# Building Sophisticated Infographics as Effective Knowledge Visualization and Knowledge Sharing Tool

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**Abstract**: Proper presentation of both numeric and descriptive data from various scientific sources becomes increasingly important as good visualization models can promote knowledge sharing, improve understanding of complex processes and enhance scientific communication. Thus researchers' skills and competences for knowledge visualization should be developed and improved both from theoretical and instrumental perspective.

The present chapter aims to explore the models and functions of infographics as effective tools for knowledge visualization. First, there are explored theoretical findings behind knowledge visualization process and infographics. Then a theoretical model for building effective infographics is proposed, discussing the steps and the layers of knowledge abstraction. Finally there is made a comparative analysis of several popular Internet tools, underlying their advantages and disadvantages for scientific knowledge visualization. The conclusion section proposes new insights about theoretical and practical aspects of building complex models for knowledge visualization and knowledge sharing.

**Keywords**: infographics, Science Communication, Knowledge Visualization, Knowledge Sharing.

## Introduction

Since the first symbols and coding systems, the instruments for visualization aim to improve the transfer of knowledge and communication processes, overcoming the limitations of time and space. Technologies enhance substantially the way people acquire and share new knowledge and information. Today there exist many different methods for visual transferring of knowledge and information, including textual and numeric systems (letters and numbers, glyphs, hieroglyphs, data and codes, symbols), pictures and graphic systems (as photos, pictograms, schemes, diagrams, tables, 3D models, graphs, maps) and multimedia systems (as video, animations, complex simulations, films, games and virtual models, data streams, interactive dashboards, and other complex graphic solutions). With implementation of new information technologies and the progressive accumulation of large volume of data (Big data processing) it becomes increasingly important to adopt more sophisticated methods and models to visualize complex systems and interdependences. More than ever, visualization becomes an important element of scientists' daily work [1]. Scientists can create visual models for various purposes including among others - to validate experiments, to explore datasets, to communicate findings and to improve knowledge retention and knowledge re-use. If appropriately presented, scientific visualizations can be highly effective communication tools expanding both the impact and the meaning of the message to a larger public. As a good example stands the illustration of black holes in the movie *Interstellar (2014),* as even if it provoked many discussions among researchers in the field of astrophysics [2] it's a successful and detailed visualization of a real scientific model, allowing lay public to understand and to get first impressions of these specific space phenomena. This example comes to show that knowledge visualization is a challenging task as it is a crossing point of many disciplines – information design, visual design, data visualization and data analysis, scientific visualization models, media literacy, computer visualization models, visual effects and IT competences, storytelling and many others. Furthermore, knowledge visualization per se can become a source of art inspiration, citing here for example the short film "Seduction" [3], based on the exploration of Mandelbrot set and the fractal geometry. Thus preparation of sophisticated knowledge visualization models often extends the scope of science communication and become a form of art. So often it's necessary to bring the expertise of different professionals and teams, sometimes exceeding the possibilities and the budget of a single researcher or even research organization. However, new technologies can help substantially to extend the researchers' competences to prepare good visualizations. That's why mastering suitable visualization methods, models and instruments should be encouraged as an important science communication competence.

While today new technologies extend the possibilities to create sophisticated, animated, 3-dimensional and interactive models, merging augmented reality and virtual objects with science models and big data analysis, the main objective behind knowledge visualization is to improve human understanding. Thus, there exist many arguments for choosing either dynamic or static models of knowledge visualization. Different studies show, that dynamic and interactive models are not always outperforming the static models as sometimes it's necessary to provide time for the target audience to get into details, to understand and to digest information [4]. Therefore to increase visual persuasion and complex model thinking, much more important is to explore the co-creation models, involving end-users in the process of activation and combination of different types and sources of knowledge (datasets), exploiting various instruments, visual metaphors, stories and storytelling (activating memory hooks) and others. Assuming the limited capacity of the human brain to understand easily textual information and to decode raw data and computer generated records, visual graphic systems give many advantages for visualizing complex processes.
In the present chapter we will analyze infographics as effective knowledge transfer and knowledge sharing tool. Infographics improve knowledge visualization, illustrate complex relationships between different data sources and dynamic computer-generated records and facilitate information comprehension, knowledge acquisition and learning, adding context and increasing the meaning of data. Even if infographics are well known and widely used, with new technologies and increasing needs for better knowledge visualization they can be further exploited in various scientific and research contexts. Moreover, visual information and proper organization of data sources becomes increasingly important with emergence of big data analysis and Internet of Things technologies. Thus mastering Infographics is set to become a key competence for visual literacy [5].

