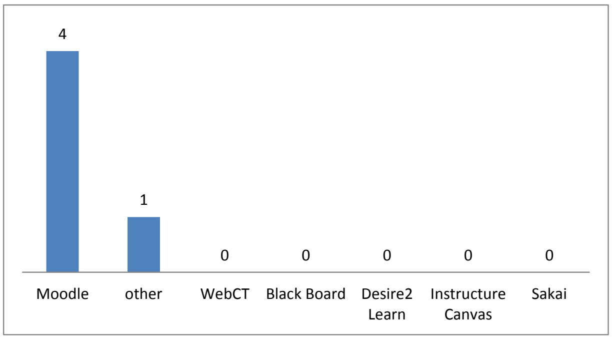

Figure 80. Rectangular bar graph.

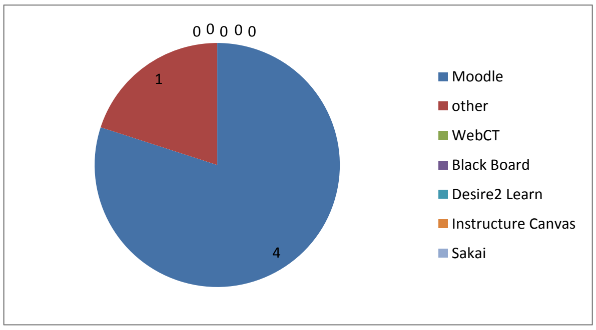

Figure 81. Circular pie graph.

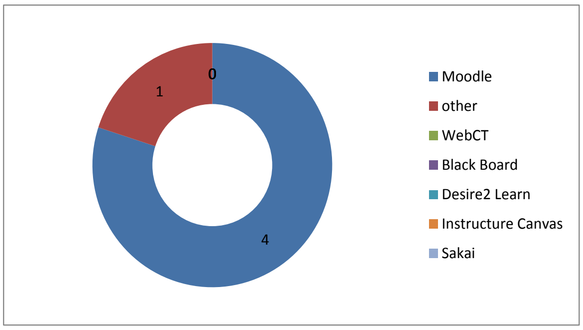

Figure 82. Circular ring graph.

- **Dataset 6.1.3**

Elementary question: "How many institutions offer teacher training by topics, and how frequently?"

Data type: quantitative; ordinal

Number of variables: 2

In the X: Training topics

In the Y: Frequency scale

	Frequency			
Training topics	**Never**	**Rarely**	**Sometimes**	**Many times**
Use of institutional platforms	0	0	3	1
Use of data bases and scientific digital repositories	0	0	1	1
Use of office tools	2	0	2	0
Use of software	0	1	3	0
Use of teaching and learning strategies, based on Communication Technologies	1	1	2	0
Use of Web2.0 tool in educational context	2	0	2	0
Use of hardware	2	2	0	0

This dataset has two attributes that represent two visual variables – training topics; frequency scale. The overall question is "how many institutions offer teacher training by topic and frequency?", and the number of institutions is the first piece of information.

If with the filter 'HEI' the dataset is non-quantitative, with the filter "Region" it becomes quantitative, what differs the types of graphs. The graphs used are: bar, stacked bar, matrix bar, matrix bubble graph.

Bar graph allows the numbers to be read individually, and although the X indicators are qualitative and therefore can be reordered, the frequency scale is not (hue) was worked in a grid with X and Y (figures, a b) and When rearranging the representation of the data by groups of topics for teacher training by frequency (figures b and c), that can lead to enhanced insight (Bertin, 2011; R. Spence, 2007). This allows the variables according to their frequency, to be more easily perceive contrary to figure a, which makes it more difficult to perceive the topics most frequently and less frequently addressed in teacher training offered by the institution.

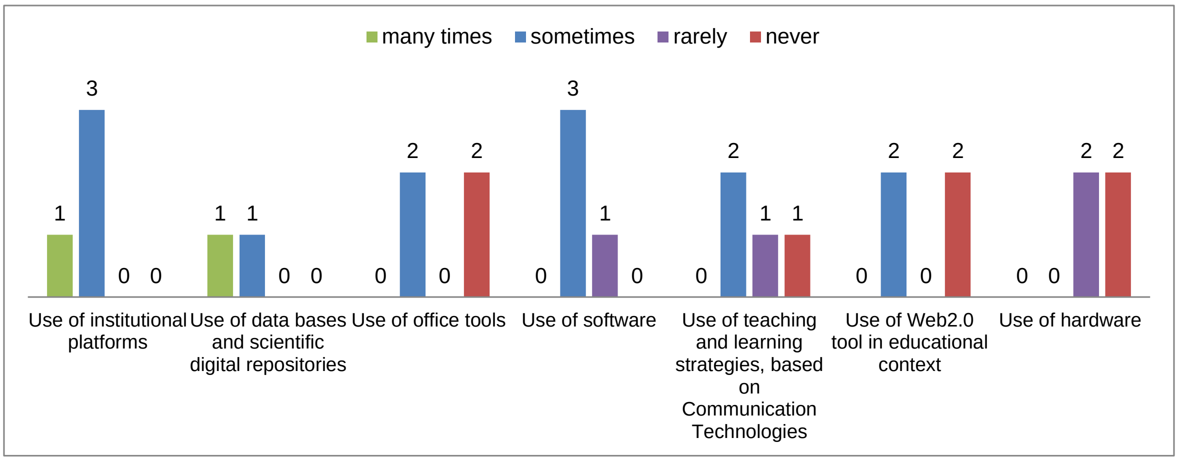

Figure 83. Rectangular bar graph.

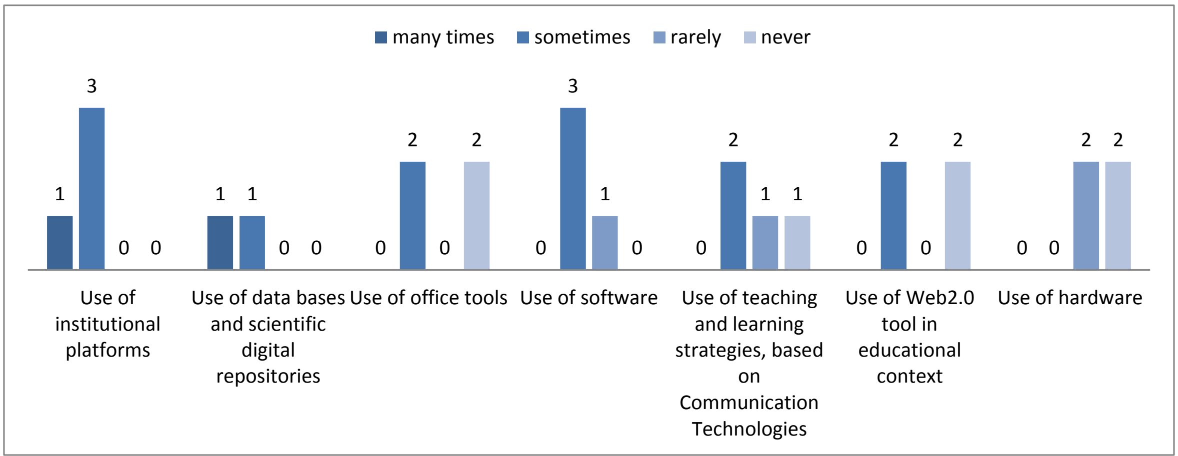

Figure 84. Rectangular bar graph.

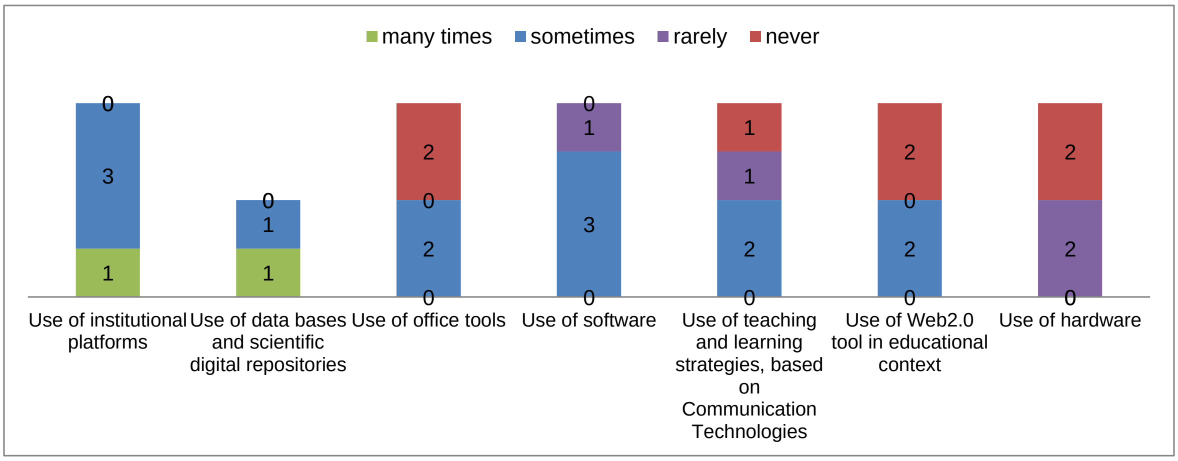

Figure 85. Rectangular stacked bar graph.

The matrix graphs shown next, bubble and bar, maps data table characteristics with double entry table.

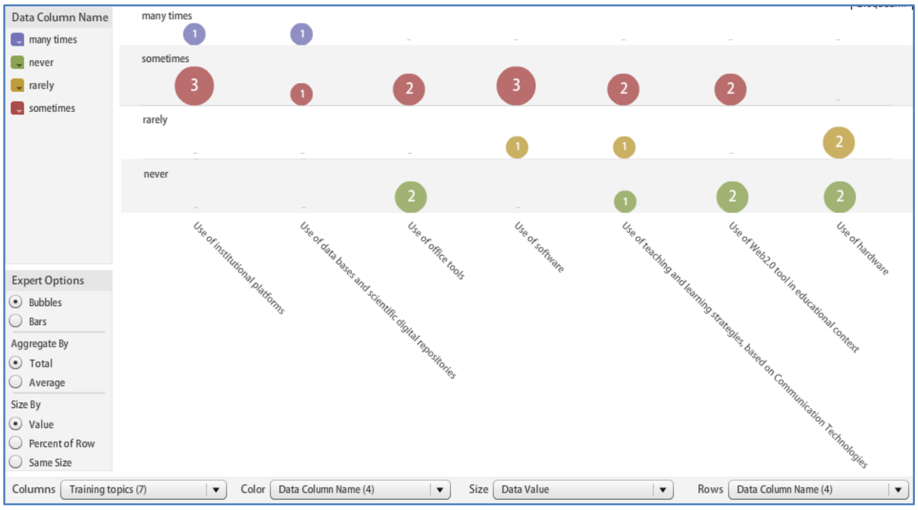

Figure 86. Matrix bubble graph. Created with Many Eyes program.

Figure 87. Matrix bubble graph. Created with Many Eyes software.

Figure 88. Matrix bar graph. Created with Many Eyes software.

Dataset 7.4.1

Elementary question: "How many organizational units have official web spaces, in the region?"

Data type: quantitative

Number of variables: 2

In the X: web spaces

In the Y: organizational units

	Web spaces					
Organizational units	**Institutional portal**	**Social networks**	**Image sharing channels**	**Video sharing channels**	**Virtual worlds**	**Mash-up channels**
Schools	4	4	2	0	0	0
Departments	3	2	2	0	0	0
Other	1	1	1	0	0	0

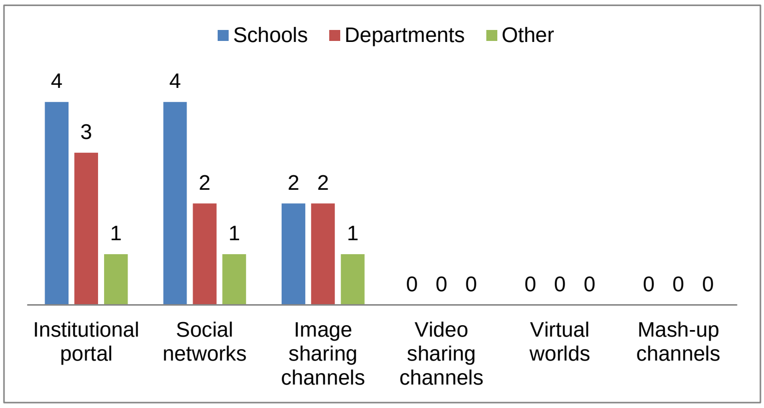

Figure 89. Rectangular bar graph.

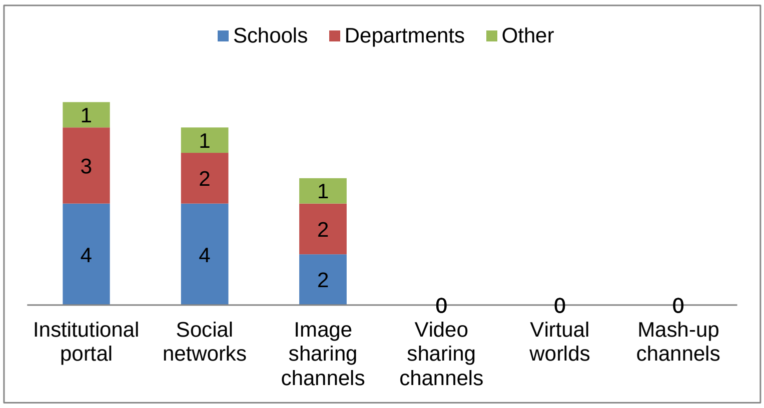

Figure 90. Rectangular stacked bar graph.

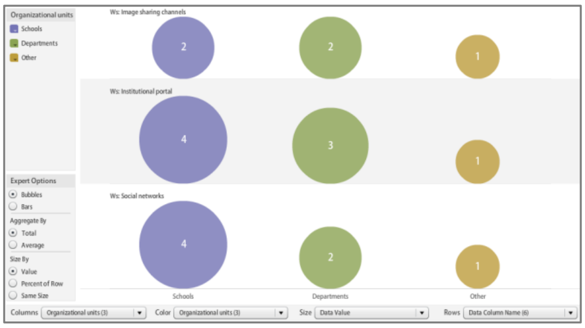

Figure 91. Matrix bubble graph. Created with Many Eyes software.

