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«Teacher and student categorization of graphics into graphical genres»

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Abstract

Visualizations have gained more importance in pedagogical material, in text books and in computer programs. Despite the co-existence of many different types of visualizations or graphical genres, learning research only has taken into account the distinction between text and pictures. This thesis aims at unpacking what, at least in learning research, seems to be one single holistic indivisible category of visualizations. We focused on teachers' and Masters students' thoughts on the existence of different types of visualizations and their presumed function in teaching and learning. Research on graphical representations is mainly focused on students' comprehension of graphical representations. However, there is very little research in extend of teachers' comprehension of graphical representations. In addition, the aspect of teacher training of graphical representations is also relatively ignored.

There are two main parts in this thesis: theoretical and empirical. In theoretical part, we presented the literature on the existence of graphical representations in worldwide curricula. Remarkable works of cartographers who played important rule for the advancement of graphic representations in context of teaching and learning. And finally, classification of different genres of graphical representations was also exhibited. Empirical part on the other hand, based on three studies conducted with in-service teachers and Masters students' about their comprehension of graphical genres.

First study was conducted with in-service teachers from France and Pakistan to investigate their basic understanding of graphical representations. Second and third study explores the Masters' students' categorization of graphical representations. In conclusion, it seems that the teacher training programs lack the training of graphic comprehension. Even in the domain of geography which is considered the major domain about graphics and graphic education, teachers were observed unfamiliar with many graphic genres. Overall, Generic graphical representations (i.e. line graph, pie charts, bar charts, maps and tables etc.) were identified more comfortably. However, classification of hybrid graphical representations (i.e. combination of map and bar graph or other hybrid graphics) was slightly difficult for the participants.

Keywords: Graphic representations, teachers and graphics, classification of graphical representations, card sorting technique, graphic genres.

Résumé

Les graphiques ont pris de plus en plus d'importance dans le matériel pédagogique, les manuels scolaires ou encore les programmes informatiques. Malgré la coexistence de différents types de graphiques ou de genres graphiques, jusqu'à maintenant, les recherches sur l'apprentissage ont seulement pris en compte la distinction entre le texte et l'image. Cette thèse vise à éclaircir ce qui, dans la recherche sur l'apprentissage, semble être une catégorie globale et indivisible : les représentations visuelles. Nous nous sommes concentrées sur ce que pensent des enseignants et des étudiants de Master concernant différents types de représentations visuelles et leurs fonctions présumées dans l'enseignement et l'apprentissage. A l'heure actuelle, la recherche sur les graphiques est principalement axée sur la compréhension des élèves. Il existe très peu de recherches sur la compréhension des graphiques par les enseignants. En outre, la dimension de la formation des enseignants aux graphiques est, elle aussi, relativement ignorée.

La thèse se présente en deux parties : une recherche théorique suivie d'une recherche empirique. La première partie du travail examine la littérature relative aux représentations graphiques dans l'histoire, dans les programmes scolaires à travers le monde ainsi que leur utilisation dans l'enseignement et l'apprentissage. Elle expose également les classifications des différents types de graphiques. La seconde partie de la thèse prend appui sur trois enquêtes menées auprès d'enseignants en activité et d'étudiants de Master en formation. La première investigue la compréhension des graphiques d'enseignants en activité en France et au Pakistan. Les deux autres ont été conduites auprès de futurs enseignants, en utilisant la méthode du tri de carte, afin d'identifier leurs compétences relatives à la catégorisation des différents types de graphiques.

En conclusion, il semble que les programmes de formation des enseignants manquent d'un enseignement à la compréhension graphique. Même en géographie, pourtant considérée comme la discipline des graphiques et de leur enseignement, nous constatons que les enseignants sont peu familiers avec de nombreux genres graphiques. Dans l'ensemble, les graphiques génériques (camemberts, histogrammes, cartes et tableaux, etc.) ont été facilement identifiés par les enseignants alors que la classification des graphiques hybrides s'est révélée plus difficile pour la plupart d'entre eux.