Infographics can be explored as complex science visualization tools as they combine elements from different research disciplines, combining graphic design, information design, visual communication, data, information and knowledge visualization, knowledge sharing, diagrams building, storytelling and others. Therefore the present chapter aims to provide a detailed overview and analysis of the main concepts and approaches for building complex infographics and to explore better their functions as effective knowledge visualization and knowledge sharing tool. The first part of the chapter will make a short review of the main theoretical concepts behind knowledge visualization, exploring the main problems in the field. Then, infographics will be presented as effective knowledge visualization and storytelling tool, classifying and analyzing different types, potential and capacity to transfer data and knowledge. The third part reviews some of the popular Internet tools for building infographics, and proposes a comparative analysis. Finally there are provided more recommendations and reflections for the contemporary approaches of knowledge visualization in scientific domain.

## Background

The problem with knowledge visualization and knowledge representation becomes especially important in the context of wider use of information technologies and recent advances in big data, sophisticated human-computer interaction models and complex systems analysis. Emergence of interdisciplinary fields of research, bringing together experts in different domains and involving communication in larger research communities, as well as accumulation of data from various digital tools, scientific contexts and environments, create specific needs for better access to knowledge, improved models for knowledge sharing and deeper knowledge understanding. All these trends, along with the daily information overload require new methods for representing knowledge in a way that enhance human brain perception. It is proved by [6] that human mind is able to perceive visual information in a shorter time and in a more efficient and permanent way compared to other written or verbal information. Further, as quoted in [7] different studies estimate that between 50–80 percent of the human brain is dedicated to forms of visual processing, such as vision, visual memory, colors, shapes, movement, patterns, spatial awareness, and image recollection. Recently [8] proved that the human visual system is exquisitely adapted to the task of extracting conceptual information from visual input with every new eye fixation, three or four times a second. This finding supports the statement that visual communication is much stronger and faster than all of the other communication methods. Further, other elements as pattern recognition and context delivery make visual information much more faster tool for transferring information compared to reading numbers, comprehending the math, and then deriving to the relations between data and concepts [9]. Conventionally illustrated text is better for analysis, discussion and study of details [10].

Thus information in graphical media can utilize text, pictures, information graphics, and graphical design in conveying its message [11]. Furthermore, visual information can be more successfully digitalized, stored and shared through various information channels (for example through social networks and different visual media), reaching more people and generating bigger impact. Thus proper use of technologies and interest to improve knowledge visualization and message delivery continue to attract different professionals in the fields as marketing, advertising, teaching, public relations, politics, journalists and others. Therefore, even if visualization is mainly a design activity, it serves as an interface, a filter and a communication tool between the product (the knowledge) and its user [12]. Or from design perspective, visualization is an instrument, a tool that helps to interpret and transfer a meaning of a message (subject of communication) and to illustrate it in a visual language, employing different metaphors and symbols that can be decoded and interpreted by the user (target audience). Therefore our theoretical analysis of the visualization process should include three main perspectives: transferring the meaning of a message, visualization methods and models and cognitive schemata of the end user. That is why, in the following sections we will shortly introduce some of the basic concepts identifying the subject of visualization ("what should be visualized"), the visualization model ("how to visualize"), and finally the cognitive competences of the end-user (knowledge recipient).

## Subject of visualization

The data-information-knowledge-wisdom (DIKW) hierarchy is a popular model for classifying human understanding in the perceptual and cognitive space [13] [14]. Based on the DIKW classification of [15], data can be seen as symbols (records), information stands for meaningful data, put in a context (responding on questions such as *who, what, where, when* etc.), and finally knowledge is application of relevant data and information, responding on questions "*why*" and "*how*". In the context of knowledge management discipline there were provided further definitions of data, information and knowledge, highlighting mainly the complex character of knowledge and extending the understanding of its explicit and tacit form. More importantly, knowledge is largely understood as a human characteristic and thus knowledge sharing and knowledge transfer should be mainly human-oriented (opposed to computer-computer interactions).

Analyzing the DIKW model, it's still difficult to make a clear distinction between the representation models for visualizing data, information and knowledge [16]. First, data visualization refers to the practice of using graphical representation and visual insights in the sets of data. Data Visualization is generally used as umbrella term and it still serves to describe every form of visual representation. It's defined that the basic objective of data visualization is to provide an efficient graphical display for summarize and reason about quantitative information [17]. Thus data visualization is the visualization of numeric values with charts, tables and graphics, or this is the transformation of raw data information to visual presentations. Data visualization may refer to both static and dynamic representations, and its most important quality is that it is based on measurable statistical data.

The term information visualization is restricted to computer-supported visualizations [18]. As such, information visualization is mainly referred to computer-supported visualization and the use of computer-supported, interactive, visual representations of abstract data [19]. It is stated that with information-assisted visualization, the IT system provides the user with a second visualization pipeline, which typically displays the information about the input data set [20]. But it can also present attributes of the visualization process, the properties of the results, or the characteristics of the user's perceptual behaviors.