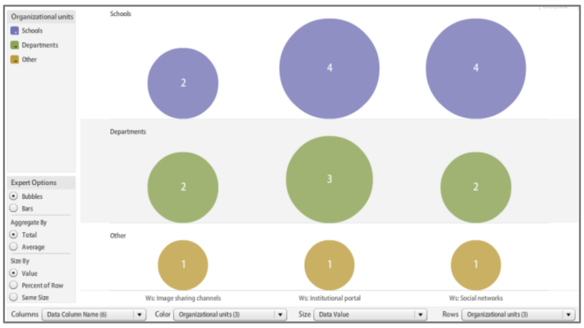

Figure 92. Matrix bubble graph. Created with Many Eyes software.

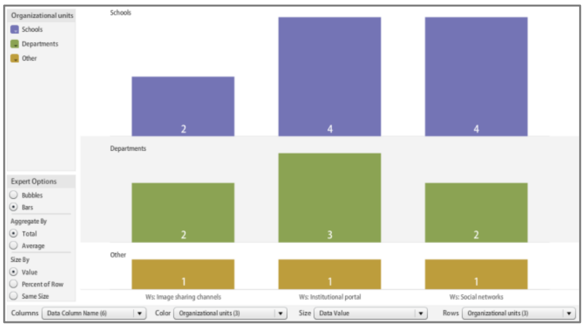

Figure 93. Matrix bar graph. Created with Many Eyes software.

Mapping Higher Education Institutions

With the filter "region of the Portuguese territory" we have the need to map the institutions, which derives from the expected results of the TRACER project: "obtain geo-referenced representation of the use of CT in all the HEI included in the study". Next, are presented the options explored for this type of representation need.

The data can be georreferenced in two ways:

a. Selecting individual indicators from the dataset and representing them on the map: see example in Figure 94 retrieved from the PORDATA tool. Nevertheless our dataset is not possible to be represented all in this way due to the non-numerical and qualitative nature of several datasets.

b. Representing in the map of Portugal, the total number of HEI of which we have data, and next to the map represent a graph of a specific dataset.

The approach of option (a) that has the overlapped representation of the value of more than one indicator per municipality. With the data we are working with this option presents as a difficulty because the data we are working with has mostly between 6 and 16 indicators to represent per municipality:

- 5 datasets with 2 indicators;
- 3 datasets with 3 indicators;
- 4 datasets with 6 indicators;
- 6 datasets with 7 indicators;
- 2 datasets with 8 indicators;
- 9 datasets with 9 indicators;
- 7 datasets with 10 indicators;
- 1 datasets with 12 indicators;
- 2 datasets with 13 indicators;
- 1 datasets with 14 indicators;
- 1 datasets with 16 indicators.

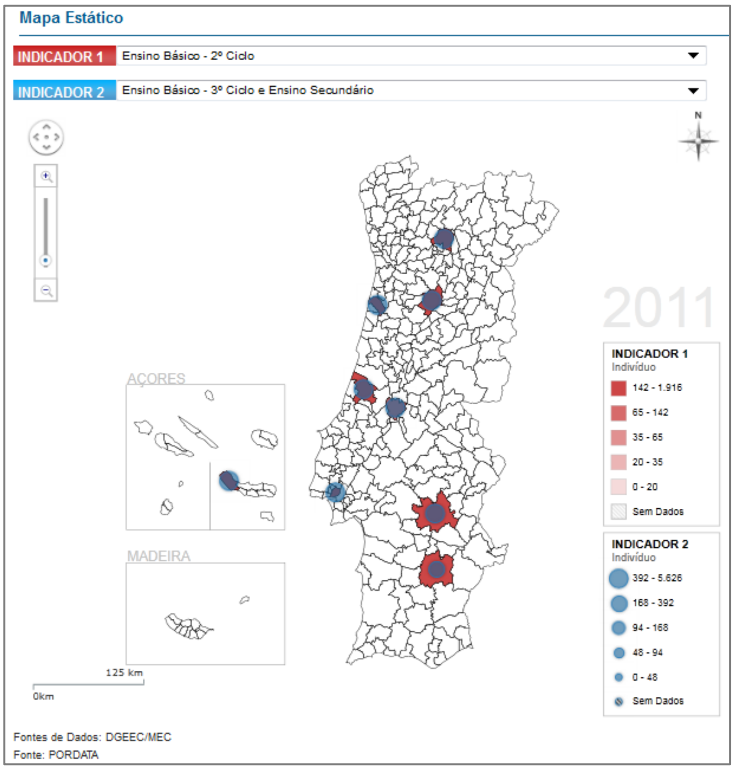

Figure 94. Image from the PORDATA tool.

The approach of option (b) can be visually represented in 3 ways: the first is with a map in which are georreferenced by making visible the municipality to which they belong (Figure 95); the second by estimated coordinates of the HEI, marking with a symbol (Figure 96); or by a visual form indicating the total number of HEI in the region of which exists data (Figure 97).

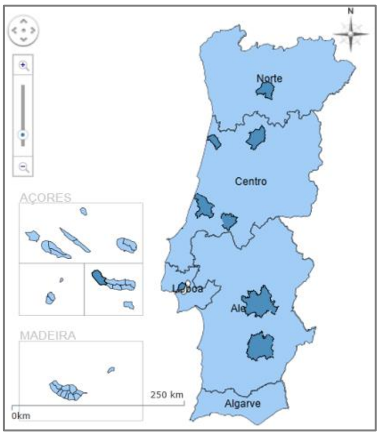

Figure 95. Map of Portugal divided by NUTS II, marking the municipalities of the 9 HEI.

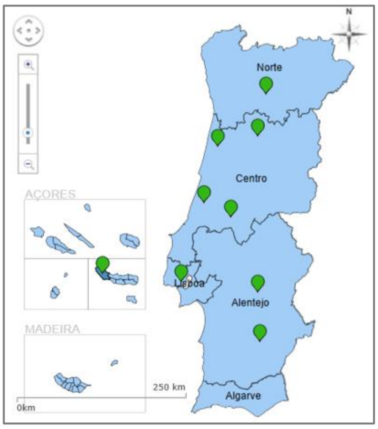

Figure 96. Map of Portugal divided by NUTS II, and estimated coordinates of the 9 HEI.

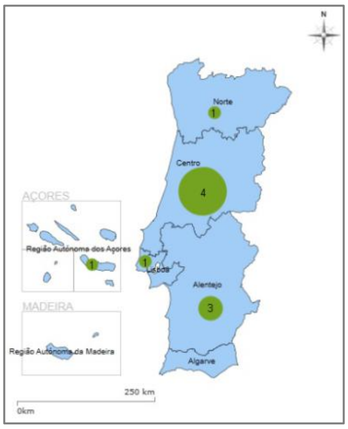

Figure 97. Map of Portugal divided by NUTS II, representing the total number of HEI per region.

4.2.3. Synthesis

Table 23 summarizes all the type of graphs used to represent the six examples of datasets, under the macro filters of 'Higher Education Institution' and 'Region of the Portuguese territory' (as shown in sections 4.2.2.1 and 4.2.2.2).

For the datasets under filter HEI, the bar graph type represented the highest number of datasets under both filters, followed by the matrix bubble and bar graphs. Both pie and ring graphs were only applied to one dataset.

For the datasets under filter region of the Portuguese territory, all graph types were used to represent the datasets, except for the color grid because the type of data under this filter is always quantitative.

Table 23.Summary of type of graphs adopted to represent the datasets under the filter ‘Higher Education Institution’ (●), and filter ‘Region of the Portuguese territory’ (✚).

Dataset nº	Bar graph	Stacked bar graph	Pie graph	Ring graph	Matrix bubble graph	Matrix bar graph	Clor grid
1.2	●✚		●✚	●✚			
1.4.1	●✚	●✚			●✚	●✚	
1.5	●✚	●✚			●	●	
2.3.1	✚		✚	✚			●
6.1.3	✚	✚			✚	✚	●
7.4	✚	✚			✚	✚	●

To respond to the expectation of providing the users of the U-TRACER® with two types of graphical representation for each dataset, based on the visual displays identified in Table 23, we choose those that enable the representation of a higher number of datasets, as shows Table 24.

Table 24. Graphs to implement in the U-TRACER®, to represent the datasets under the filter ‘Higher Education Institution’ (●), and filter ‘Region of the Portuguese territory’ (✚).

Dataset nº	Bar graph	Matrix graph	Clor grid
1.2	●✚		
1.4.1	●✚	●✚	
1.5	●✚	●	
2.3.1	✚		●
6.1.3	✚	✚	●
7.4	✚	✚	●

Regarding the visual display of the HEI in the map of Portugal, the overall visual representation would have the organization of the information seen as in Figure 96, fulfilling the possibility to georreference institutions in the map, adding the zoom interaction feature over the map to allow a better reading of regions with a large number of HEI represented in a small area.

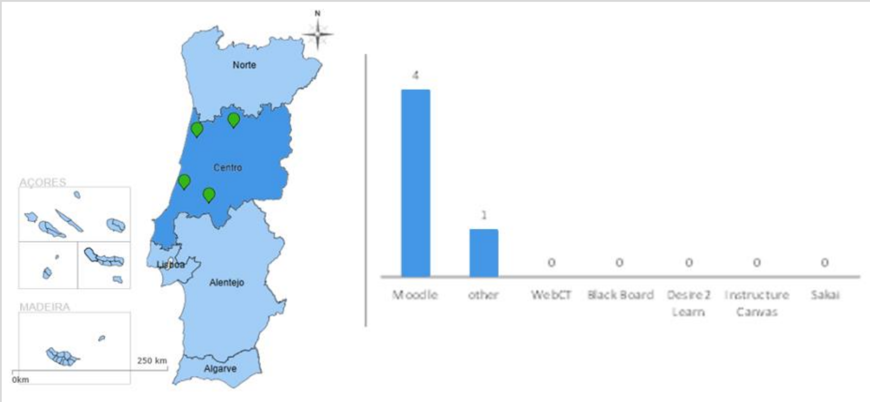

Figure 98. Data display for region

4.3. Phase 2 - Test the reading effectiveness of the graphs[61]

At this stage, the work developed in this study was combined with project TRACER, and the graph proposals presented previously in Table 23, were also presented to the company hired by the project TRACER to develop the U-TRACER® tool. The aim was to integrate the visual displays chosen into the tool.

The graphs proposed for the U-TRACER® beta2 phase, will be tested with the goal of selecting the one type of graph, between 3 different types proposed: stacked bar; circular pie-ring; and matrix bubble. The type of graphs selected by the participants in the test, will be implemented in the U-TRACER® tool.

Therefore, to choose from the graphs presented an online demo of the graphs was developed by the company, in order to allow a set of used to interact with the graphs in an online environment and evaluate the reading effectiveness of each graph. The test was applied through a questionnaire (Appendix 3 - Questionnaire "Reading effectiveness of the graphs") structured to obtain information focused on two evaluations:

- Global reading efficiency of the graphs;
- Comparison of graph encodings and labels.

The graphs of the online demo that were to be tested by participants by completing a questionnaire, were: bar graph (Figure 99); circular pie graph (Figure 100); stacked bar graph (Figure 101); pie-ring graph (Figure 102); and matrix graph (Figure 103).

Several types of tests can be implemented to evaluate graphs, depending on the goal of the study. Some authors propose tests with a set of tasks that focus on the representation details of the visual representation of the graphs (color, background, titles, sub-titles, word or number tags), others on

[61] The results presented in this section were published in a report of project TRACER, in July 2013.

the reading efficiency of the data of the graph, or on comparisons between one or more display patterns, and some test interaction with the graph using tasks with specific measures (time of performance, number of correct/incorrect answers to a set of questions the participant has to answers by reading the graph), or test preferences through subjective readings.

These subjective readings of graphs, can be useful for the phase of tests that aim at the evaluation of preferences of the participants based on the reading effectiveness of the graphs, towards the different types graphs proposed.

Spence (2007) highlights a simple evaluation proposal, taking into consideration the personal preferences of the participants, underlining that information collected about common usability may not be measured. The author exemplifies the type of question possible to ask a participant: “Did you find it easy to retrieve the answer to the question?”, which could be answered by selecting one of the 5 alternatives “Very easy”, “Easy”, “Indifferent”, “Difficult”, and “Very difficult”.

Ware (2004) has experimented the evaluation of different graph patterns through the process of asking the users to rate how well they can read each pattern in the graph, in a scale from 1 (good) to 5 (bad). The Likert scales are used to answer broad questions about preferences for more than one solution of pattern display, resulting to be excellent to measure relative preferences Lohse (1993) approaches the test of graphical perception, and describes 3 experimental tasks the participant performs: 1) Reading the question; 2) Seeing the graphs; 3) Answering the questions based on the information of the graph. The test measures the response time to answer the question, the short term memory capacity and the level of difficulty to acquire information. Variables, such as color, texture, location were observed.

From the types of graphs proposed to be tested by users, and developed in the online demo, the matrix graph offered some difficulties to the company. This difficulty led the company to propose an additional graph, the pie-ring graph, which in their opinion could be used to represent more than one variable in substitute to the matrix graph. This option was discussed within project TRACER team and although this it did not meet consensus, possibility of integrating the pie-ring graph together with the bar and matrix graph in the online interactive demo reached agreement.

The graphs developed in the online demo are shown in (Figure 99, Figure 100, Figure 101, Figure 102, Figure 103).

Graphs for datset dataset 1.2. “How many organizational units does the institution have?”

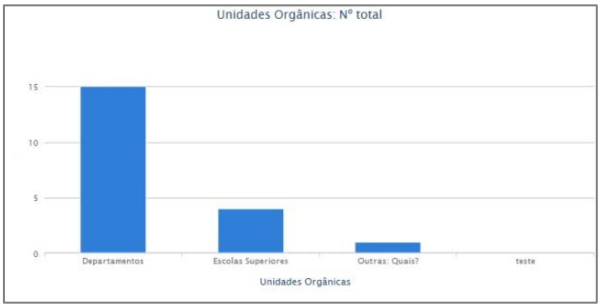

Figure 99. Online demo: Bar graph for dataset 1.2.

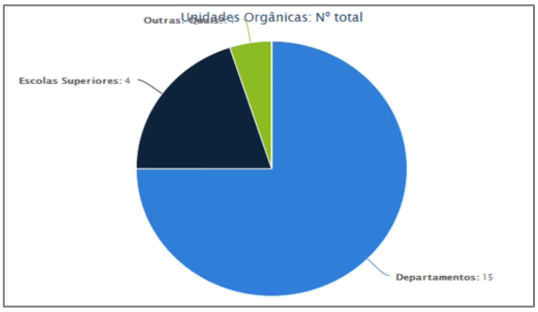

Figure 100. Online demo: Circular pie graph for dataset 1.2.

Graphs for datset 1.4.1, related to the question “How many courses does the institution have, per Bologna study cycle and teaching and learning methodology?”