Mot Clé : Graphiques, Enseignants, Classification des graphiques, Technique du tri de carte, Genres graphiques.

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1. Introduction

This chapter is a brief summary about the introduction and importance of graphical representations. The importance of graphical representations in everyday life and learning environments is also discussed. This part ends with a lead towards our research on graphical representations in teaching.

The prominence of the Chinese proverb “a picture is worth a thousand words” shows the importance of graphical representations in a convincing way. Graphical representations can express a large quantity of information in a very concise format. Graphical representations are commonly used in everyday life from a simple cartoon in a daily newspaper to a scientific representation of a molecular structure. Graphical representations have also gained more and more importance in pedagogical material, in text books and in computer programs. Therefore, to today’s children, born in a multimedia world, being able to use graphical representations is as important as using texts, understanding discourse, and manipulating digits.

Although graphical representations are used in every field of life, they do not always fully convey the intended information. A good graphical representation is an amalgamation of good content, context, construction and the absence of any of these three aspects can obstruct the purpose of a graphical representation (Chen, Härdle, & Unwin, 2008). So, despite the fact that data visualization is a flourishing domain, little is known on the efficacy of different types of graphical representations. Multimedia learning research distinguishes text and pictures, or verbal and visual information, and graphical representations fit in the latter category (Schnotz, 2002).

The issue of how to spatially and temporally arrange visual/graphical and verbal/textual information has been much studied. Another example about the use of graphical representations in several professions and domains is Baynes (2008) "*Quick on the Draw exhibition*" about the need and use of graphical representations. He identified more than 100 different professions where people directly use images and drawings to enhance their work quality.

The use of graphical representations at school level is very common but the graphical competency of teachers is still an unresolved issue. Graphical representations have become such an important part of the learning process that today's comprehension of knowledge despite of many differences between domains is difficult without comprehending graphical representations. Common compositional rules of graphical representations are still debatable and teachers are not deliberately trained to understand, construct and demonstrate graphical representations. A large number of remarkable graphical representations have already published but pedagogy is an aspect which is quite neglected in this respect (Gallimore, 1990). Subsequently, it is very important to educate our teacher's community so that they can develop the skill of graphicacy in learners for better utilization in new situations. If we look closely at the teacher training programs, we can find graphical representations but attention is paid to the text and graphical comprehension is neglected as an individual aspect of teacher training.

Most of the research in the domain of graphical representations involved student's comprehension of graphical representations in schools and colleges (Wainer, 1980; De Vries, 2006; Aberg-Bengtsson & Ottosson, 2006; Lee & Gerber, 1999). But there is little research to analyze teacher's comprehension of graphical representations and to improve their proficiency.

Teachers have double role to play, because they have to understand the graphical representations themselves and explain it to the students. (Gerber & Boulton-Lewis, 1998).

This thesis aims at to explore the teachers and Masters students' comprehension of graphical genres. An exploration of how the students and the teachers categorize the graphical representations. And what are the difficult cases/genres of graphical representations in their categorizations. Comprehension of graphical genres will allow us to give an overall expression of their comprehension of graphical representations

There are five chapters in this thesis. Chapter one is the theoretical part which is further divided into three parts: graphical representations in curricula of different countries, remarkable works in advancement of graphical representations and identification of different graphical genres. Chapter two is based on our first study in which we inquired in-service teachers' (from France and Pakistan) comprehension of graphical representations. Chapter three is our second study which was conducted with Masters Students from the domain of Educational Sciences to investigate their knowledge of graphical genres. Chapter four is based on our third and final study in which we investigated the knowledge of graphical genres of Masters Students from the University institutes of teacher training in France.

2. Theoretical background

The aim of this chapter is to give an overview about three perspectives of graphical representations: the existence of graphics in the curricula over the globe, the history of graphical representations in the context of teaching and learning and major genres of graphical representations. The principal objective of this chapter is to provide an insight of graphical representations al representations in education.