Finally, knowledge visualization examines the use of visual representation methods that can improve the transfer and the creation of knowledge between at least two persons [21]. Thus, knowledge visualization is admitted to be a creative process that is difficult to formalize [22]. Moreover, knowledge visualization is about transferring the knowledge gap, when it comes to collaboration (from transnational team organization) and cooperation (with different experts), as it reduces data and information complexity and improve common vision about the problems. That is why, knowledge visualization and the use of multimedia is increasingly important part of learning and knowledge acquisition [23].

Furthermore, in the paper of [24], knowledge visualization is discussed as emerging and complex discipline, covering different aspects such as: communication, storytelling, inductive transformation from data to visual space, expression of concepts through meaningful graphical mapping, link between visualization and information overload, crucial knowledge process and others. Thus visualization of knowledge is much more human-oriented approach and aims to improve communication and in particular the human interactions around cognitive processes. Knowledge Visualization and Visual Thinking fabricate the necessary understanding of all knowledge processes because knowledge needs to be "seen". All these perspectives suggest that without successful models and methods for transfer, knowledge is meaningless. So in [25] it's emphasized on the process-driven concept of knowledge visualization, or as they state, the act of visualizing is more important than the image itself: and therefore medium is bigger than the message.

**The process of knowledge visualization**

While methods for data visualization and statistical graphics are well researched, our main interest is to identify tools, methods and instruments for effective visualization of knowledge. In [26]

propose a type of knowledge visualization through concept maps, defining them as graphical tools linking concepts that are connected via specific relationships (propositions). It’s further explored by [27] the interactive knowledge maps that visualize implicit personal and shared knowledge structures of users in different communities and provide multi-perspective access to community information spaces. His model extends the knowledge mapping approach by combining document maps and concept maps and visualizing implicit structures of personal and community knowledge. Knowledge maps are further discussed in Knowledge management literature, mainly as visualization models of explicit and tacit knowledge within organizations [28].
An alternative approach for knowledge visualization is proposed by the technique of storytelling. Storytelling as identified in [29] has the capacity to transfer visually content in a much more active form of simple knowledge representation. More interestingly, [30] explored the role of storytelling in scientific visualization, and provided arguments that it is an important tool when showing findings in complex context. Storytelling features in this case often provide different views of the same data features to make them easier to understand. As stories are sequences of causally-related events, [31] pacing matches the audience’s ability to them, second, they hold the audience’s attention, having interesting settings, plots, characters and others and finally they leave lasting impressions. Thus storytelling approach can enrich a lot science communication and knowledge visualization, improving the capacity of the lay public to observe and understand complex processes and interdependences.

*End-user or target audience*
The main function of knowledge visualization is to enhance the processes of knowledge acquisition and learning. As learning is co-creation activity that requires purposeful efforts and cognitive capacity of the learner (knowledge receiver), it’s important to analyze his role in the knowledge acquisition process. Assuming different learning theories for active (intentional) and passive (observational) learning, end-user should be put in the center of knowledge visualization framework. Therefore, knowledge visualization should facilitate the both learning processes in the co-creation of meaning for the user (or user-centered design) [32]. Thus knowledge visualizations should be considered as problem-solving tools deployed according to their efficiency in a given context and for a specific target public, leading to different kinds of languages, visual metaphors and cultural approaches. From this perspective, knowledge visualization is about deciding what and how to show of a given data set or information based on the context, shared by the end-user. Thus choosing visualization techniques and languages should take in consideration the proposed objectives, target public (end-users) and contexts in which they will be deployed [33].

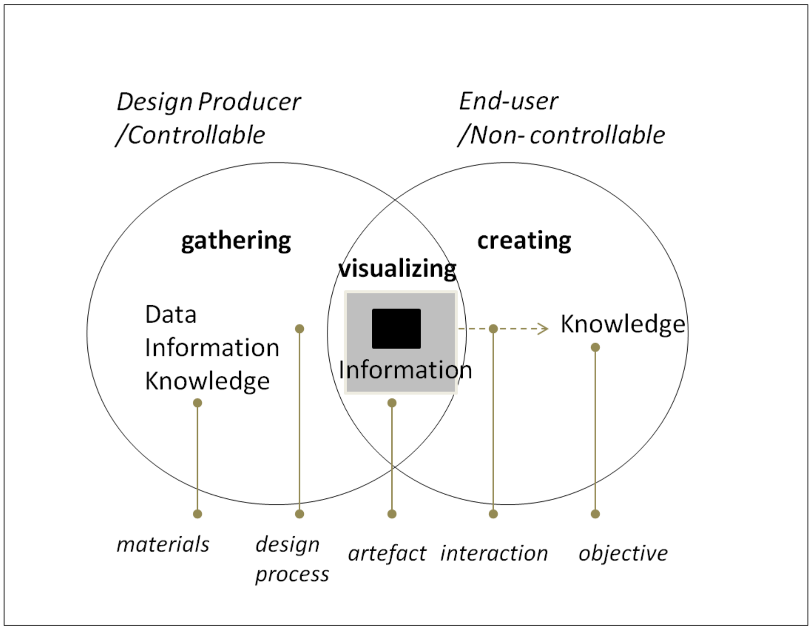


*Figure 1. DIK process of knowledge visualization, based on Masud et al., (2010)*

**Infographics as effective knowledge sharing tool**

*Defining Infographics*

The term "infography" was initially used for information graphics in media context, but now designate larger visual messages tools used to present information. The term is derived from "information design" or infography, designating the process of making visual design of messages [34]. Thus "Information Graphics" refers to the tools and techniques involved in the graphical representation of data, but enriched by infographics' background, including complex visualization, design and the art of telling stories.