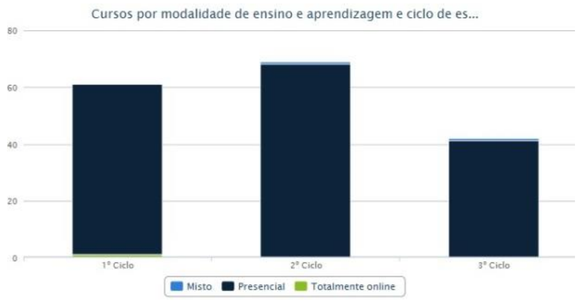

Figure 101. Online demo: stacked bar graph for dataset 1.4.1.

Figure 102. Online demo: circular pie-ring graph for dataset 1.4.1.

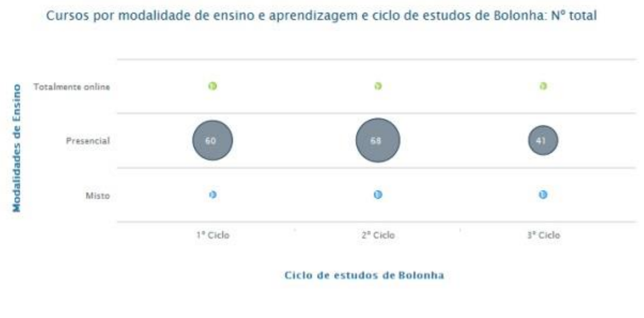

Figure 103. Online demo: matrix bubble graph for dataset 1.4.1.

The matrix graph presented above in Figure 103 has one error: it represents the zero values and it should not, adding to this the zero value has the same size as the values for ‘1’, conducing the reader of the graph to an error in reading. The correct way to represent the dataset would be as shown in Figure 104 and Figure 105.

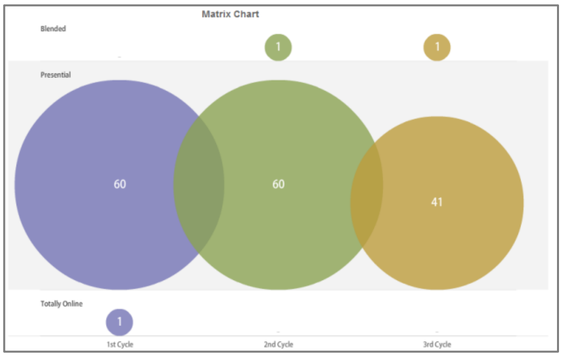

Figure 104. matrix bubble graph for dataset 1.4.1. with teaching methodologies in vertical axis. Created with many Eyes software.

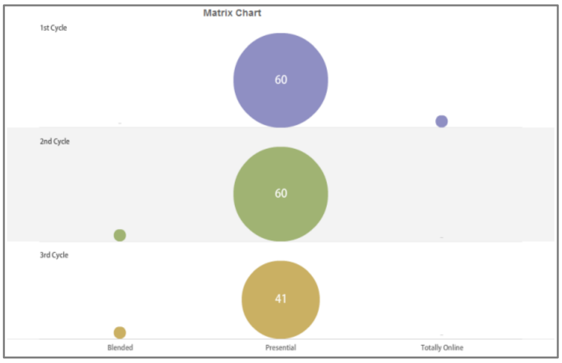

Figure 105. matrix bubble graph for dataset 1.4.1. with teaching methodologies in horizontal axis.Created with many Eyes software.

The participants only interacted with the matrix graph of the online demo (Figure 104), during which were informed of the error of having the zero values represented, and were asked to ignore this error.

4.3.1. Results of the test to the reading effectiveness of the graphs

The questionnaire - reading effectiveness of the graphs – was completed by 12 participants, and following we present the result of the analysis to the questionnaire. The participants were asked to speak aloud their thoughts while interacting with the graphs in the online demo, therefore the comments were also analysed

Perceptions of the reading effectiveness of the graphs

In the questionnaire participants were asked to compare the reading effectiveness of two different graphs to represent a same dataset. Participants had to indicate which graph (Figure 106, Figure 107), for them, allowed a better reading of the data result from the dataset indicating "Number of organizational units of the higher education institution". Seven participants considered the pie graph as the graph which allows a more effective reading of the data, and 5 participants chose the bar graph. The proximity of the numbers show that both graphs are adequate for reading the data.

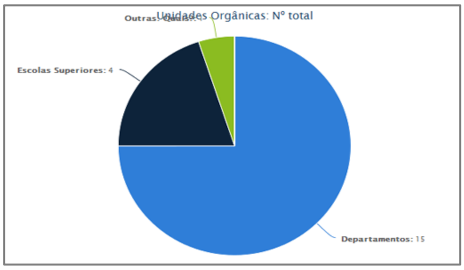

Figure 106. Question 2.1, circular pie graph (7 participants)

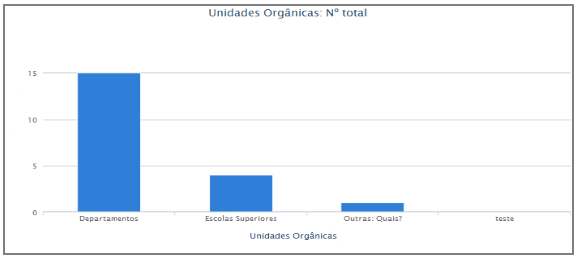

Figure 107. Question 2.1, bar graph (5 paticipants)

The overall comments of the participants while interacting with the graphs in the online demo, focused on suggestions of improvements to the graphs (Table 25 and Table 26). Participants were of the opinion the tooltips of the bar graph did not give them the information they needed.

Table 25. Participants comments to the bar graphs representing question 2.1. (P): Participant.

Comments of the participants to the bar graph of question 2.1.	
Participant	**Comments from the participant**
P2	It would facilitate the reading if you put the numeric value on top of the bar graph.
P5	The bars should have three different colors such as in the pie graph.
P6	I found the tooltips by chance, there is no visual indicator that there are tooltips in the bars that I can interact with.
P8	The tooltip informs very little besides what is already shown in the graph.
P12	Title should have both vertical and horizontal axis.

There were only two comments aloud to the pie graph, nevertheless the comments also focused on the need for an existing tooltip, which in this graph did not appear, and that should indicate a specific information, and a suggestion to add a color label to the graph.

Table 26. Participants comments to the pie graphs representing question 2.1. (P): Participant.

Comments of the participants to the pie graph of question 2.1.	
Participant	**Comments from the participant**
P5	Should have a color label to accompany the graph.
P10	Must have a tooltip indicating the total number, use color hue.

For question 2.2 "Number of courses per teaching and learning methodology and bologna study cycle offered by the institution?" The participants were informed by the researcher that the matrix graph had an error in its representation: the zero values were represented as the smallest circles, but they should not be represented.

Participants considered the pie-ring graph (5 participants) to be more efficient to assist reading the dataset. Nevertheless the stacked bar graph was considered to be more efficient by 4 participants, and the bubble matrix was chosen by the lower number of participants (3). The choice of the graphs did not indicate a clear choice.

Figure 108. Question 2.2: Pie-docnut graph (5 participants).

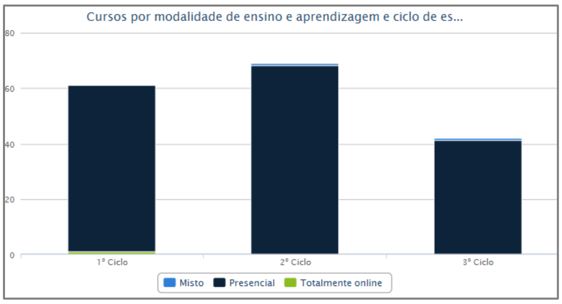

Figure 109. Question 2.2: Stacked bar graph (4 participants).

Figure 110. Question 2.2: Matrix graph (3 participants).

The participants were informed about the error in the matrix chart, and asked to ignore the "zero" values represented.

The overall comments to the bar, pie and matrix graphs were suggestions to improve the labels and color of the graphs. One of the participants commented that none of the graphs were adequate to represent this specific dataset, and therefore chose none of the graphs.

Relating to the stacked bar graph participants identified the difficulty of reading the small numerical values. Additionally they revealed difficulty regarding the interaction of the labels, due to the lack of indication that they were interactive or by resulting in an action contrary to the one the participant wanted (e.g.: the participants clicks on the color lable hoping to highlight an area of the graph, but there was a contrary result, the area of the graph was turned off. Only two participants interacted with the labels.

Table 27. Participants comments about the stacked bar graphs graphs representing question 2.2. (P): Participant.

Comments of the participants to the stacked bar graphs in question 2.2	
Participant	**Comments**
P2	The small values have less visibility
P4	The bar with the small values have less visibility
P5	Small values have less visibility
P7	The label below the graph is having the action contrary to the one I want, I want to 'activate' and it 'deactivates'.
P8	The color green cannot be seen
P10	Should be pointed out that the legend is interactive because I only realized by chance; use a color hue or three distinct colors.
P12	The small values have less visibility

The matrix graph was less commented, having the participants focused mostly on the dispersion of information.

Table 28. Comments of the participants about the matrix graphs in question 2.2. (P): Participant

Comments of the participants to the matrix graphs in question 2.2	
P2	The circles should be bigger
P7	It is visually more clean but the information becomes lost.
P8	it is not clear what information is being prioritized
P12	The disperse information leads to lose its' reading

The comments to the pie-ring graph all focused on the lack of color labels that help the reader understand the pie-ring graph.

Table 29. Participants comments about the pie-ring graphs representing question 2.2. (P): Participant

Comments of the participants to the pie-ring graph in question 2.2	
P4	There should be a color label with the graph
P6	I did not realize which were the totals. It's not understood because it does not have 'Totally online' in every ring.
P7	should have a color legend with the cycles and their totals.
P8	The legends should also have color
P10	must have a legend indicating the total number; the axis should be in reversed order

For question 2.3 "Frequency with which teacher training is offered by types of training", 5 participants considered the stacked bar graph to allow a more effective reading, 3 participants chose the circular graph, 3 the matrix bubble graph and 1 participant opted for null answer. Three participants (P7, P11, P12) commented that none of the graphs were adequate because the data to represent was non-quantitative.

Figure 111. Question 2.3: Staked bar graph (5 participants)

Figure 112. Question 2.3: Pie-docnut graph (3 participants)

Figure 113. Question 2.3: Matrix graph (3 participants)

The majority of participants commented that they were unable to read the pie-ring and the matrix graphs. Both graphs visually quantify the pie or rings of the graph, or the bubbles in the matrix, and the dataset was non quantitative.

Once again, the participants were informed about the errors in the demo matrix graph: the numbers in all the bubbles should not be represented, and the smaller bubbles should not be represented at all because as the image shows they represent a zero value and therefore meaning that those options of teacher training versus frequency do not exist.

Table 30. Participants comments about the graphs representing question 2.3. (P): Participant

Comments of the participants to the graphs in question 2.3		
Participant	**Graph**	**Comment**
P8	**Pie-ring**	The object of analysis was lost
P12	**Pie-ring**	Because there is non-percentile data it does not make sense to represent the information with this type of graph, it is not adequate
P10	**Bar**	The horizontal axis should have the “course type” and not the frequency scale, the axis should be inverted
P10	**Matrix**	The horizontal axis should be on top (an inverted L)
P8	**Matrix**	The object of analysis was totally lost

This analysis reveals two main problems in adapting visualizations that are meant to represent quantitative data, to represent non-quantitative data: the first is the habit the reader gains in reading a type of graph related to a type of data, as is the case of the graphs bar, pie-ring and matrix for quantitative data; the second problem is a consequence of the first, the confusion it may generate in the readers ability to read a graph when the measurement changes, in this case from quantitative to non-quantitative.

Comparing graphical representations for the same graph type

In this section the participants were asked to indicate which representation they preferred, comparing two graphs of the same type but with a single difference between them.

The first graphs to compare were those in Figure 114 and Figure 115. 11 of the participants chose the graph in Figure 115, with the numerical values represented on top of each bar. When comparing the graphs in Figure 116 and Figure 117, 8 of the participants chose Figure 117, with the numerical values represented within the parts of the pie. In comparing the matrix bubble graphs in Figure 118 and Figure 119, 8 of the participants chose the graph in Figure 118, with the white background color.

From both options of bar graphs, participants made a clear choice regarding their preference between the two examples, 11 participants chose the graph with the numbers represented on the top of the bar (Figure 115). Additionally suggestions were made to improve the bar graph, to the numerical value may appear when the mouse passes over the bar and to eliminate both the background lines and the numbers of the vertical axis.

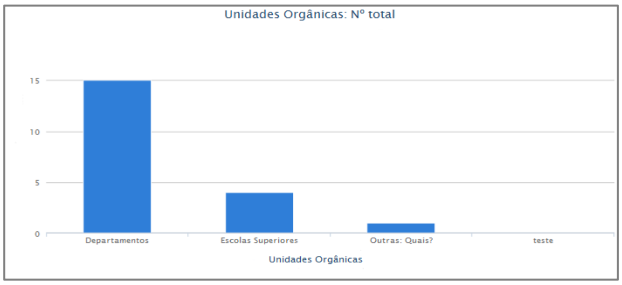

Figure 114. Bar graph of question 3.1: scale on the vertical axis.

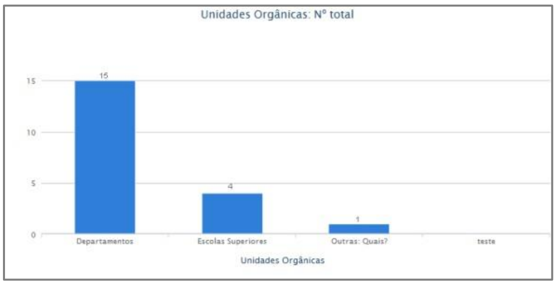

Figure 115. Bar graph of question 3.1: quantity numbers represented on the top of the bar.

Comparing both graphs, 4 participants indicated to prefer pie graph with numbers represented on the label, but the majority of the participants, 8, indicated to prefer the graph with the numbers represented within the circle. Additionally one suggestion of improvement of the graphs was made: the numerical value may appear when the mouse passes over the circle.

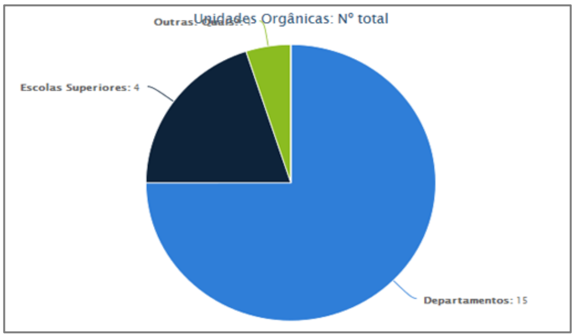

Figure 116. Pie graph of question 3.2: quantity numbers represented on the label.