Formal advancement of graphical representations was gradual which started from the cave paintings and evolved into today's 3D graphics. In past, people who could read, write (literacy) and do the basic mathematics (numeracy) were considered educated. With the passage of time, trends changed and educationalists started using drawings, images and other audio visual aids to enhance the learning environment. There was time when graphic development of graphical representations was considered as the responsibility of the cartographers and geographers only. Computer software of graphic development has brought graphical representations into a new era by making the process of graphic development easy even for novices of cartography. Today, a common person can develop comprehensive and complicated graphical representations with computer software. Developing colorful and comprehensive graphical representations is only one part; the second part is comprehension of graphical representations. It is assumed that majority of the people can develop a variety of graphical representations but not everybody can understand and interpret them. Therefore, graphical representations are considered very significant in education systems around the world and the students are taught to develop, understand and use graphical representations.

There are three subparts in this chapter and every subpart is meant to provide a ground to our studies. First part explains how graphical representations are important all around the world via presenting the examples of world curricula. This part illuminates how different countries are working to teach graphical representations. Second part describes how different cartographers emphasized different aspects of graphicacy and how the graphical representations evolved with the passage of time. Third part is based on different taxonomies of graphical representations. This aspect enforces the idea that the cartographers not only worked on the graphical representations as a whole but also paid attention to ameliorate the graphical representations individually.

2.1. Graphical representations as a part of worldwide curricula

Graphical representations have gained importance in curricula all over the world. Irrespective of cultural, economic and geographical differences, graphical representations are accepted equally important along with numeracy and literacy. Graphicacy is so critical for school students that it should be a part of school curricula along with literacy, numeracy and articulacy (Danos, Xenia & Norman, 2009).

We presented below some examples of world curricula of Geography. Although Geography is a vast subject which covers the study of land, phenomena of earth etc. But Geography is the only domain in which the students are deliberately taught to develop, interpret and read the graphical representations. Therefore, we discussed the curricula of Geography as a whole as well as teaching, learning and evaluation of graphical competencies. This part will allow us to explore how different countries focus on the education of graphical representations in their society.

Here are some examples of geography curricula of geography from some countries.

2.1.1. Australia

The implementation of a national geography curriculum in Australia is teachers' major responsibility (McInerney, Berg, Hutchinson, Maude & Sorensen, 2009). Geography is considered an important subject in Australia because it contains qualitative and quantitative knowledge and it's an effective mode to enhance literacy and numeracy skills in students. Teaching of geography should enable students "*think geographically*" and when students will think geographically they will, learn how to get the information, location of places, identify environmental, economic and demographical activities, use and significance of scales in understanding and well informed behavior towards environment (McInerney et al., 2009). The Table 1. Structure of national geography curriculum in Australia *(*McInerney et al., 2009, p. 33)below presents the expected structure of geography education from primary to high school in Australia. This table mainly presents three major aspects; the pedagogical aspects of teaching graphical representations, the skills and concepts that the students will learn and the knowledge and insight that they will get through this curriculum.

Table 1. Structure of national geography curriculum in Australia *(*McInerney et al., 2009, p. 33)

Image

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It is also expected that after studying geography during 10 years of school education, students will have achieved a high level of literacy, numeracy and graphicacy. They should have general knowledge about the world geography and have ability to developed different graphical representations with given data. . Particularly, they should have knowledge about the Australian environment, its resources and the biophysical system of the earth in general. School teachers should also be motivated to take an active part in the curriculum development process and there should be sufficient number of trained geography teachers to deliver curriculum knowledge to students. It can be concluded that the Australian authorities are working on preparing graphically literate students in their schools. Focus of Geography in Australia is not only on understanding local and international geography but also on developing and understanding of graphical representations.