Infographic can be defined as a "visualization of data or ideas that tries to convey complex information to an audience in a manner that can be quickly consumed and easily understood" [35]. Infographics are the most memorable visualization type as they contain pictograms, color and high visual densities. In addition to being "the sweet spot where linguistic and nonlinguistic systems converges" [36], infographics enable user (audience, learner) to visualize the big picture of a complex idea or content [37]. That proves the explanatory power of the infographics and its possibility to make complex subject matter apprehensible and intelligible. It's a great example for visually communicating informations to a broad, non-expert audience [38]. The infographics are further used where complex information needs to be explained clearly and quickly, such as in signs, maps, newspapers, technical writing, and education.

For [39] the purpose of infographics is to present intense and complex data content in a regular and perceivable manner. Therefore, the most important feature of infographics is to transform complex and unsystematic masses of information into comprehensible structures by making a story out of it and the most important development in recent years for the infographics is gaining high definition and interactivity features as a result of the technological progress. Infographics present data, information and/or processes related to a certain subject in a story like visual arrangement.

This visual story making may include various elements like image, illustration, typography, map and data visualization. Infographics can be used in different media formats.
The main role of information graphics is to inform (visualize message), but they may be as well entertaining. They aid communication, enable better understanding and comprehension, improve readability and increase retention of stories [40]. Thus, infographics provide the reader with a rapid and easily grasped overall view of a message and are therefore highly suitable as an introduction or as a summary of a subject.  As Wainer (2009) observed: "graphical representation has been shown repeatedly over the past two hundred years to be perhaps the best way to communicate complex technical information to an intelligent, lay audience." According to [41] the goal of the infographic is to represent data in such a way that the intended audience is able to quickly grasp the content primarily by sight. Infographics are a popular visual approach to deliver abstract, complex, and dense messages in small areas [42].

*Origin and use*

As [43] remains, some of the roots of the modern information graphics can be traced in the tradition of making posters and advertisements. These visual forms of communication spring from a past in older times, when pictures and texts were combined into information on circus and theatre posters, and on signs on inns. The oldest posters were created at the end of the 14th century, when printing on paper started in Europe. Leaflets with text and simple pictures were used by booksellers and travelling theatre companies and for political agitation. On the other side, the posters' roots can be traced back to antique Athens, where the City Fathers put up notices with regulations.
On the other side, it is interesting to recall that the first illustrations in manuscripts started to appear in the late Antiquity when codex replaced the scroll, improving the text readability, the separation of words, capital letters, and punctuation, and introducing tables of contents and indices facilitated direct access to information. Thus, knowledge visualization in books became a common practice just in the last few centuries when pictures and illustrations started to enrich the book content and to facilitate text comprehension.
Tracing back the first examples of visualized stories, [44], remain about Charles Minard's famous map of Napoleon's march on Moscow, discussing its role as storytelling visualization. It is a particularly interesting example to study as it depicts the size of Napoleon's army at different stages during the campaign. The graphic is notable for its representation in two dimensions of six types of data: the number of Napoleon's troops; distance; temperature; the latitude and longitude; direction of travel; and location relative to specific dates. In addition to the map, which affords imagining travel, the left-to-right direction is a natural one to follow, making it easy to read for people who are used to that reading direction. The connection with the temperature chart at the bottom also provides a hint as to the causes of the soldiers' deaths [45].

## 1. Infographics as storytelling tool

Among the main characteristics of infographics is that it outperforms data visualization by introducing storytelling and graphic design along numeric data sources  [46]. Thus, infographics combine data visualizations, illustrations, text and images into a comprehensive and complete story. This means that data visualizations are no longer considered to be complete infographics but they are only a part of the story design. Thus lately, infographics transformed to become more active knowledge sharing instruments, aiming to inform (provide data and information), entertain (motivate), and persuade the audience (lead to action, increase co-creation) [47]. By applying appealing visual design, infographics not only transfer information but actively engage readers and

acquire readers' attention (or motivate them to take time and to read the infographics). In the conclusions they set calls for action, so the readers have some indication of what they should do with the information they have just learned [48].
According to [49] a successful test for the efficacy of an infographics could be based on the first-century architect, author, and engineer Marcus Vitruvius Pollios principles of good design. His principles to measure the impact of the design include utility, soundness, and beauty. First ***utility*** refers to whether the infographics meets the researcher's (designer's) objectives or not. Second, ***soundness*** refers to whether the information presented in the infographic is complete, correct, and valuable to the viewer. Finally, ***beauty*** refers to whether or not the design of the infographics is appealing and appropriate to illustrate the research outcomes.