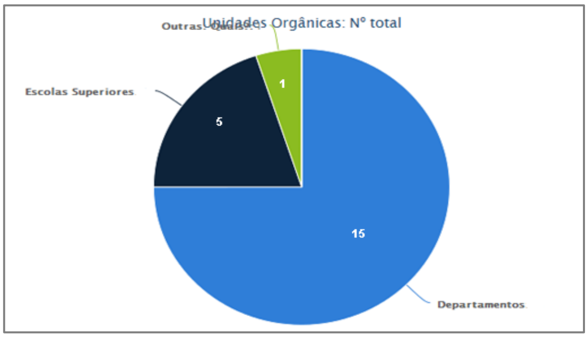

Figure 117. Pie graph of question 3.2: quantity numbers represented within the circle.

Finally, when comparing the matrix graph, the majority of the participants, 8, preferred the only white background over the white and grey background preferred by 4 participants. No additional suggestions of improvement of the graphs were made by the participants.

Figure 118. Matrix graph of question 3.3: only white background.

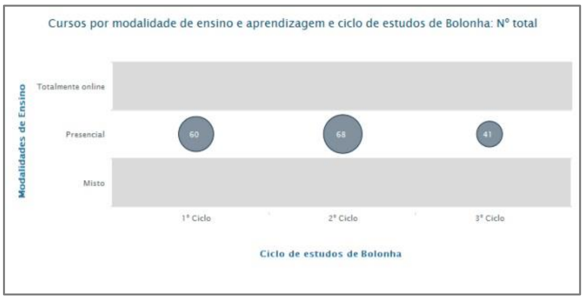

Figure 119. Matrix graph of question 3.3: white and grey lines in the background.

4.3.2. Synthesis

Synthesizing the results of the questionnaire applied to 12 participants, regarding their preferences towards the graphs that allow a more effective reading of the data, will allow us to define the types of graphs to be implemented in the U-TRACER®. Table 31 aggregates the information about the number of participants that indicated to prefer the five different types of graphs to represent 3 datasets associated to three questions.

Table 31. Preferred graphs by total number os participants who chose them. (n/a): not applicable.

Question nº	Bar graph	Stacked bar graph	Pie graph	Pie-Ring graph	Matrix bubble graph
2.1	5	n/a	7	n/a	n/a
2.2	n/a	4	n/a	5	3
2.3	n/a	5	n/a	3	3

The results show that for each question (dataset), the preferences of the participants were not clear towards leading graph. Nevertheless, despite the small distance between the number of participants who chose each type of graph, the most preferred were the pie and pie-ring graph, followed by the bar and staked bar graph, and finally the less preferred graph was the matrix bubble. We consider valid the results of the bar and staked bar graphs, and of the pie and pie-ring graphs because they were correctly drawn on the demo. But we do not consider the results of the matrix graph valid because the graphs had misrepresentations which could have led to the lower preferences of the participants, which despite that were indicated as preferred graphs by three participants in each of the two questions that had multidimensional datasets (questions 2.2, 2.3).

4.3.2.1. Improvements to the graphs

The improvements on the graphs resume to the following suggestions:

- Bar graph: have the numbers represented on top of the bar, with a white background.
- Pie graph: have the numbers represented within each section of the circle.
- Matrix graph: have a white background.
- Labels: add color labels to explain the content of the graphs.

Regarding the graphs that were used to represent non-quantitative datasets (stacked bar and pi-ring graphs), the participants identified that the types proposed were not adequate because they were types of graphs to represent quantitative datasets. Meeting the participants improvement suggestions and comments related to the inadequacy of the bar, stacked bar, pie or pie-ring graphs to represent non quantitative datasets. We will stress the proposal of representing the non-quantitative datasets with the color grid graph made previously in section 4.2.

4.4. Information visualization features for the U-TRACER® prototype.

The prototype proposal for the U-TRACER® is an outcome of the work developed in this study, described in sections 4.1, 4.2 and 4.3 and a close work with the company hired by project TRACER to develop the U-TRACER® tool.

The prototype of the U-TRACER® interface was to integrate the interaction features and visual displays resumed briefly in Table 32, and was presented to the company in order to develop the final prototype.

Table 32. Summary of interaction features and graph type proposals to integrate the U-TRACER®

Interaction features	Graph types
1. Guide users: how to use, FAQs.	9. Bar and stacked bar graphs.
2. Filters: HEI; Region: Theme use of CT.	10. Pie and pie-ring graph.
3. More than one visualization type.	11. Color grid graph (for non-quantitative datasets).
4. Share visualization in social networks.	
5. Download the datasets.	
6. Download the graphs generated.	
7. Details on demand.	
8. Contextualized help.	

The figures shown below (Figure 120, Figure 121) are prints of the final prototype presented by the company, with which were to be performed the usability tests with end users presented in the next section 4.5.

Figure 120. Prototype of the U-TRACER®.

Figure 120 shows that the prototype offers the user a stacked bar graph and a pie-ring graph to represent non-quantitative dataset. The stacked bar graph was adapted to represent non-quantitative data, rather than creating a color grid graph. In the staked bar graph an error prevails: the bars show a number that relates to the likert scale of the data with a qualitative scale from 'never' (1) to 'many times' (4); the likert scale is not correctly ordered. Additionally in map, the red and grey circles which represent HEI who provided or did not provide data, should only appear inside the area of the region selected.

Figure 121. Prototype of the U-TRACER®.

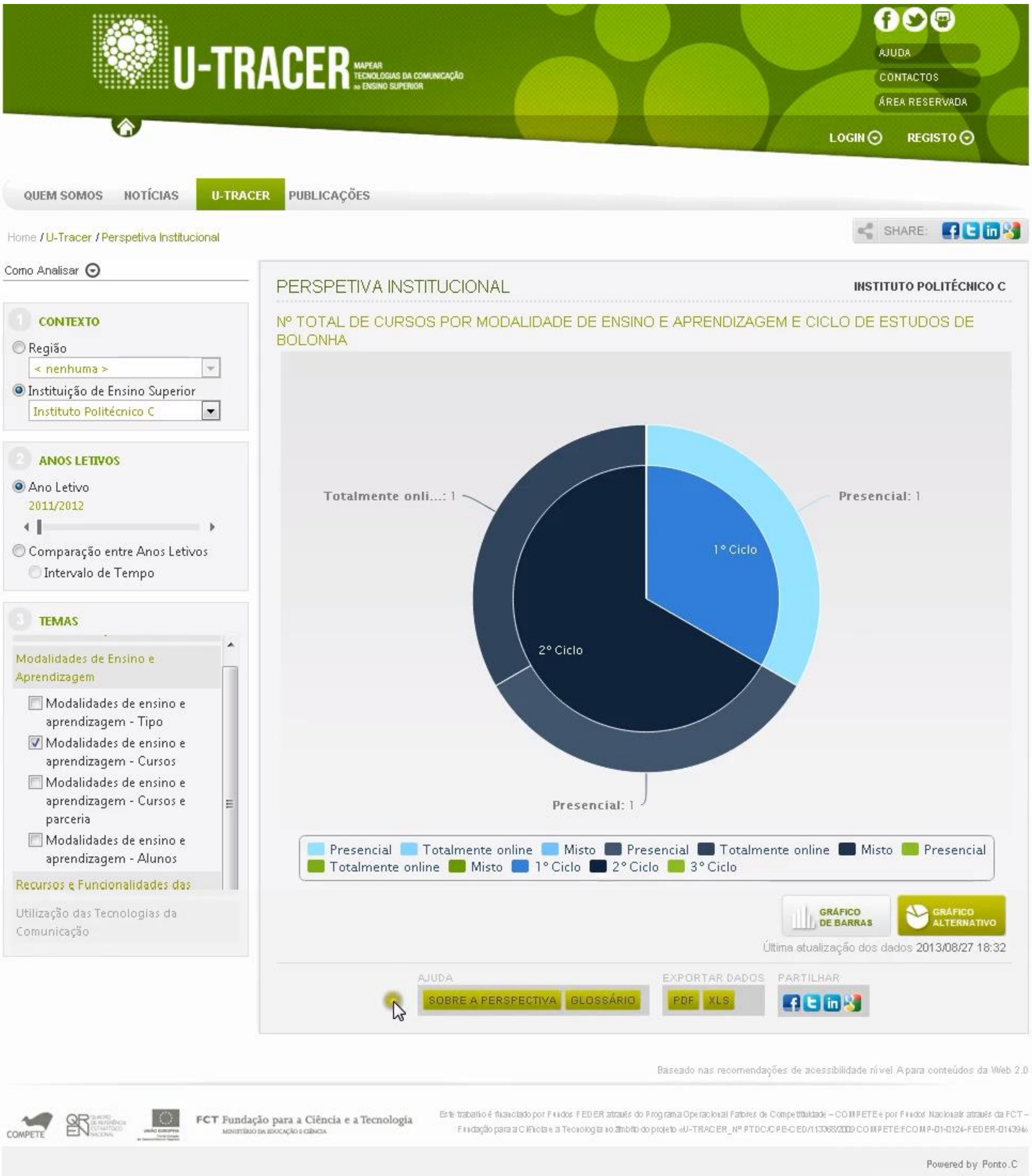

Figure 122. Prototype of the U-TRACER®.

Figure 122 a pie-ring graph representing quantitative dataset, added a color label to the graph, but does not represent the numeric value within each part of the circle, and did not delete the labels surrounding the circle that are repeated in the color labels.

The prototype meets most of the requests made, and Table 33 shows the features that were and were not implemented. This is important to resume after the usability test which will be performed with end-users interacting with this prototype.

Table 33. Interaction features implemented in the U-TRACER® prototype. (✓): implemented; (×): not implemented

Interaction features			Graph types		
1.	Guide users: how to use, FAQs.	✓	2.	Bar and stacked bar graphs.	✓
3.	Filters: HEI; Region: Theme use of CT.	✓	4.	Pie and pie-ring graph.	✓
5.	More than one visualization type.	✓	6.	Color grid graph (for non-quantitative datasets).	×
7.	Share visualization in social networks.	✓			
8.	Download the datasets.	✓			
9.	Download the graphs generated.	✓			
10.	Details on demand.	×			
11.	Contextualized help.	×			

4.5. Phase 3 - Usability tests to the U-TRACER® [62]

According to Nielsen and Hackos (1993) and Nielsen (2012) in a qualitative study, for the usability test the recommended number of test users is 5, number which will allow to identify most of the problems with interface designs. Additionally the author states that for the usability test the concern of the researcher should be on big design problems regarding user experience, and not to focus on small issues (Nielsen, 2012). In this study we applied the usability test to the front-office, with 7 users. The same usability test included tasks performed by the participants, to the back-office of U-TRACER® that served simultaneously the need of project TRACER to test this area of the tool. The usability test to the front-office can be consulted in Appendix 4 (Usability test to the front-office of U-TRACER®), regarding which in this study we will describe and analyse the activities performed by the participants.

The prototype which the users interacted with was described in the previous section 4.4 and illustrated in Figure 120, Figure 121 and Figure 122.

4.5.1. Results of the Usability test

Usability test to the Front-office (FO) of the U-TRACER® required participants to perform 12 tasks and achieving the indicators of task completion. In Table 34 are presented the tasks performed in FO, by the sequence in which they were performed, revealing the number of participants who completed or not each task.

[62] The results presented in this section were published in a report for the TRACER project in September 2013.

Table 34. Task guide for the usability test to the Front-office. Total of 7 participants.

<table>
<tr><th colspan="2">Tasks performed in Front-office</th><th rowspan="2">Indicator of task completion</th><th colspan="2">Nº of participants who executed the task</th></tr>
<tr><th>Nº</th><th>Description</th><th>Yes</th><th>No</th></tr>
<tr><td>2.1.</td><td>Access the tab ‘U-TRACER®’, ‘Institutional Perspective’.</td><td>- Clicked on the institutional perspective tab.</td><td>3</td><td>4</td></tr>
<tr><td>2.2.</td><td>Look for the descriptive information about the ‘Institutional Perspective’</td><td>- Clicked on the institutional perspective button.</td><td>6</td><td>1</td></tr>
<tr><td>2.3.</td><td>Look for information about ‘How to use this page’.</td><td>- Clicked on the how to use button.</td><td>7</td><td>0</td></tr>
<tr><td rowspan="6">2.4.</td><td rowspan="6">Generate a graph for institution ‘University Test’, for ‘school year 2011/2012’, on the theme ‘Profile" in the sub-theme ‘Teachers - total number".</td><td>- Clicked first on the institution.</td><td>2</td><td>5</td></tr>
<tr><td>- Selected the institution.</td><td>7</td><td>0</td></tr>
<tr><td>- Selected the school year using the double slider.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct sub-theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the graph.</td><td>6</td><td>1</td></tr>
<tr><td rowspan="2">2.5.</td><td rowspan="2">In the ‘Glossary’ see the definition of ‘full-time faculty’, and return to the view of the graph.</td><td>- Clicked on the glossary button.</td><td>7</td><td>0</td></tr>
<tr><td>- Closed the glossary window.</td><td>7</td><td>0</td></tr>
<tr><td rowspan="6">2.6.</td><td rowspan="6">Generate a graph for institution ‘University Test’, for ‘school year 2011/2012’ on the theme ‘Types of teaching and learning’ and the sub-theme ‘Courses teaching and learning methodologies".</td><td>- Clicked first on the institution.</td><td>7</td><td>0</td></tr>
<tr><td>- Selected the institution.</td><td>7</td><td>0</td></tr>
<tr><td>- Selected the school year using the double slider.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct sub-theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the graph.</td><td>7</td><td>0</td></tr>
<tr><td rowspan="3">2.7.</td><td rowspan="3">In the bar graph generated in task 2.6, generate an alternative display.</td><td>- Identified the button for the alternative visualization.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the graph.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the labels of the graph.</td><td>7</td><td>0</td></tr>
<tr><td rowspan="6">2.8.</td><td rowspan="6">Generate a graph for the region ‘North’, for the ‘School year 2011/2012’, on the theme ‘Features and functionality of communication technologies’ for the sub-theme ‘Spaces and resources’.</td><td>- Clicked first in the region.</td><td>7</td><td>0</td></tr>
<tr><td>- Selected the North region.</td><td>7</td><td>0</td></tr>
<tr><td>- Selected the school year using the double slider.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked on the correct sub-theme.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the graph.</td><td>7</td><td>0</td></tr>
<tr><td rowspan="2">2.9.</td><td rowspan="2">Look at the graph generated in task 2.8 and indicate the total number of respondent institutions of the North region.</td><td>- Identified the number of institutions.</td><td>7</td><td>0</td></tr>
<tr><td>- Interacted with the labels of the graph.</td><td>7</td><td>0</td></tr>
<tr><td>2.10.</td><td>Share the graph generated in task 2.8 in a social network.</td><td>- Identified the button to share the graph.</td><td>5</td><td>2</td></tr>
<tr><td rowspan="2">2.11.</td><td rowspan="2">Download the graph generated in task 2.8, in the in excel format.</td><td>- Clicked in the pdf button.</td><td>7</td><td>0</td></tr>
<tr><td>- Clicked in the excel button.</td><td>7</td><td>0</td></tr>
</table>

All the interactions of the participants in the front-office of the U-TRACER® and the comments made aloud during the completion of the usability test, were analysed. The tasks performance were widely commented by the participants, making overall observations, identifying difficulties and errors, and giving opinions about the interface design which went beyond the tasks being performed.