2.1.2. France

In French schools, geography and history are considered to be one subject named "Histore-Geographie". The ministry of education (MEN, 2010) emphasis that curriculum developers should make sure that at the end of high school, the students should be able to identify and compare information and can become critics of texts, images, maps and graphs etc. Furthermore, students are expected to be proficient in producing maps, sketches, diagrams, cartographic data, charts etc. Table 2 presents the objectives of teaching history-geography in French schools.

Table 2.Objectives of the French History-Geography curriculum

Learning objectives and Methods	
Identify and locate	Identify and locate major landmarks Locate and characterize a date in a chronological context Identify and locate a place in a geographical space
Change the scale	Place an event Identify a place and scales on maps Compare historical and / or geographical situations
II Mastering specific tools and methods	
Operate and confront information	Identify documents (type, author, date)Collect, classify and compare information according to specific approaches depending on the document or the corpus Identify the general meaning of a document and link it with historical or geographical studies

Organize and synthesize information	Classify document types (text, images, maps, graphs etc.) Describe geographical situation with the help of a map Make maps, sketches, diagrams, charts, diagrams with arrows and different graphical components Write an essay or make an oral presentation and build an argumentation using specific historical and geographical vocabulary Read a document (text or map) and express key ideas, parts and essential components orally or in writing
Using ICT	Use computers, software, digital devices for writing texts, making maps, diagrams and graphs etc.
III Master the methods for individual work	
Expression of ideas	Use search engines and online resources (internet and blogs etc.) Develop oral or written arguments to confront other views Participate in a course in progress at the request of a teacher and explain something if necessary
Prepare and organize work autonomously	Take notes: make notes for revision (plans, concepts and key ideas, key facts etc.) Carry out research individually or in a group; take part in a collective production prepare for further studies in class

Source: (MEN, 2010, p. 2, our translation).

Table 2.Objectives of the French History-Geography curriculum not only shows the content for teaching of visualizations in French schools but also provides a detailed methodology of teaching that content. This training at schools is divided into three major steps. At the first step, students are taught to identify the location of places and read different scales used in geography (i.e. reading a map about the movement of armies in a world war). At the second step, students are taught to consult different types of documents, collect data from documents and distinguish different types of graphical representations. Moreover, students need to learn to develop graphical representations from given data and express information in their own words. The use of computers to develop graphical representations is also taught at this level. At the third step, students are taught to use online sources to develop material on specific subjects and justify their

productions. In short, French curriculum developers consider geography and graphicacy very important. The national Baccalaureate exam (which is equal to A-level in UK) therefore tests students on their performance in interpreting and constructing graphical representations.

2.1.3. Pakistan

Geography education starts from schools in Pakistan and there is a compulsory subject in Pakistani schools named "Pakistan studies" which covers the history and geography of Pakistan. We discussed the education in Pakistan and graphical representations in Geography textbooks of Pakistan (see 3.2 and Table 8: Frequency of different types of graphics in four different schoolbooks). It was found that the majority of graphical representations in Pakistani textbooks are poorly designed and in black and white form. Furthermore, Pakistan is blessed with a multitude of cultures and topographies but the geography curriculum developers has failed to present a comprehensive curriculum which cover all aspects of national and international geography (Aly & Team, 2007)

2.1.4. England

The Department of Education and Development in collaboration with the curriculum development authorities of England presented a model for teaching geography in schools (Department for Education and Employment, 1999). The model describes the aims of teaching geography in England and details what a student should be taught at a certain age in school (see Table 3).