## 2. Infographics' functions

As discovered in the previous paragraphs, infographics functions outperform the pure data visualization. Therefore, the designer (researcher) should identify what should be the main purpose or function of the infographics, based on his objectives and knowledge visualization goals. Furthermore [50] define the following main functions that can be explored in infographics.

- Instruction infographics: with main function to deliver step-by-step schematic visualizations of how a process, algorithm or series of actions is to be performed in several steps, in a practical, simple, quick, and safe way, using symbols and signs.
- Information infographics: with main function to provide specific quantitative and qualitative information, visualizing specific knowledge, context of use and deploying storytelling via various visualization metaphors, exploring important characteristics and others.

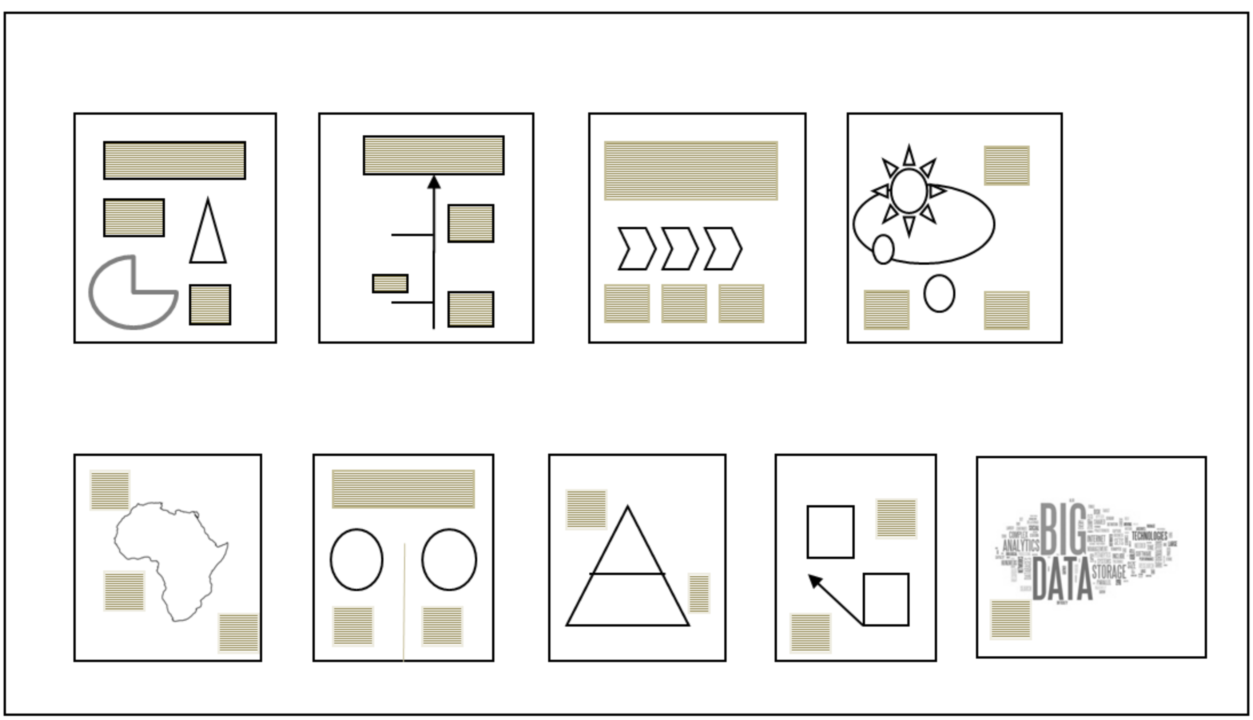

*Figure 2. Types of infographics for information visualization*

More specifically, information infographics can be organized around the following functions and types, empirically found (as shown on Figure 2):