Task 2.1: Access the tab 'U-TRACER®', 'Institutional Perspective'.

Four of the participants did not click on the tab 'Institutional Perspective', because by clicking in the tab 'U-TRACER®' it automatically redirected the user to the 'Institutional Perspective' area. This was identified by three participants as an error that needed to be corrected in the prototype. Three participants commented during this task, making two suggestions that: P3 suggested that when entering the 'Institutional Perspective' area, the random graph that is generated to show the user of the tool the type of graphs that himself can generate, should have activated the filters which generated the graph. I the prototype no filters were selected for the random demonstration graphs; alternatively P6 suggested to only have a tab 'U-TRACER®' that would lead the user to visualize information on what U-TRACER® is and how to use the tool, and after have a button to lead the user to the 'Institutional Perspective'.

In the U-TRACER® prototype the tab with the same name as the tool has the function of giving the user access to an area where he can access the infovis features, interact with filters of information and generate graphs according to his own interest. Figure 123 illustrates the correct tabs the participants had to click in order to open the infovis area of the tool [63].

Figure 123. U-TRACER® prototype for usability test: tab.

The difficulty of the participants in completing this first task – 3 completed, 4 did not complete the

[63] The two drop down tabs that are within the main U-TRACER® tab relate to two different datasets collected by project TRACER: Institutional Perspective of the use of CT, the one referred to in this study; Teachers perspective of the use of CT. In this study we only work with the dataset for Institutional Perspective because it was the only dataset existing in the beginning of this study, which had the data collection happen between January and May of 2012. The data for Teachers perspective of the use of CT was collected between May and July of 2013.

task - led us to rethink that 'Institutional Perspective' (and 'Teachers perspective') of the use of CT as filters of information that can be integrated in the area of interaction with the remaining filters. This area is the left column shown in Figure 124.

Task 2.2: Look for the descriptive information about the 'Institutional Perspective'.

Six participants successfully identified the button 'Institutional Perspective' (Figure 124). Nevertheless 5 of the participants (P1, P3, P5, P6, P7) commented that their first attempt was to click on the main title above the graph area, suggesting that the button below the graph be deleted and its information placed in a contextualized help near the title "Institutional Perspective".

Figure 124. U-TRACER® prototype for usability test: Institutional Perspective button.

P1: "... I have to scroll (to see the information), if it is a useful information I do not know why it can't be up here (near the title), because it is important to know what you mean 'Institutional Perspective' and de definition must be by its beside";

"If in the map of Portugal this is the region selected, why is the title of the region far away from the map?"

P5: "It makes no sense to have the button (*Sobre a perspetiva*) in that place. The information should be in context, and all help is below the cutoff line of the screen, additionally the window opens downward. (*Sobre a perspetiva*) should be near the title with a help icon as a question mark or a letter i."

P6: “*Sobre a perspetiva”* should be near the title. The buttons below are not visible, I have to scroll down to see them.”

P7: "(...) You should have that same text next to the title of the page, a window that opens and collapses, or the small icon arrow"

Task 2.3 - Look for information about ‘How to use this page’.

All the participants execute this task with success. Five participants observed that this button was less visible than other buttons, and that the pop-up box did not close when the user clicked outside of the box in the attempt to close it. This was identified as a difficulty that should be improved (P1, P2, P6, P7). Additionally participants considered the text of the instructions about how to use the filters, was very short, and one participant (P5) suggested that these types of instructions should be the equivalent to contextualized help distributed where needed in the interface.

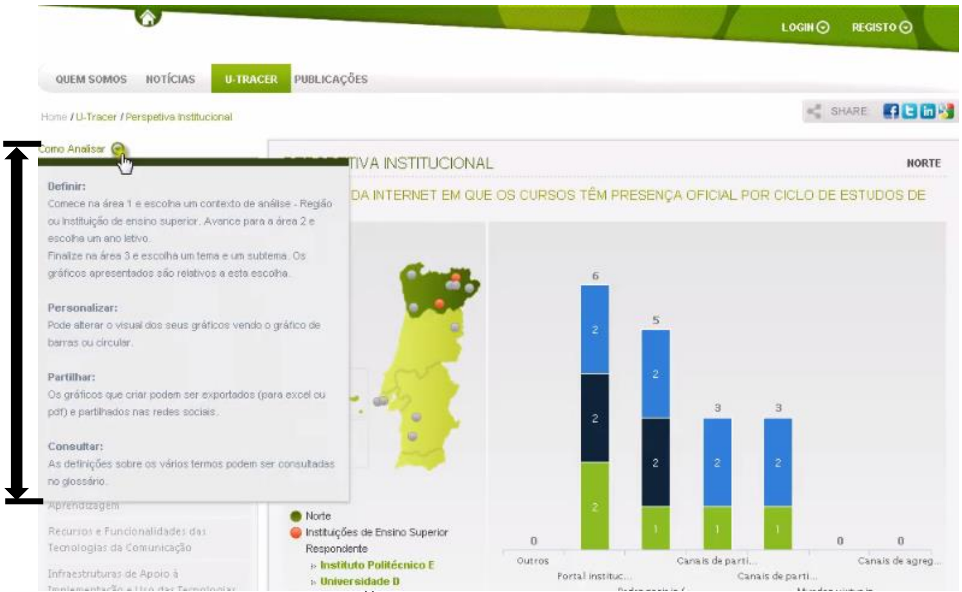

Figure 125. U-TRACER® prototype for usability test: How to use button.

P3: “The first thing I usually do and I feel the need to do here is to know “how to analyze. But that text is so summarized, because the person who wrote this new how to analyze this (…) sometimes simplifying is too much! Each step the user needs to make should be in a separate line.

P4: “This button (*Como analisar*) is less visible. I was expecting something more green, more look-a-like the other buttons”

P5: “The words used should be more direct, like nan instruction. Change for example: ‘Personalize’ to ‘Personalize the graph’. I tis bad that all the help is concentrated here, they should be in the context.”

P6: “(the button *como analisar*) It’s very hidden. When I access the platform for the first time I should have access to a vídeo tutorial explaining how to use. Then it should be a button on the top right corner, because on the lefts I am expecting to perform actions. The button should also have only one action, only to open.”

“The number ‘1’ for the area of ‘*Contexto*’ has a serious color contrast problem.

P7: “It’s never good to overlap information (with the pop-up box *Como analisar*). All the boxes should be standardized, because now each one is opening up in a different direction”

Tasks 2.4, 2.5 and 2.6 will be analysed as a group because they correspond to tasks that involved the same selection of the main filters of information.

Task 2.4 - Generate a graph for institution ‘University Test’, for ‘school year 2011/2012’, on the theme ‘Profile" in the sub-theme ‘Teachers - total number".

All the participants executed the task with success, and the overall comments of six participants, to this task, focused on four aspects. **The first**, identified by 3 participants, relates to the need of clarifying the user about the option of selecting one or another filter, between the Region or HEI.

P1: It should have visual feedback, indicating to select one or another (filters ‘Region’ or ‘Institution’). For just two school years, I don’t know if it's the (double slider) is the best tool to show only two (academic years)."

P6: "There must be an indication ‘OR’ between the filter Region and Institution because there is no indication of that. The integration of information is always like a dropdown menu, before I have never interacted with a slider like this one (double slider to select academic years), and I think this type of interaction is not justified."

P7: "I thought that I would have to select both (filters Region and Institution). The information is limited (in the bar graph)."

The second, mentioned by 4 participants, regards the double slider which serves to timeframe the data (school years) considering that it could be substituted by drop-down menus, a more direct way to select the school years.

P2: “There are two dropdowns so close to each other (Region and Institution) that it gives me the feeling that one affects the other.

> This scroll bar (double slider) may ultimately cause difficulty (in the selection of school years). It could possibly be a dropdown menu with the years.
>
> P3: "(in the double slider) it would be easier if there was a title saying 'select one school year' or 'select more than one school year'.

The third concerns the graph area, that shows a random graph when the user enters the U-TRACER®. The random graph was either related to the dataset concerning one HEI or of a dataset concerning a region of Portugal. The graph is shown but the check-boxes of the respective filters did not appear selected. During the users interaction with the filters, to complete this task, the random graph maintained static because it would only generate a new graph when the user selected all the necessary filters. The participants manifested the expectation that their interaction with the filters would have resulted in an immediate change of the random graph and into a similar graph (P2, P3). This did not happen because the random graph represented data of one region of Portugal and the graph this task requires participants to generate relates to data of one HEI.

Finally, the **fourth aspect** focused on the reduced information of the graph, which caused difficulty in reading the graph, suggesting to include a contextualized help in the graph.

> P3: (after generating the graph for the task, P3 comments) "When I clicked in the tab Institutional Perspective I noticed it appears the map, the bar graph. When I finish the whole filtering task (task 3.10) I'll be waiting for it to appear the same (map, bar graphs), and it does not appear ... this is weird. I found it odd! This here is one more reason not to focus so much to giving a suggestion to the user, because then as something else happens, and the problem is that these inconsistencies put the user nervous about what he will do (…)."
>
> P5: "It makes no sense for the bar chart to have the number 2 on the top of the bar. It lacks the most important the explanation of what the number is about: the total number of teachers. This graph is simple to understand, but the other graph (pie-ring) is not. We need a little help in context about the graphs information. The words in the label of the graph (bar) are "swimming".

Task 2.5 – In the 'Glossary' see the definition of 'full-time faculty', and return to the view of the graph.

All the participants completed the task correctly. During the completion of the task two participants suggested that the glossary list of terms should appear as an "accordion" type of list, rather than having the definition of the term appear in a pop-out box which features of drag and drop have no usefulness whatsoever to the user (Figure 126, Figure 127).

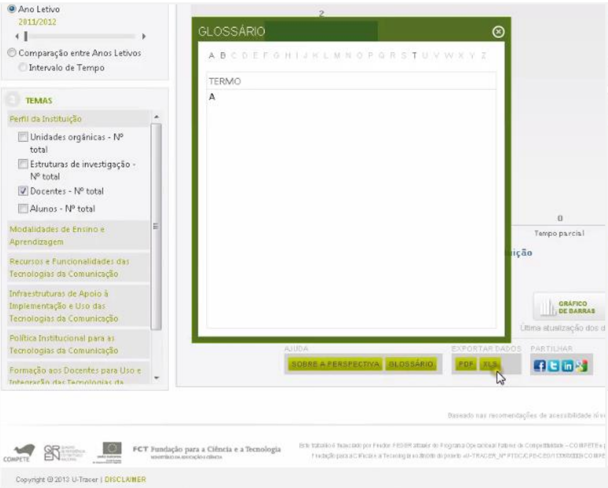

Figure 126. U-TRACER® prototype for usability test: glossary.

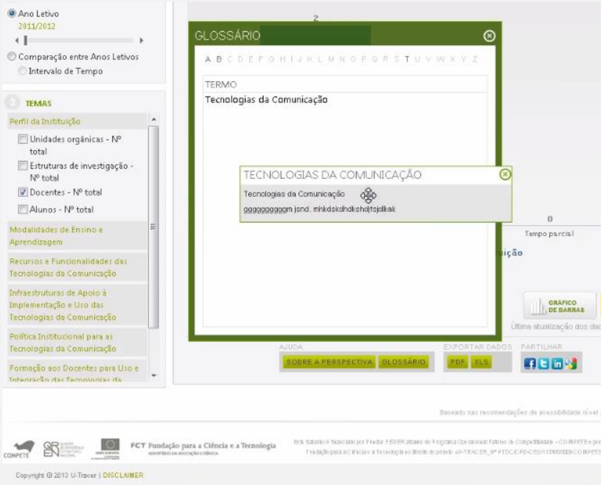

Figure 127. U-TRACER® prototype for usability test: glossary.

P1: “If the glossary is important then put it at the top (near the title)”.

P3: “I don’t like this interaction. Why can we drag and drop? I would be expecting for it to appear in a list of terms and when I click on one term it opens in accordion. But to have one window, and another window and now I have three windows just for the glossary. When I open the glossary the background should darken. Worst is that I continue to interact with other filters without having to close the window. The user should not be distracted with other things.”

P4: “Why does the box (with the definition of the term) drag? (…) It should open like an accordion. To drag makes no sense.(…) When we click outsider of the glossary box the box should close.”

Task 2.6 - Generate a graph for institution ‘University Test’, for ‘school year 2011/2012’ on the theme ‘Types of teaching and learning’ and the sub-theme ‘Courses teaching and learning methodologies’. And **task 2.7 - In the bar graph generated in task 2.6, generate an alternative visual display.**

All the participants were able to execute both tasks with success. The comments from four participants all focused on the information in the labels of both bar and pie-ring graphs. P1, P3 and P4 all identified that the color label below both graphs had different information, while the bar graph as three components in the label (Figure 128), the pie-ring graph counts with 12 components (Figure 129). This confused the users, revealing difficulty in reading the data in the pie-ring graph. P3 also identified that the words of the labels in the circle were incomplete, requiring for him to always use the mouse over function to access the complete word and therefore be able to interpret the information. The same happened in the bar graph.