Table 3. Three levels of Geography education in England

Key stages of geography curriculum in the schools in England
I. Stage One: At the Age of 7
To ask geography related questions and identify the buildings in their streets To express views related to people and places To communicate through pictures, text or orally Use of basic geographical vocabulary Recording information (i.e. marking places on a local map) Using globes, maps and plans at a range of scales Using CDROMs, photographs, pictures and videos etc. Developing pictorial maps from a story To recognize how places have become the way they are and how they are changing To compare places (local with places elsewhere in UK) To recognize changes in environment and how to improve/sustain the environment
II. Stage Two: Age of 11
To undertake geographical enquiries To use appropriate geographical vocabulary for different activities To use appropriate fieldwork techniques To use atlases and globes, maps etc. To use secondary source of information i.e. aerial photographs, internet/satellite images etc. To locate and explain why places are like they are in terms of weather conditions, local resources etc. How decisions about places and environments affect the future quality of people's lives Water and its effects on landscapes and people Changes in land use, building new housing and environmental issues
III. Stage three: Age 14
To ask geographical questions, identify issues, collect, record and present evidence analyze and evaluate evidences and draw and justify conclusions To use extended geographical vocabulary, use appropriate fieldwork techniques, use atlases, globes, maps and plans at a range of scales To draw maps and plans at a range of scales, using symbols, keys and scales To describe and explain environmental change i.e. deforestation, soil erosion etc. To study at least two countries in significantly different states of economic development, and their causes and consequences and why each country may be judged to be more or less developed

Note. Adapted from (Department for Education and Employment, 1999)

In the early years of school, students are taught to understand local geography, maps, environment and proper vocabulary of geography. At the second level, the students carry out some simple tasks using the geographical tools. Their understanding of graphic data evolves and students become capable of expressing their views on locality and environment. At the end of school education, English students are expected to be capable of reading, understanding and organizing geographical information.

2.1.5. United States

Geography education in the Unites Stated was reformed in 1989 when President George Bush and 50 state governors agreed on six goals for the improvement of education in United States. One of those goals was that every American student who leaves grade four, eight and twelve should be competent in five core subjects: English, mathematics, science, history and geography (Gaile & Willmott, 2003).

In the last half of 1980s, a teacher staff development program organized geography educators meetings all over the country and proposed five themes to enhance educators' understanding of geography. In 1986, the National Geographic Society started collaboration with all states to improve pre-service and in-service teacher training of geography teachers. Meanwhile, the publication of national standards for geography named "Geography for life" was another milestone in which geography content was grouped into five core elements: the world in spatial terms; places and regions; human systems; environment and society; and the use of geography. The objectives of geography teaching included the preparation of geographically cultured students who are able to study people, places and environments. In 1997, the Rediscovering Geography committee recommended that there should be more research on geographic literacy, learning and problem solving. They also suggested improving the national education standards on teaching geography (Bednarz, 2002).

In the context of preparing well trained geography teachers in the United States Bednarz and Bednarz's model (1995) was appreciated (see *Figure* 1. Model of Geography (Bednarz & Bednarz, 1995, p. 483).

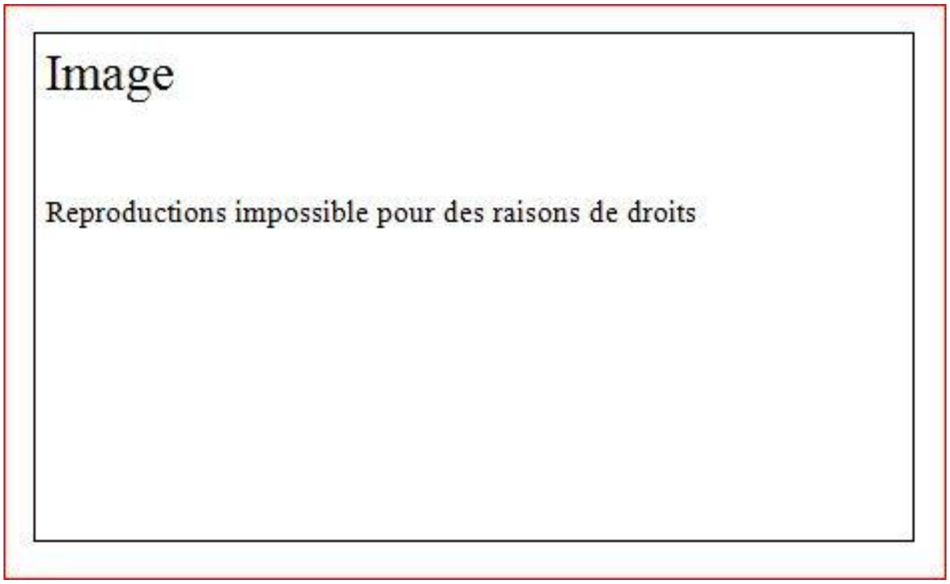

Figure 1. Model of Geography (Bednarz & Bednarz, 1995, p. 483)