1. **Statistical Infographics**: its main function is to display meaningful statistic data, combining or making a summary or overview of data from various data sources, displaying one or more graphs, tables or lists. For better illustrating data interdependences, statistical infographics often deploy visual pictograms. Statistical infographics can be used successfully for science communication and research visualizations, as they allow visualization of multiple data streams in a coherent style.
2. **Timeline Infographics (time-oriented infographics)**: its main function is to underline the time data sets and time series and to highlight the progress over a specific time period. It can match various data sources and visualize some complex interrelationships providing more intricate details and visual displays (as for example fig. 2 Minard’s map).
3. **Process Infographics**: its main function is to highlight and to illustrate a linear or branching process and to provide a common schema to explore a method, a methodology or a flow chart, or choices in a decision trees. Process infographics can successfully display algorithms, sequence of events, cause and effects diagrams and others.
4. **Informational Infographics**: its main function is to overview the relationships between various concepts and to summarize the related terms. It can be based on a mind maps (knowledge maps) or it can describe a specific item, element or visual model (as for example - plant illustration in botany). Knowledge there can be visualized in a poster form, providing illustrations and putting metaphors for creating appealing storytelling with additional information.
5. **Geographic Infographics:** its main function is to visualize location-based data, contextualizing geographically different data sources or illustrating dynamic processes of movements. Therefore there can be combined different data sources that can be organized on a map. Cartography and making maps are among the first science visualization models.
6. **Compare/Contrast Infographics:** its main function is to provide comparative analysis between elements, processes, models and others. It aims to illustrate and draw attention on similarities or differences as for example: “this versus that”, “before and after”, data attributes and others. This type of infographics can be organized as a table, a list or just as attribute diagram tool.
7. **Hierarchical Infographics:** its main function is to illustrate hierarchical interdependences between elements and sets as organograms, pyramid hierarchy, parts of the whole relationships, various sets interdependences, food chain and others. For example it can successfully visualize charts with levels and others.
8. **Research-based Infographics**: its main function is to visualize original data, derived from research and to analyze it and illustrate it in a different context. It can be similar to the statistical infographics, but is mainly derived from research-obtained data. This type of infographics can be used to compare unlike items with popular sets of data
9. **Interactive Infographics:** its main function is to provide web-based tools and dashboards-like charts that can visually present some simulations based on specific selections of interactive data and their interrelationships. Thus viewers have the control to modify the data sets in the infographics, making visualization more user-oriented. While users have more freedom to explore it reduces the amount of control that visualization designers have over how the story is told. Therefore, the interactivity of visualization should be carefully balanced against the need to guide the viewer through the data. Thus a recommendation can be to start the visualization

in a non-interactive mode, ensuring that the most salient features of the dataset are presented, and then allow users to explore the rest of the dataset afterwards [51].

**10. Word Cloud Infographics:** its main function is to display a cluster of words in order to show associations between words and concepts. It can be used to draw attention on a semantic relationship, as linguistic visualization tool, for text-processing analysis and visualization or just for illustration purposes. Word clouds gain popularity in different online and offline contexts and can enhance knowledge understanding by visualizing textual data (changing words size and underlying specific terms) and deploying storytelling metaphors.

Analyzing further specific roles that infographics can have in science visualization context, there can be described some additional functions for improving knowledge sharing and knowledge communication. In learning context, infographics can create additional channel for improving knowledge sharing in universities and learning institutions. For example, infographics can further improve the illustration capacity of lecturing materials, including research/ lecture presentations, books illustrations, production of visual materials as posters, maps, and classroom displays and others. Furthermore, developing interactive infographics can improve data visualization through electronic books, simulations and e-learning materials and e-learning platforms. Moreover, through visually motivating infographics and storytelling there can be gamified some learning processes and materials and this can further improve knowledge acquisition.

Employing storytelling and appealing infographics schemes can substantially improve science communication in different science events as science fairs, conferences, science exhibitions, science newsletters, research projects disseminations and others. Infographics can successfully visualize as well poster presentations and illustrate data discoveries, further motivating researchers and lay public to get interested in science communication models. Infographics can improve dissemination of science results and communication of research materials.

## 3. The process of building infographics

The process of building successful infographics involves different competences and visualization skills, requiring sometimes a whole team of experts. However, knowledge visualization aims to facilitate mainly knowledge communication and therefore, the researcher/s or the knowledge holders should take the main role. Thus it's important to discover the main goals of the infographics and knowledge visualization and further to define the main communication elements, discussed in the first part of the chapter: what should be the message (knowledge), what should be the content delivery mechanism (story, design and form) and how to address the target audience (knowledge receiver).

### *3.1. Identify infographics objectives and target public "takes-away"*

The first step is about defining the infographics message, function and context. Thus the infographics' designers (knowledge holders) should clearly conceptualize what are the main aims, purposes and functions from science communication perspective. There should be identified as well the "takes-away", or what will be the main knowledge transferred to the target audience, what will be the learning process, the feelings of the public (e.g. amused, surprised, comfortable etc.) and others. It's important to put the target end-user in the center of the message transfer, as he or she will finally co-create the meaning of the message based on his or her previous knowledge, experience, cultural background and cognitive capacity.

### *3.2. Define the story*

The second step consist of defining the story – or designing the delivery mechanism behind the knowledge visualization model. As [52] state, a story is an ordered sequence of steps, with a clearly defined the path through it. Therefore, each element of the story can contain text, images, visualizations, video, or any combination thereof. Moreover, many of the good infographics follow a simple three-part story format: introduction, key message, and conclusion. Thus in order to develop a good story scenario it's good to analyze the types of data available and how they can be visualized (on timeline, on flow chart, relationship/proportion graphs, or others).