> P3: "I cannot interpret the bar graph well because of the number 2 on top of the bar. The color label should be above the graph or in the right corner of the graph area. The tooltip (in the chart) informs '1st cycle Presential: 1', and it should have the measuring unit. '1' what? 1teacher? 1potato?. Note that the title (of the graph) is often overlooked."
>
> "In the alternative graph (pie-ring) cut words, this should not happen. It always forces me to use the mouse over. In color label there are many more things than on the graph: it has 12 filters and the graph does not have 12 things. Do not show the user content that does not exist. "
>
> P4: (Pie-ring graph) has the same color label of the other graph (bar)? The label is quite confusing, it could appear on one of the sides of the graph ... I was totally confused now with this label! In the bar graph it was quite simple, and here (pie-ring) it seems that I am seeing another dataset, it completely confused me!
>
> P6: "Here (in the tooltip of the bar graph) has the total number, but I think it should have an interpretation: in Cycle 2 has x courses in teaching ..."

The way information is presented in the tooltip and the color labels will have to be corrected in all graphs, in order to help the user read the graph with no difficulties. Also two users suggested that in the tooltips of the graphs should have described the unit of measure, for example: the tooltip informs "1st cycle: 1", to which should be added the unit of measure 'course' and correctly read "1st cycle: 1 course".

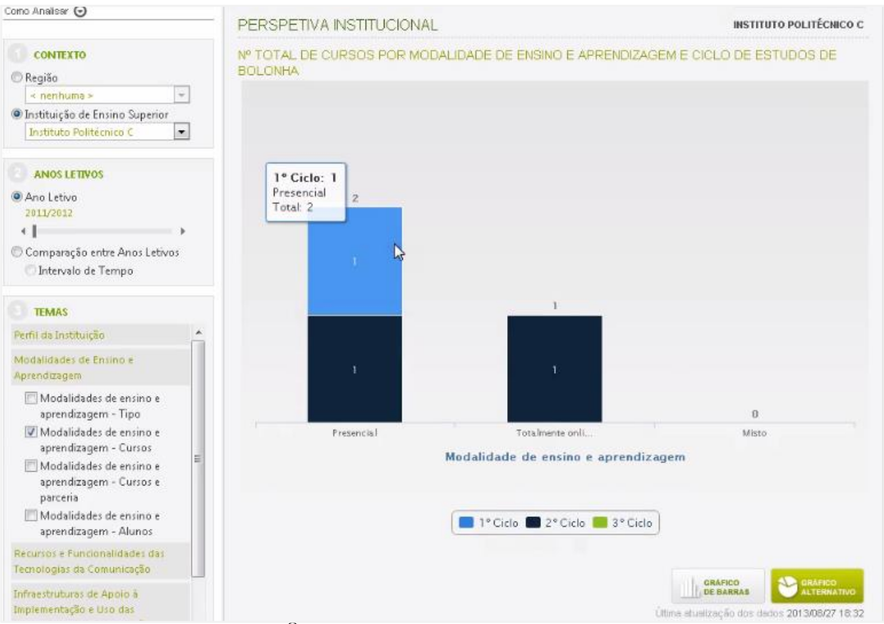

Figure 128. U-TRACER® bar graph in the front-office. Source: usability test.

Figure 129. U-TRACER®: pie-donut graph in the front-office. Source: usability test.

Regarding the alternative visual representations, the users did not spend time in analyzing the data with the alternative visual graph, which can be explained because the two types of graphs showed the same data for the same purpose. Ware (2013) refers to this this, stating that when the user is confronted with tools that perform the same task, the one that allows more work to be done over time will be chosen. An explanation of why this happened in this task, may relate to the fact that the bar graph was the default graph and therefore faster for the user to access.

> P3: "The sub-themes and the title of the graph should be standardized! If the subtitle begins with 'teaching methods', the title (of the graph) should not begin with the 'number of courses'."

Tasks 2.8 and 2.9 will be analyzed as a group task. **Task 2.8 - Generate a graph for the region 'North', for the 'School year 2011/2012', on the theme 'Features and functionality of communication technologies' for the sub-theme 'Spaces and resources'. Task 2.9 - Look at the graph generated in task 2.8, and indicate the total number of respondent institutions of the North region.**

All the participants executed both tasks with success. Three participants gave a similar suggestion regarding the color label of the map of Portugal, to eliminate the green colored label that indicates the Region, because it confused them by creating an expectation that they would find a green circle within the map area.

> P1: "(In the color label below the map) the area of a map is usually represented with rectangles and not circles, otherwise I will be waiting for the green circles to appear here (in the map). The color of the active circle should be green and the other of another color."

> P3: " In the color label the dark green circle makes no sense, people will be waiting to see green dots on the map, as appear the red and grey. Advantage of having the grey circles is that it gives me the impression that this site has a database with all the institutions."

> P5: “the green color label of the map should not exist, because it seems as i tis referring to a green circle in the map”.

Two participants suggested that the names of the HEI in the label should be interactive, allowing the user to click on them and leave the view of aggregated data from all HEI within a region, and enter a view of the data regarding the one institution clicked on. Additionally one participant suggested the integration of a zoom feature, to allow the user to zoom in on a specific region.

> P6: “It would be interesting to have the name of the institutions (in the label) linked, and we could access the institutions data.”

> P2: “You can click in the North (region) and zoom in the region, and have a window of information about active and non-active institutions. Grey circles should not have as much weight as red.”

Comments to task 2.10 - Share the graph generated in task 2.8 in a social network.

This task was executed with correctly by five of the seven. The two participants who did not execute correctly the task, both clicked on the share button on the upper right corner of the webpage rather than clicking on the button ‘share’ situated below the graph area. The participants who executed correctly the task identified this duplication of buttons and all six participants suggested that the button ‘share’ on the upper right corner (which shares the whole page) should be deleted and only be maintained the lower right button situated below the graph (P1, P2, P3, P5, P6, P7) .

> P2: "It is redundant to have the button ‘share’ the graph and ‘share’ the page."

> P5: “Now this page has three facebook buttons, it makes no sense. The button for sharing graph makes sense."

> P6: “The share button should be at the upper right corner of the graph, and you should delete the button to share the entire page."

> P7: “You can delete the buttons that share the page, because they are repeated.”

Task 2.11 - Download the graph generated in task 2.8, in the in excel format.

All the participants executed the task with success, having the overall comments of two participants identified that the file downloaded lacked to have the date of download.

P5: "The value zero (in the excel downloaded) appeared empty."

P6: "The date in which the download was made is missing."

P7: "The date of download is missing."

Global satisfaction of use of the U-TRACER®

After performing all the tasks, the participants were required to answered a question about the overall satisfaction of use of the U-TRACER®, indicating in a scale from 1 (not satisfied) to 5 (very satisfied) (Table 35). The results reveal the diversity of classification of the degree of satisfaction, having most answered between 2 and 4 in the satisfaction scale. The overall use was of satisfaction of use, having two users indicated to be somewhat satisfied, three users quite satisfied and only one very satisfied.

Regarding the satisfaction of interacting with the filters (context, school years, themes), users mostly revealed to be satisfied (three participants) and one indicated to be very satisfied.

The interaction with the graphs, five of the participants indicate their satisfaction to be between scale 1 and 3, which indicates a low satisfaction that can be understood by recalling the comments made during the performance of the tasks that involved interaction with the graphs, as described in the analysis made previously. The satisfaction towards the visual displays of the graphs reveal a higher satisfaction of the participants, of whom five indicated to be quite satisfied.

Table 35. number of participants per global satisfaction item in the use of the U-TRACER®.

	1 (unsatisfied)	2	3	4	5 (very satisfied)
Global use of the Front-office.	0	2	1	3	1
Interaction with the filters "context", "year" e "themes".	0	1	3	2	1
Interaction with graphs.	1	1	3	2	0
Type of graph metaphors.	1	1	0	5	0

4.5.2. Improvements to the U-TRACER® prototype

In this section we present the synthesis of the results of the usability tests, integrating them as improvements to the prototype tested (Table 36).

Table 36. Improvements to the U-TRACER® prototy, result of the usability test.

Interaction features	**Results of the usability test**	**Improvements to the interface**
1.Guide users: how to use, FAQs:	a) "How to use" button must be more visible, and have more extensive instructions. Additionally these instructions could be distributed where needed in the interface.	‣ Create a new tab named 'How to use', on the U-TRACER®s' menu serve the purpose of guiding the user on how to use the tool
2.Filters: HEI; Region; Theme use of CT:	a) Difficulty in accessing the menu tab 'Institutional Perspective'. b) In the context filters, put the word "or" between the boxes "Region" and "Higher Education Institution", to clarify the user about the option of selecting one or another filter. c) In the filter for school years, remove the double slider and put a drop down box menu with a list of years. d) By clicking on the Higher Education Institution filter, the chart area should be adjusted immediately to what will be the final view, eliminating the map of Portugal.	‣ Apply the changes suggested in a): delete the tabs 'Institutional Perspective' and 'Teachers perspective' of the use of CT, and substitute them as filters of information, situated in the left column. ‣ Apply the changes suggested in b), c) and d).
3.Share visualization in social networks:	a) Eliminate the button share on the upper right corner (which shares the whole page), and only maintain the lower right button situated below the graph.	‣ Apply the changes suggested.
4.Download the datasets and the graphs generated:	a) Add to the file downloaded the date of download.	‣ Apply the changes suggested.
5.Contextualize d help:	a) Delete the button: , and place the information as contextualized help within filter "*Perspetiva de institucional*" b) The glossary list of terms should appear as an "accordion" type of list, rather than having the definition of the term appear in a pop-out box that can be dragged and dropped.	‣ Apply the changes suggested in a) as contextualized helps with icons that help the user obtain more information about definitions.
6.Graph:	a) The labels should not have incomplete words b) Color labels for the bar and pie-ring graphs should be the same. c) In non-quantitative graphs delete the numerical values that appear by error. d) In the tooltip of the graph area include the description of the unit of measure. Example: *Tempo integral: 2 docentes.* e) In the map graph, deleted from the label the indication of the name of the region. f) In the label of the map, the names of the HEI	‣ Apply the changes suggested in a), b), c), d), e), f), g) and h).

	in the label should be interactive, which would take the user to the view of the data regarding the institution he clicked on. g) Put the title in the region closest to the map. h) Zoom in on a specific region in the map.	

Most of the improvements were communicated to the company who was developing the tool, to enable them to improve the prototype tested. Within a negotiation process within project TRACER and the company, due to contract limitations, all the improvements were required with the exception of 6f and 6h identified in Table 36. Nevertheless those improvements are maintained as a proposal in this study, for future work on the U-TRACER® tool.

The improvements implemented by the company are presented and marked in Figure 130, and in Figure 131 showing the improvements made to the pie-ring graph. The improvements implemented are the following:

- 1a: Create a new tab named 'How to use', on the U-TRACER®s' menu serve the purpose of guiding the user on how to use the tool.
- 2a: delete the tabs 'Institutional Perspective' and 'Teachers perspective' of the use of CT, and substitute them as filters of information, situated in the left column.
- 4a: Add to the file downloaded the date of download.
- 5a: Delete the button '*Sobre a perspetiva'*, and place the information as contextualized help within filter "*Perspetiva de institucional*".
- 6c: In non-quantitative graphs delete the numerical values that appear by error.
- 6e: In the map graph, deleted from the label the indication of the name of the region.
- 6g: Put the title in the region closest to the map.

Figure 130. U-TRACER® final interface layout: stacked bar graph.

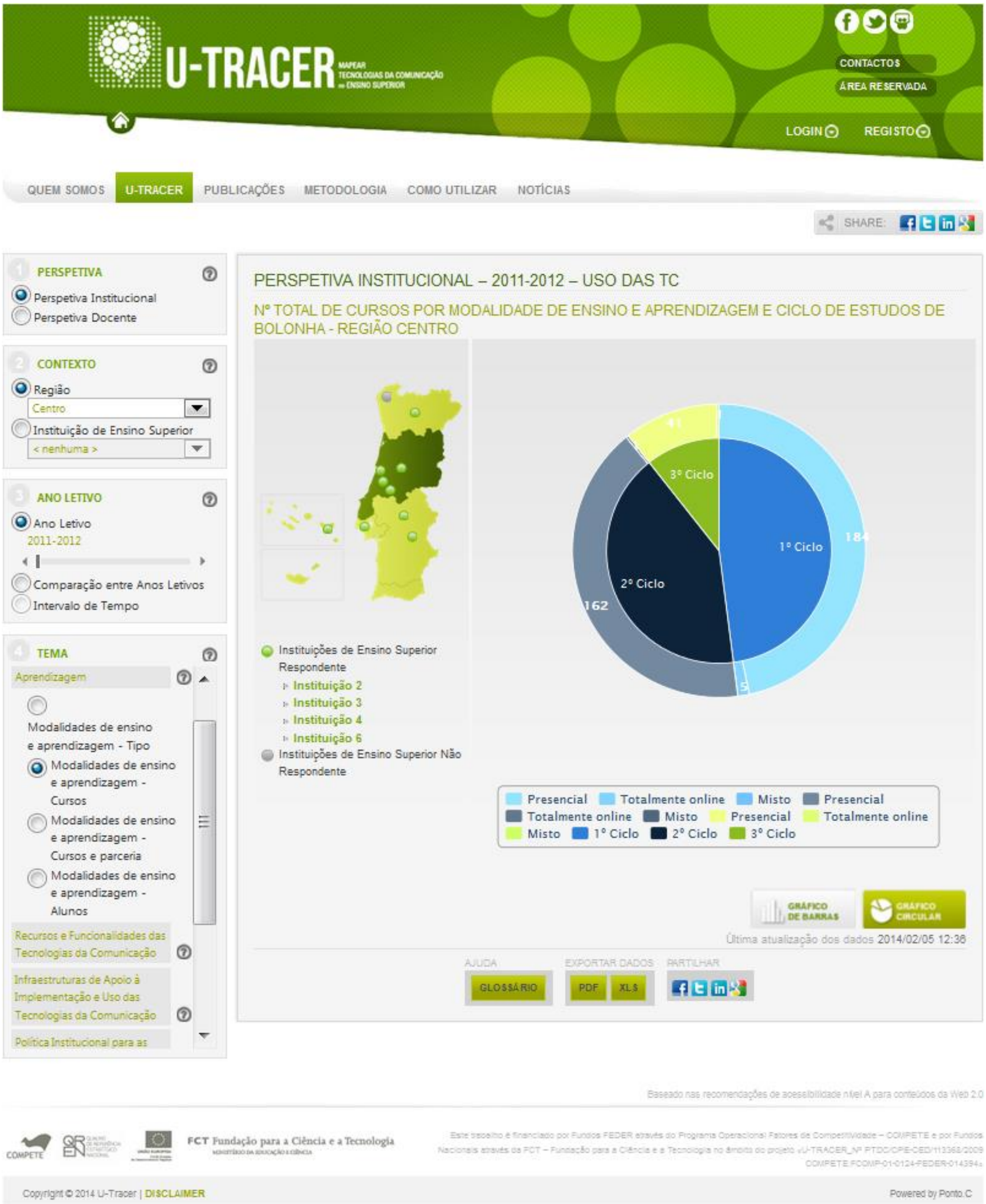

Figure 131. U-TRACER® final interface layout: pie-ring graph.