In the US, Geography has gained a great place in all aspects of education. Another important step is the decision of National Aeronautic and Space Administration (NASA) to include geography along with mathematics, science, engineering and technology in their educational program. Despite the many achievements in the field of geography in the US, many organizations are still working to develop more graphically literate people.

2.2. Milestones in the history of graphical representations

The use of graphical representations for teaching and learning has deep roots in history. Even in the era where there was no concept of formal education, people used to draw on rocks to convey messages. Cave paintings are considered the earliest form of graphical representations (Friendly, 2008).

The aim of this section is to provide an overview of important individuals and events in history which played a vital role in the progress of graphical representations. Every personality presented in this section played a unique role for the advancement of graphical representations.

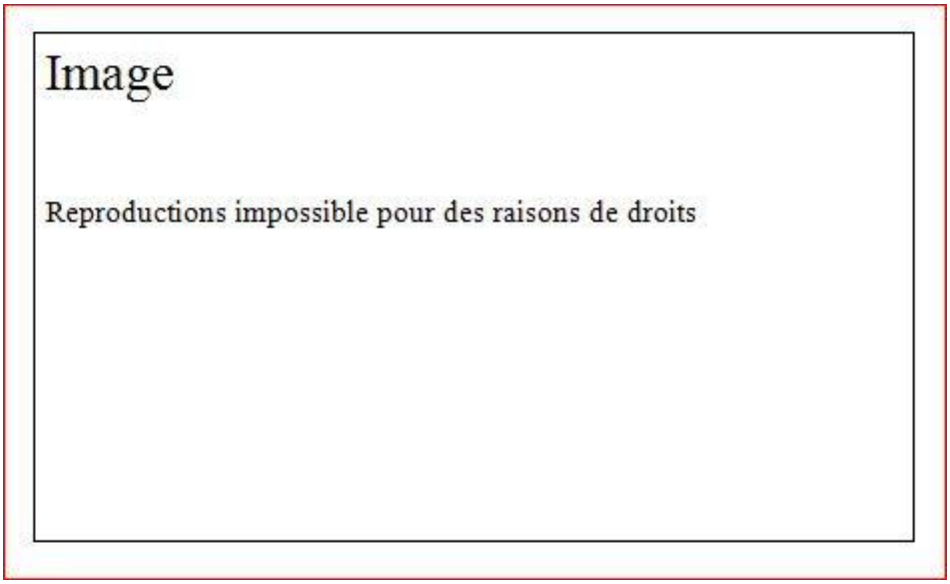

Figure 2. Time course of graphic developments (Chen et al., 2007, p. 18)

The line graph in Figure 2 precisely presents the advancement of graphical representations from their beginning to the modern age. Two important aspects can be noted: the proliferation of graphical representations over time and the density of graphical representations in each period. Furthermore, in the early period of graphical representations development, the production and use of graphical representations was very low in quantity. In 1983, Tufte stated that the number of printed statistical graphics and images lied somewhere between 900 billion and 2 trillion. Since then, these numbers rapidly increased with the use of graphical representations in all domains. In the following, we present four individuals who played an important role in the advancement of graphical representations. The first two individuals developed graphical representations in the early era and the last two modernized the graphical representations.

2.2.1. William Playfair

William Playfair is considered to be the inventor of most of the graphical representations known today, such as pie charts, bar charts and statistical line graphs (Wainer, 1997; Tufte, 1983; Friendly, 2008). Playfair changed the way of data presentation in statistics. Tufte (1983) considered him to be responsible for replacing conventional data tables with systematic visual representations. Playfair published many innovative graphical representations in his book “*The commercial and political atlases”* Amongst which the first known bar chart (see Figure 3).