*3.3. Resume the data*

Going deeply in the process of storytelling, [53] derive to a working model, based on the journalists work model. Thus, the first stage is to collect information through desktop research, identifying key facts, deriving to main questions and data sources. Then they tie those data together into a story that may look very different, and not directly use any of the source materials (like data collected). Since the goals and tasks during the research phase are different from writing, so are the tools. Some of the material from the research phase, such as pieces of video, might end up in the final story. Most of the source materials only serve the raw material for the written piece. At its best, scientific visualization acts as an extension of our senses, allowing us to perceive and manipulate data at otherwise impossible scales and perspectives.

*3.4. Visual design*

The next stage is to identify the most appropriate visual design for illustrating data sources, the story behind, the trends and the facts that can be visualized. As the good infographics design is about storytelling by combining data design and graphic design, there should be identified proper design models and visualization tools, metaphors and visual elements. When discussing scientific results visualization, it's a good approach to increase usability and reduce resistance by adding humor elements (if appropriate), to build clear and easy to understand data graphics, emphasizing on the most important trends, and visualize easy to follow processes, using pictograms, pictures, photos and other visual elements. The target audience will define the best visualization approach; however, it's good technique to make infographics meaningful for the end-users by motivating their interest and opening questions, rather than providing ready answers.

*3.5. Share and improve the process*

As knowledge visualization aims to further improve knowledge transfer, the next step is to share infographics and to estimate its potential impact. As [54] highlight, knowledge visualization should be considered mainly as a process and not as a final product. Thus the last phase of infographics building has to ensure the analysis of the impact by sharing, communicating, and learning, getting feedback and making conclusions. The final process should ensure knowledge improvements and up-dates.

On figure 3 is displayed the overall process of Infographics building.

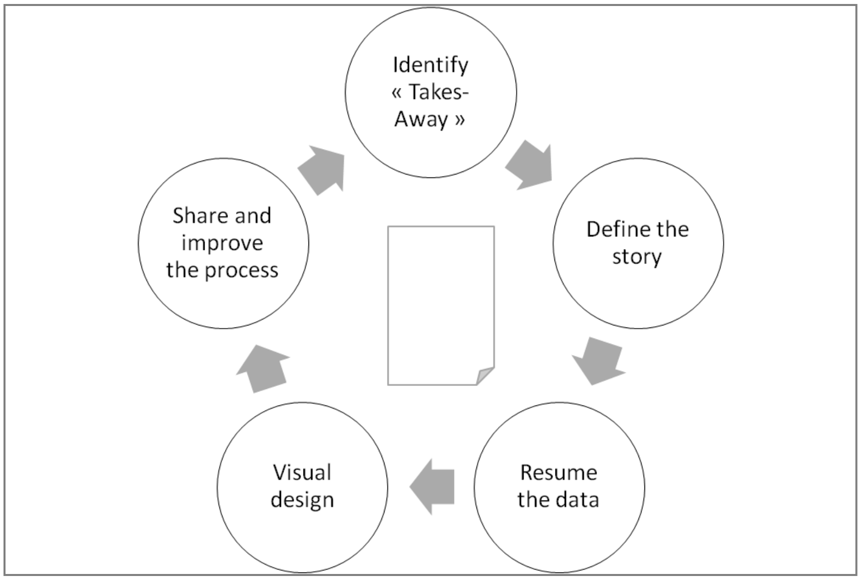

*Figure 3. The process of building infographics*

Summarizing the factors of success, some empirical findings bring the following list behind effective knowledge visualization infographics:

**1. Problem-oriented:** The main goal of an infographics is to answer on a specific question or problem. The graphics should be clear and easy to understand.

**2. Creativity and storytelling:** Original storytelling approach and creative design is what makes the infographics to differ from a simple chart.

**3. Visualization models:** shapes, charts, texts effects and diagrams help visualize the data. The data visualization and knowledge communication should be the main focus of infographics.

**4. Organization:** all data used behind the infographics charts should be relevant, precise and well-organized, following a clear logical flow of images and visual elements. Quote properly all information sources.

**5. Accuracy of data representation,** by avoiding to use sizes and shapes that can skew the relationship and scale of the raw data.

**6. Relevant style,** coherent to the story behind the infographics and appropriate for the context and topic.

**4. Available ICT solutions for building science infographics**

Professional infographics designers rely primarily on a vector graphics software program (such as *Adobe Illustrator®*, *Photoshop®* or other) to create sophisticated infographics designs. First, the main advantage is that all the elements as icons, charts, images, illustrations, and data visualizations are treated as separate objects that can be easily moved, resized, overlapped, and rotated. And second, the expertise of professional designers made it easy for them to operate with complex graphic tools. However, in order to build an infographic it's not necessary to master specific graphic software solution. A proper infographic can be build even using simple presentation program as for example *Microsoft Powerpoint®, Microsoft Visio® or Microsoft Publisher®*. However, due to the increased interest, in the last few years a number of online tools have emerged that allow anyone to create appropriate visual content. All of these programs can be accessed online and are designed for creating infographics that can be downloaded or displayed on a website. Moreover, they offer different tools, as image libraries, charts, fonts and templates that can substantially improve the learning phase. None of these have the full capabilities of a professional desktop application, but serve as a good visualization tools for making simple but well-looking infographic.