Chapter 5. Validation of the U-TRACER® tool

"A graphic is never an end in itself: it is a moment in the process of decision making." (Bertin, 1981 *In* Spence, 2007)

5.1. Phase 4 - Validation of the U-TRACER®: Interviewing Higher Education decision makers

In this chapter we present the analysis to the interviews made to 10 HE professionals from 8 of the 9 HEI that provided data to project TRACER, the same data that is represented in the U-TRACER® tool. This will contribute to answer the second research question of this study: What is the perception of decision makers of Portuguese public HE institutions, as to the usefulness of the U-TRACER® tool?

The discussion of the content analysis to the interviews is made by grounding the results with the literature review and the research goals.

Validating the U-TRACER® led us to the concept of usefulness, in the logic that if the tool is useful for its main stakeholders, then its creation and sustainability is validated. The concept of perceived usefulness adopted in this study is defined as the belief that a user of a tool has, that its use will increase his or her job performance within an organizational context (Davis, 1989; Lederer *et al*., 2000; Teoa et al., 1999). The direct effects of perceived usefulness can be a strong motivator for the use of the tool (Teoa *et al*., 1999).

5.1.1. Interviews with Higher Education decision makers

The aim of the interviews was to assess Higher Education decision makers perception of usefulness of the U-TRACER® tool, attempting to predict attitudes towards the use the tool. The importance of gaining this insight is a direct consequence of two main aspects of the U-TRACER®: a tool that feeds on data provided by Higher Education Institutions; a sustainability of the tool that depends on the continuous participation of HEI on providing data, therefore, on the perception of usefulness by the institutions decision makers who have the power to decide the continuity of providing data to feed this tool.

Research indicates that the perceived usefulness may be tested when the person has used the tool (Davis, 1989; Lederer *et al.*, 2000). Initially it was predicted that the U-TRACER® prototype would be complete therefore enabling the HE decision makers to use the tool before the interview. But delays which exceed our control, led us to decide on performing the interviews basing the knowledge of the participants in the interview about the tool, to a demonstration that would be made previous to the interview. Therefore, a demonstration of the U-TRACER® first beta version was shown to the decision makers interviewed, and it was based on that knowledge that they gave shared their opinions and views during the interview. Full transcripts of the interviews can be consulted in Appendix 11 - Full transcripts of the interviews with Higher Education Institution decision makers.

In the initial conversation with the participants in the interview, we questioned about the professional role in the institution, to understand at what decision level they worked.

The first question - Regarding your professional role, in which processes of decision making do you participate in the institution, that involve an institutional adoption of Communication Technologies?

The aim of this question was to understand what types of decisions regarding the institutional adoption of CT the interviewees participated in the institution. This revealed three groups of decision processes: the first, at an institutional decision at the rectory level or presidency level participated 4 interviewees; at the second, institutional decision within other academic structures participates also 4 interviewees; and third with no participation in decision process were 2 interviewees (Table 37).

Table 37. Interviewees role in decision processes regarding institutional adption of CT. (P): Participant in the interview; (n/a): not applicable

Current professional role in the institution	Institutional decision at the rectory or presidency level	Institutional decision within other academic structures	No participation in decision processes
Pro-rector/pro-president	P1, P5, P7	n/a	n/a
Vice president	P3	n/a	n/a
Director of Computer Services	n/a	P2, P4, P6, P8	n/a
Responsible for information systems	n/a	n/a	P10
Chief of Communications office	n/a	n/a	P9

The institutional positions occupied at the rectory or presidency levels are as pro-rector or pro-president, professionals who directly assist the rector or president in specific areas and who have a power to make decisions, while the vice-president is a position of replacing the President in his absence or impediment, who does also has a decision making power. We will categorize these professionals as decision makers.

Detailing the levels at which the decision makers work and decide, the pro-president P1, works mostly at the strategic planning level and is part of the working team for the distance learning technologies. Three other decision makers are more closely dedicated to decisions about the institutional adoption of CT. Pro-rector P5, participates in all processes of institutional adoption of CT “Everything that has to do with the adoption and use of CT passes by me” (P5). Pro-rector P7, described his role as a decision maker who helps to create the necessary conditions to the use of CT, supported by the collaborative work with other members from the academic community. The vice-president (P3), regarding institutional CT adoption, assumes a role of formally deciding all issues related to institutional adoption of CT, as a member of the board of management and substitute the President in the absence or impediment.

The professionals P2, P4, P6 and P8, participate in decisions in other academic structures, and revealed that their role is closer to being supporters of decision makers. The three interviewees are directors of Computer Services, and were consensual in describing the type of support they provide to the decision makers at the rectory or presidency levels: mainly providing reports and assessments regarding the software or hardware to support strategies of the institution regarding CT, for academic management processes, or communication components, or pedagogical applications.

> P2: "We propose, but the decision is always made by the president or to whom his powers are delegated. Regarding the e-learning area we propose the use of a particular type of technology or application, but who decides is at the central level."

> P8: “I would say that in general all activities that university develops that directly or indirectly have to do with technology always has our assessment, and in many cases our direct intervention.”

Two additional interviews were done to two professionals of one HEI, nevertheless both professionals to whom was delegated this interview by an institutional decision maker, revealed to have no participation either in processes of decision or support decisions (P9, P10). One was a Chief of Communications office professional who had coordinated all the data gathered to be provided to the TRACER project, and the other is a professional responsible for information systems who also participated in the data collection. Consequently, we have decided not to include in this analysis the interviews made to P9 and P10, maintaining our focus on the perception of decision makers.

Second question - In your opinion, what usefulness is there in the information about the use of CT in the Portuguese Public Higher Education Institutions, collected by project TRACER, and presented in U-TRACER®?

All of the decision makers (P1, P3, P5, P7) and the supporters to decision makers (P2, P4, P8) with one exception (P6), agreed that the information was useful mainly for the purpose of comparing their institutions data with the other institutions. The answers correlated the usefulness of the information and the usefulness of its presentation in a tool such as the U-TRACER®.

The decision makers focused the usefulness mostly towards the analysis of national trends of CT use, the comparative analysis with other institutions' data to position their institution in the HE market, and also for benchmarking and communication of institutional results.

> P7: "(…) benchmarking is something important, as I said before starting the interview, the first thing I did when it was delivered (first report of the survey results from project TRACER), was trying to understand the institutions with which we like to do benchmarking, those who I see as competing in the same league of our university, and went looking for them to make comparisons, I wanted to know how is our position regarding some of the questions that were put there (survey instrument)."

This collective openness to comparison of data between institutions may not be surprising because of the wide dissemination and acceptance, for example, of university world rankings. Nevertheless rankings are also surrounded by criticism and manifested concerns, mainly regarding their methodological foundations and the impact they might have on institutions that do not reach high positions, or that are not included in the rankings. Also in the U-Map tool report HEI stakeholders who participated in the pilot study, mentioned the same concerns regarding the methodological grounds of data collection and analysis, although considering comparison between HEI as essential (van Vught *et al.*, 2010). Also there was the perception that the U-TRACER® would contribute to make information available, more visible and better communicated about the diversity of institutional profiles, and for benchmarking exercises, which overlaps with the opinion expressed by U-Maps stakeholders (van Vught *et al.*, 2010).

The following questions of the interview, third and fourth, inquired about the information visualization features of the tool, attempting to understand the acceptance and usefulness of its overall features.

Third question - The tool allows you to interact with information through the selection of macro filters (analysis by region, institution, school year, dimensions). Which advantages and disadvantages do you identify?

All the interviewees stated to be satisfied with the filters of information offered in the U-TRACER®, previously demonstrated to them, seeing those filters as an advantage to the comparison between institutions at different levels, and also as a support to the institutions management and decision making needs.

For two decision makers (P5, P7) the geographical filter does not have interest. P7 justifies that HEI are not organized by territory, making this filter less interesting. This pro-rector suggested that another filter be added, one that would allow any institution to be compared with the national average and with the top two or three institutions, or lowest two or three institutions regarding any specific field of use of CT.

> P7: "(…) what interests me most is the national aggregate, to compare how I am against the national aggregate, and then one thing I have not seen here but you can do is to take the average of the top two or top three (institutions) so I can compare with my institution, or the average of the negative top two or top three (institutions). This is to have the entire medium, but after having that on average have better good practice, and the average of those who are lagging behind in the process.
>
> Researcher: Identifying the best institutions or knowing the average without being identified would be sufficient?
>
> P7: Just the average. In the background I do not need to know who are the best (institutions), I need to know what the best are doing at the moment so I know which way I have to go."

Given the fact that institutions are not organized according to the region they belong to, as was mentioned by interviewees, positioning their institution in the market of HE gaining insight into how other HEI are using CT and comparing with them, was seen as an asset of the participation in the U-TRACER®. Nevertheless, as P1, P7 and P8 state, the interest in the comparison is mostly towards HEI with similar dimensions, rather than belonging to the same region.

The fourth question of the interview: What advantages and disadvantages do you see in having graphical representations of the information in U-TRACER®?

All the interviewees considered the graphical display of the data to be an asset of U-TRACER®, making it faster and easier to understand the numbers in a time when information overloads, mainly because it also allows the user of the tool to download the dataset for a more detailed analysis and also consult the full report of the data analysis. Participant 6, a director of a computer service and who supports decision makers regarding the adoption of CT, revealed that the graphical features help translate the data into information which can be very important for a decision maker that needs to analyse and make a strategic decisions.

Decision makers P5 and P6, both emphasized to be satisfied with the visual display of the information, but which in itself is only a summary underlining the additional importance enabled by the download of the dataset and access to the full report of the data analysis, to deepen their analysis.

A common aspect of visualizations is that the viewer creates in his mind an understanding or an interpretation of something, easier and faster (Spence, 2007), but such as the participants mentioned, when the interest it to deepen the analysis of the data it is relevant to have access to other information. This need to access more details of data that generate the graphs for a deeper analysis of the data, was referred by decision makers.

The fifth question - What concerns do you have regarding the U- TRACER?

The feeling of concern regarding the U-TRACER® was not an issue for all participants. Two decision makers and one professional that gives support to decision makers, stated to have no concerns whatsoever about the tool or their institutions participation (P3, P4, P5). Nevertheless the remaining professionals all manifested concerns related to three aspects: first, the confidentiality of the data (P1, P7); second, the sustainability of the data collection (P2, P1); and third, relating to the methodological grounds for the data collection (P2, P6, P7, P8).

The concern regarding the confidentiality of the data relates to the fact that at the time of this interview the name of the institutions were coded, being impossible for any user of U-TRACER® to relate the datasets visualized in the tool with the HEI to which they belonged. But the participants were informed that in a more advanced stage of the tool, that the aim of project TRACER was to make the names of the institutions public in the U-TRACER®. Two decision makers (P1, P7) were aware of this, but were of the opinion that the names should be maintained coded and confidential. P1 justified that HEI have diverse contexts, dimensions, financing or know how that may not be comparable. In a setting where all institutions are competitors, it would be preferred to be cautious and also not to risk the willingness HEI had in providing data:

> P1: “At this early stage it might be wise, because we are talking about an initial tool, and I putting myself on your side who want this tool to be powered as possible, perhaps this issue of reservation and anonymity is an asset in this phase.”

P1 and P7 were concerned that the information about the institutions use of CT could be misused, and P7 explained that in previous situations journalists had made a misuse of information about the institution, and it had media impact, therefore in the U-TRACER® it would be better to maintain anonymity of the institutions.

A linked concern related to the methodological grounds of the data collection, as P2, P6, P7, P8 stated to be concerned about the guarantee that the data provided by HEI is correct. This concern is consistent with the concern expressed by interviews to HE stakeholders for the development of tools U-Map and U-Multirank.

Additionally two people mentioned having concerns about the sustainability of the U-TRACER® because it can be difficult to keep institutions interest and effort in the continuous data collection (P1). This can be a very relevant because as identified in the U-Map tool report, HEI are many times “serious survey fatigue” as result of the administrative burden to respond to information requests (van Vught *et al*., 2010, p. 32). An additional concern mentioned by P2 related to the dependence of this tool on public funding, because the tool is an outcome of a funded project, and when the funding reaches its end the tool will reach its end too.

> P2: “(…) while the project is funded it will show some kind of results, and when the funding ends I have seen that typically it (U-TRACER®) closes too. And if there is some dependence of the institution (funded) for the continuous collection of information, it is a window of opportunity of accessing that information that closes”.

Sixth question - What advantages and disadvantages do you consider there is for your institution to have a profile in the U-TRACER®?

The participants all considered existing only advantages in their institutions participation with a public profile in the U-TRACER®. Because this question ultimately seeks to understand the acceptance of the tool trough the perception of its usefulness, we will detail the opinion of every person.

Decision maker P1 (pro-president), stated that it is an advantage to have an institutional profile in the U-TRACER® because it helps the institution to understand where they are positioned at a national level, regarding the use of CT, and assist them in gaining knowledge about how other HEI use of CT.

Decision maker P3 (vice-president), believes it is an advantage and stated that in the institution they are supporters of transparency.

Decision maker P5 (pro-rector), sees advantage in making their institutions performance, known to other institutions.

Decision maker P7 (pro-rector), sees as an advantage to have a profile of the institution in U-TRACER® because it is useful for those who within the institution have to make decisions and for scholars with work related to the field of use of CT for institutional and pedagogical support in HE.

We can conclude that decision makers perceive two advantages: one more strategic regarding the having a profile of the institution in U-TRACER® to access information about other HEI and make known the institutions work; and the other is to support decision making and research.

The set of professionals who in their work support decision makers, say it is an advantage to support management and decision making (P6, P8), and also to have an institutional presence to share their institutions information and access the other institutions information (P2, P4). Giving information to receive information. P4 added that there is also an advantage for students who want to look into how the institution is using CT.

Seventh and eighth questions - Will the U- TRACER be useful to you as a decision maker? Do you plan to use the U-TRACER®?

The perceived usefulness according to the definition adopted by Lederer et al (2000, p. 270) is "(…) the degree to which a person believes that a particular information system would enhance his or her job performance (i.e., by reducing the time to accomplish a task or providing timely information)."