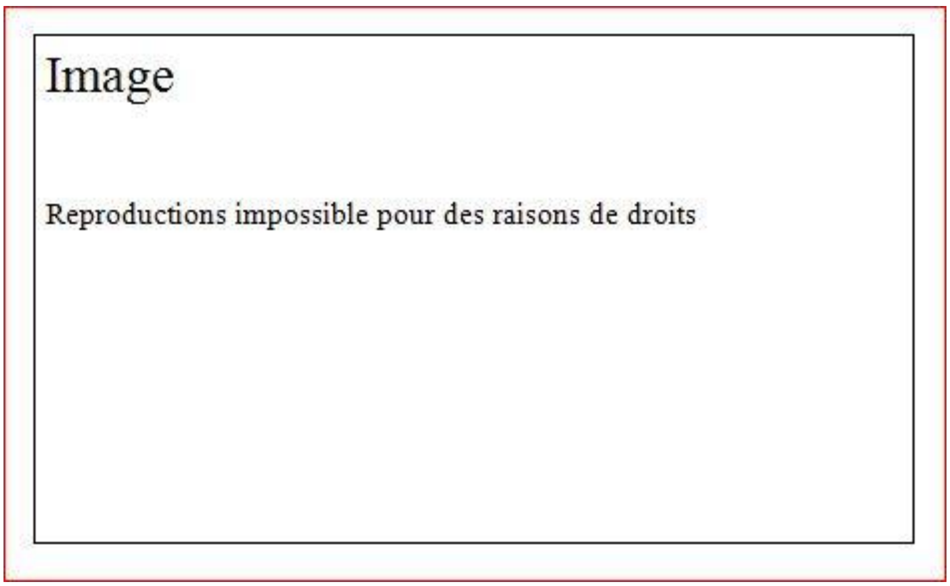

Figure 3. The first bar chart republished by Tufte (1983, p. 33)

Playfair experimented different approaches of data presentation in statistics. In addition to introducing graphical representations for effective data presentation, Playfair kept the readers’ convenience in mind. (Friendly, 2008). Therefore, he devoted many pages of his book to explain to readers how to read and understand line graphs used for several data presentations. Figure 4 shows another example of a remarkable pie-circular line chart published in 1801 by Playfair.

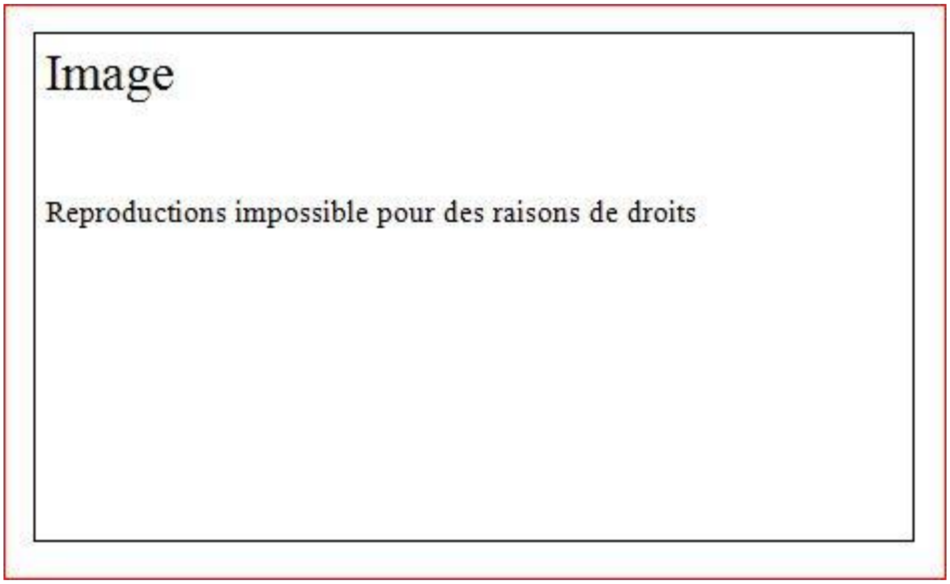

Figure 4. Playfair's pie-circle line chart (Republished by Friendly, 2008, p. 24)

Although, graphical representations were not very common those days but he developed the graphical representations in a very simple way which was understandable even for novices (Wainer, 2005). In the beginning, he felt the need of graphical representations for his personal use and late on to demonstrate the statistics of workers efficiency.