Among the most popular online tools for building infographics are identified: Piktochart, Infogr.am, Venngage, Canva, VIDI, Visme, Easel.ly and others. All of these tools are evolving quickly, and this is just a snapshot of their current capabilities. In the following paragraphs are identified some of their main characteristics. The overview of the software tools is based on a summary of data and comparative analysis provided in the blogs of Cool Infographics [55][1], Creative Blog [56][2], Moz [57][3], and others.

- **Piktochart (piktochart.com)**

Piktochart is one of the most recommended infographics programs as it is easy to use, offer many high quality templates, themes and categorized icons, resizable canvas, design-driven charts, interactive maps and even allow video embedding. It has intuitive user interface and can be fast adapted for classroom, office, website, or social media setting. Piktochart can be successfully used for various science communication and knowledge visualization purposes.

- **Vengage (https://venngage.com/)**

Venngage is another highly recognized online tool for infographics creation and publishing. It is simple, intuitive and easy to use. Moreover, it supports storytelling and knowledge visualization through hundreds of free charts, maps, icons and visuals, themes, and others.

- **Canva (canva.com)**

Canva provides number of options for professional and personal projects. Among the benefits of using Canva are the well designed tutorials, many templates for social media, blogs, presentations, posters, business cards, large image library, easy and intuitive to use. Some of the problems include lack of editable chart objects and lack of build-in data visualization tools (as charts and others), inappropriate payment model (per use and not based on subscriptions as the other SaaS models).

- **Visme (visme.co)**

Visme supports knowledge visualization by designing interactive presentations, infographics and other engaging content. It provides templates and big library of free shapes & icons to choose from for making visual content easy to produce. One of the greatest aspects of this service is changing percentages within the charts.

- **Easel.ly (www.easel.ly)**

It's mainly a design program, but provides less variety, just basic design layouts and small library of image assets. New charts feature allows support of some basic editable charts. In general it provides less support, guidance and templates than the other alternatives.

- **Infogr.am (infogr.am)**

Infogr.am supports extensive data visualization charts, including more than 30 different types of charts, data analysis and tools. It can easily visualize data with Infogr.am's built-in spreadsheet, or imported own data with XLS, XLXS and CSV files. There are available educational and Non-profit pricing plans available it supports embedded videos from Youtube and Vimeo. However, it supports only infographics and charts. It supports small selection of infographic templates, lack of image library and download options require paid subscription.

[1] http://www.coolinfographics.com/blog/2014/10/10/5-great-online-tools-for-creating-infographics.html
[2] http://www.creativebloq.com/infographic/tools-2131971
[3] https://moz.com/blog/10-tools-for-creating-infographics-visualizations

## Conclusion

As quoted in [58], in 2010, Sam Loman designed the infographic *Underskin*, mapping eight different systems within the body (digestive, respiratory, arterial, etc) and highlighting the major connection points, using the visualization style of a subway map. The design visualization was unique, and even if the sub-way map design style is well known, it had never been applied to the medical topic before. This brought substantial interest to the *Underskin* and unprecedented popularity to the research subject, sharing infographic on many popular web sites and social networks. This example illustrates successfully that good science infographics can have tremendous impact for knowledge sharing, knowledge communication and knowledge transfer both to professional and to lay target audience.

As the volume of data collected by scientists expands exponentially, the interest towards various data and knowledge visualization models increase substantially. Proper knowledge visualization allows researchers on one side to make observations or detect patterns and on the other side – to improve processes for communicating and sharing knowledge. Thus scientists improve knowledge visualizations models and extend its use for various purposes, as for example, to validate experiments, to explore datasets, or to communicate findings to others. When the intended viewers of the research outcomes as papers, data sets, reports, conference proceedings and other are scientists in the same field the common concepts are easily shared and they need very little persuasion. However, difficulties arise when scientific visualizations are introduced to broader audiences. Then even the best visualizations can be incomprehensible if their concepts are not conformed to the target audience, its culture, previous knowledge and interest. Thus scientific visualization is often designed based on familiarity with the subject matter and does not reflect knowledge sharing principles. The present research addressed the problem of proper knowledge visualization and proved that if appropriately presented, such visualizations can be highly effective in conveying narratives and storytelling. However, scientific storytelling is not a trivial endeavor and thus research community needs to recognize and further strive for improving its competences in the field.

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