For two participants (P5, P7), the U-TRACER® will not be useful as a tool to support their work. Nevertheless, for P5 (pro-rector) the tool will not be useful to support processes of decision making regarding the adoption of CT in the institution, but will be used to obtain information for primary activities, to compare the institution with other institutions, and to gain knowledge about how other institutions use of CT.

For P7 (pro-rector), the tool will be useful for research and development, mainly when it aggregates temporal data for more school years and an over-time analysis can be made. The fact that the full report of the data collection methodology and analysis is made available to the users of the U-TRACER® seems a good solution for this decision maker to access the information needed to deepen the understanding of the data being visualized. Therefore the usefulness of the tool is towards information for primary activities for the institution is its position in the HE market to make known where the institution is regarding CT use in comparison with others, and to obtain information on how other HEI are using CT.

Coincidently all interviewees with professional roles as supporters of decision makers (P2,P4,P6 and P8) stated that the tool may be useful to obtain information for support activities, supporting information requests and also to justify to the management and decision makers the options made towards the adoption of a certain CT. The justification lies in the aggregation of information about their own institution as well as other institutions, which is usually disperse.

The decision makers P1, P3 and P7 agreed that the tool will have an important impact in revealing some activities useful for the academic community.

> P3: "I believe it will be useful, to me, to schools, to presidents, students, research projects. I'm sure of it. To have the systematization of data."

P7 goes further in expressing that the interest of the U-TRACER® is for scholars and academic decision makers, rather than for the general public.

P7: "I see no interest (in the U-TRACER®) for the general public. (…) I see this for scholars in the field, decision makers in the field, people who have to make decisions at departmental and units' level."

5.1.2. Synthesis

Synthesizing the analysis of the interviews to 8 higher education decision makers, four of which decision makers at the rectory or presidency level, and four decision makers of other academic structures, enabled us to answer the second research question and reach a deeper understanding accomplishing the research goals:

1. Understand the possible relation between the use of the information visualization tool, by decision makers, and the support to decision making processes.
2. Understand the usefulness decision makers see in having data of their higher education institution represented in the tool.
3. Understand what are the advantages, disadvantages and main concerns decision makers identify about the tool.

Table 38 systematizes the categories of analysis and confirmed indicators result of the interview analysis presented in the previous section, showing two clear things: the first is that there were no disadvantages indicated; and the second is the largely perceived usefulness and advantages of the U-TRACER® tool for these decision makers.

Table 38. Categories and indicators for the concept acceptance of the U-TRACER®. (+) new categories added as result of the analysis

Category	Indicator	Participants who confirmed the indicator
Perceived usefulness	Information for support activities	P2, P4, P5, P6, P8
	Information for research and development	P1, P3, P7
Advantages	Inform decision makers (Query and information retrieval)	P6, P7, P8
	Customization tool	P1, P2, P4, P5, P6, P8
	Comparable information on other HEI	P1, P2, P3, P4, P5, P7, P8
Concerns	Data: Methodological ground/collection of data	P2, P6, P7, P8
	(+) Confidentiality regarding the names of the institutions	P1, P7
	(+) Sustainability of the tool	P1, P2

The perceived usefulness focused mainly on two types of activities:

- Information for support activities such as: I will use this site for information about my institutions' competitors; I will use this site for profile information about my institution; I will use this site for communicating information about my institution.
- Information for research and development such as: scholars, teachers and can use this site for research and development information.

The advantages focused on retrieval of information considered an asset to inform decision makers and to compare their institutions information with other institutions information on the use of CT. Although it was perceived that the information would not be used to support decision making processes. Comparison between institutions was largely seen as an advantage of the U-TRACER®, because having comparable data regarding this universe of institutions and theme is a novelty and considered useful by the decision makers and the professionals who support them.

The fact that it was perceived that the tool would contribute with information for research and development, above all because of existence of the existence of comparable data on higher education institutions, but also because the tool allows for information to be customized, enabling the user to search for information about a specific interest.

Regarding the concerns about this tool, two decision makers expressed concerns over the confidentiality of the names of the institutions in the public profile of the tool. During the demonstration of the tool, the names of the institutions were given a number to code the name, but all interviewees were informed that in the final prototype of the tool the names of the institutions would be revealed. But these concerns took mainly two directions: the sustainability and possible misuses. The first, was set by a decision maker who brought awareness to the fact that the lack of confidentiality could lead to be felt as a possible threat towards the institutions. This could affect their willingness to sustain the tool by continuously providing up-to-date data. Another perspective on the sustainability issue was manifested, related to the fact that the U-TRACER® results as the outcome of a funded project with the duration of three years, ending in 2014, which threatened the sustainability of the tool.

The second type of concern focused on the possibility of the information being misused by users of the tool, mainly by social media. The decision maker who shared this concern stressed that this situation had happened before with institutional data provided his HEI. Therefore, considering the need for ponderation when it comes to his decision to provide data about the institution, and also ponderation needed by those, such as U-TRACER®, who will treat and disseminate the data.

Regarding the goal towards understand the possible relation between the use of the information visualization tool U-TRACER® by Higher Education decision makers, and its use to support decision making processes, it was not possible to establish that relation. The infovis features were seen as an asset of the tool, but to support decision process it was consensus that a decision maker would need deeper access to the data and the data analysis methods.

Chapter 6. Conclusions and future research

The growing number of information visualization tools regarding data representing Higher Education institutions reflects the potential use of infovis for this particular field. Ranking systems such as Times Higher Education rankings, existing since 2004, have recently added information visualization features to the international ranking presentation offered, to the institutional profile card and to the card of comparison between institutions. More recently, pioneering European projects (2008 to 2011) aimed to create qualitative profiles of Higher education institutions through a classification tool, the U-MAP, and a multi-dimensional university ranking the U-Multirank, which integrated information visualization as the main features focusing on the users experience of interaction with the information, adding to that the possibility of the user to customize their own ranking table according to specific interests. The impact of ranking results on HEI give rise to reactions frequently related to concerns over methodological ground of the data collection that support the rankings and consequently the comparison between higher education institutions. This makes it crucial for newcomers such as U-TRACER® tool, that propose to collect data from and about higher education institutions and disseminate that data in an online tool, to involve the HE stakeholders in the design process, and to understand their perceived usefulness of the tool. A deep understanding about the main stakeholders' expectations and acceptance of this type of tool is even more important because all the data that feeds the tool is collected and validated together with the institutions, deciding at all times if they are willing to continue to provide their data.

This study makes two main contributions: the first contribution is to involve HE stakeholders in the design process of the tool; and the second contribution is towards the acceptance of the tool by higher education decision makers, understanding their perception of usefulness of the tool, and being able to predict the future needs for the sustainability of the tool and necessary outcomes needed to guarantee the continuous involvement of these partners.

6.1. Significance and limitations of the study

The final prototype of the U-TRACER® tool reflects a process of involvement of Higher Education stakeholders in the design process (professors, researchers, PhD students, decision makers), to approach and correspond to their needs. The different versions and improvements proposed to the prototype of the tool were almost fully developed, resulting in a functional tool that can be used by the participants in this study and all interested about the use of CT to support teaching and learning in HE. It was possible to make a demonstration of the tool at the conference organized by project TRACER in February of 2014.

We position this tool within the group of transparency tools that assist Higher Education in grasping the advantage of transparency and competitiveness for benchmarking practices and comparing strengths through comparable data of other institutions (Proteasa, 2010). In the European context, the European Union (EU) and European Commission (EC) has supported the development of transparency instruments, within which are tools similar to U-TRACER® that help HE systems and institutions identify and compare their strengths (EHEA, 2012; ENQA, 2011; EUROASHE, 2012). Also, as the Lisbon Declaration recognizes, the evolution of universities from elite to mass systems of HE implies diversity of institutional profiles, missions and strengths (EUA, 2007), and transparency tools assist this knowledge of diversity. For this study we deepened knowledge of existing tools such as U-Map, U-Multirank and University Autonomy in Europe comparing their infovis features and understanding their development process to obtain inputs for the conceptualization process of the U-TRACER®.

To find the most adequate graphical displays to represent quantitative dataset with one and more dimensions and non-quantitative dataset was a challenge. This characteristic of the data is not found in ranking tools or transparency tools for HE, we have described in chapter 2. The type of data is only quantitative and scores clearly determined in order to enable comparison of indicators between institutions. Constraints and difficulties in the development of the matrix chart and the color grid graph (for non-quantitative data) revealed that the developments of different visual displays in an online demo, is a time and costly process, which can impose the adoption of existing solutions. The test results to the reading effectiveness of the graphs did not have evident graph preference results. The difficulty reading non-quantitative data in a same type of graph used to represent quantitative data was not effective for the participants in the test. This difficulty was again demonstrated after the usability test performed to the U-TRACER® prototype, where participants indicated to have low satisfaction with the interaction with the graphs, although indicating to be satisfied with the type of graphical metaphors (stacked bar graph, pie-ring graph), and proposing eight different improvements to the graphs of which included the correction to bar graphs that were adapted to represent non-quantitative datasets. The dataset we were working with demands both from the information designer and the reader of the graph careful attention in helping the reader understand and read correctly the information.

Regarding the interaction patterns, proposed in this study and tested with users, it was possible to implement diverse interaction tasks to search, select and share information, as well as share and download the outputs of the graphs created by the user. These features were positively assessed by the usability testers. These are also innovative features when compared to the infovis tools such as U-Map, U-Multirank or the Times Higher Education World University Rankings, which do not allow the user to share or export the visualization and dataset created as a result of their interaction with the filters of information. U-TRACER® takes advantage of the knowledge transfer both via social web allowing the user to share and allowing the user download the datasets. The online version of the tool can be consulted at http://tracer.web.ua.pt/frontoffice/.

Nevertheless, developing a study with the nature proposed involves a set of limitations that have to be taken into consideration. External constraints are mainly related to the tight calendar between the work of this study with an explorative academic nature, the calendar of project TRACER timeframe and budget limitations, and the company. This required a rigorous understanding of the needs of all involved in the development of the U-TRACER®. The main limitations identified relate to the difficulty of implementation of all the interaction features, and mainly of the visual displays proposed.

One other limitation between the calendar of this study and of the other parties involved, relates to the implementation of the focus group sessions before the data collection was finished within project TRACER, having lead us to focus the sessions on the interaction features and not include discussion about possible the visual display to represent the dataset. At the time we did not show the participants the questionnaire of data collection, which placed focus group 2 in a disadvantage comparing to the focus group 1 who were aware of the content of the questionnaire because they were part of the TRACER team.

The divergence of calendar required that phase four of this study, the interviews made to HE decision makers, to be anticipated to a time when we only had the first prototype of U-TRACER®, which made it impossible for the interviewees to access and explore the tool freely before the interview. Nevertheless a detailed demonstration of the tool was made. The second version of the prototype was delivered in early February of 2014, which also left us without time to add to this research the final assessment of the tool by the HE decision makers.

In fact this became to be understood as a limitation, although through another lens this dependence could also be seen as an advantage, meaning that this study went beyond testing with prototypes, and was effectively developed into a fully functional online tool, tested and used by end-users.

6.2. Main conclusions

Recalling the research goals and questions raised, we evidence those that have been achieved.

For the research goals for question 1 ‘What information visualization proposal is most adequate to represent the dataset concerning CT use in Portuguese public HE institutions?’ we were able to reach fully three of the four research goals:

We have attempted a deep understanding of how information visualization is being used to represent data concerning of Higher Education institutions, focusing on the tools that have more impact in HE, rankings and transparency tools, some of which work in close collaboration with HEI to obtain and validate the data that is subsequently disseminated data through those tools. We identified a use of infovis features in ranking tools that have existed for almost ten years, and to a greater use in more recent tools that invest more on the graphical display of the data – such as the case of the European transparency tools.

The concept of information visualization, its history and trends were deeply studied, involving tour knowledge of a field were open infovis tools are emerging, allowing almost anyone to upload a dataset and explore it by creating graphs. We integrated the trend of open creation of visual displays of data to approach a proposal for the visual display regarding the dataset about the use of communication technologies in Portuguese public HEI. This was part of the process of conceptualization of the U-TRACER® tool, which also integrated the interaction features of the information visualization, designed with the collaboration of HE stakeholders. The interaction features were theoretically grounded and accomplished with a high level of satisfaction as indicated by the participants in the usability test. We were able to obtain a full prototype proposal, which was fully developed and which will be made available for anyone to access online at http://tracer.web.ua.pt/frontoffice/.

One of the final goals that we achieved was to identifying, describe and make a general critical reflection about how information visualization was being used to represent data about the context of the HE although we could have deepened the critical reflection about its challenges and implications for institutions. Looking back at all the work developed and literature reviewed we believe that the challenges of infovis use to represent data from any context brings great contributions to a more accessible understanding of the data, easier for a greater number of such big range stakeholders to understand. We also realized that combined with infovis should be the access to detailed reports of the data, to satisfy the need of different depths of analysis of the data.

The research goals for question 2, ‘What is the perception of decision makers of Portuguese public HE institutions, as to the usefulness of the U-TRACER® tool?’, we accomplished all four goals. We understood that a tool with or without infovis features is will only be used to support to decision making processes if it is built initially as a decision support system. Even so it was possible to establish the relation between the use of the information visualization tool and the usefulness the decision makers see for the tool, mainly a relation of quick access to an information output that could be useful to support for activities. The main advantages were identified as the benchmarking exercises, making information about their institution available and accessing information of other institutions. Having an institutional profile in U-TRACER®, decision makers were clear in stating that comparing their institutions data with other institutions was a great advantage of the tool, to which they added the fact that the tool allows them to customize the information accessed enhancing the query and information retrieval.

However the decision makers also identified concerns about the tool, being the most common concern the methodological ground of the data collection, mirroring the concern identified for the ranking and transparency tools aforementioned. Two other concerns related to the confidentiality regarding the names of the institutions which at the prototype phase were coded but that institutions new they would be revealed in the final version of the tool. Finally the concern related to sustainability of the tool.

The final research goal that was to critically analyse the acceptance of information visualization tools within the European context of higher education, was partially accomplished, but that could have been more deeply discussed in a unique section of the state of the art.

6.3. Future research

For future research we would like to focus on deepening the understanding of the information needed by national and international HEI, regarding the CT use to support teaching and learning practices, policies and strategies. Additionally if the information needed could lead institutions show interest in providing their data, to be presented in an infovis tool for public consultation, facilitating access and connection between the information and those who have interest in it. It would also be challenging to understand at an international level, the acceptance of a tool like U-TRACER® and its upgrade into a tool that helps identify institutions who could be partners in future projects, due to their proximity, complementarity or difference in characteristics regarding the use of CT to support pedagogical practices.

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APPENDIX - Contents enclosed in CD-ROM