2.2.2. Charles Joseph Minard

Minard was a French engineer who was known for his innovative techniques of figurative maps. His early work concerned maps about routes of goods alongside the rail tracks. His maps became popular in France because he used numerical and relational aspects of flow. Minard stated himself that he preferred to develop graphical representations that convey quick message which simple numbers can't provide without mental calculation (Robinson, 1967). He developed several remarkable graphical representations including his famous Napoleon's March chart (Figure 5. Napoleon's march to Moscow (Republished by Tufte, 1983, p. 41)). Most of his work was published privately but he made his impression in the domain of visual communication by this famous chart of Napoleon's advance on and retreat from Moscow. Tufte (1983) described this chart as "it well may be the best statistical graphic ever done". (p.40)

Image

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Figure 5. Napoleon's march to Moscow (Republished by Tufte, 1983, p. 41)

2.2.3. Edward Tufte

Tufte may be the most accomplished cartographer in modern era. He precisely focused on effective display of data through graphical representations. Tufte pointed out the cartographers that principles of graphic development are not like mathematical rules which should absolutely be followed. And rules can be violated to make data clear, easy tounderstand and graceful (Mulrow, 2002). Tufte himself states in his book « The visual display of quantitative information » that today's graphical representations are not just to replace statistical tables but the instruments for reasoning about quantitative information. Tufte worked in the domain of *information design* and *visual literacy* and gave new meaning to visual communication. He invented the term « chartjunk » which refers to the useless decoration and to confusing elements in graphical representations. He highlighted some other vital issues for effective display of visual information like *lie-factor*, the *data-ink-ratio* and *data density*. A good graphical representation does not have to be very colorful or decorated; in contrary, well designed graphical representations are the simpler ones. He republished several historical examples of visualizations to make his case strong (i.e. John Snow's cholera outbreak map, Charles Joseph Minard's Carte Figurative and Napoleon's March chart, early space debris plots, and Maya Lin's Vietnam Veterans Memorial etc.). Tufte's books are must read for people involved in writing, editing, designing or simply displaying graphics. It is useful not only for professional editors, but also academic writers, journalists and even for school students.

2.2.4. Jacques Bertin

Jacque Bertin played a vital role in the progression of graphical representations. He not only developed many remarkable graphical representations but also worked on the effective presentation of data as well as on the understanding of graphical representations. He stated himself that "*a graph should not show only the leaves; it should show the branches as well as the entire tree. The eyes can then go from detail to totality and discover at once the general structure and any exception to it"*. (p, x). There is a common assumption that a graphical representation is to display information precisely but Bertin on the other hand states that the primary purpose of a graphical representation is information processing rather than display. He identified different stages of reading a graphical representation so that a common reader can understand the graphical representations by following those steps. According to him, comprehension of graphical representations is a two-step process; external identification and internal identification. In external identification, before formally reading a graphical representation; the reader must identify, in the mind, the invariant and components involved in the information. External identification relies on acquired habits, on the recognition of words, shapes, or colors. In internal identification, the reader must recognize visual variables of the components presented in a graphical representation. Bertin also worked on educating cartographers about how to develop graphical representations and provided three simple rules of graphic construction. "(1) To present the information in a single image, or in the minimum number of images necessary. (2) To simplify the image without reducing the number of correspondences. (3) To simplify the image by reduction and thus create a clear and efficient message" (Bertin, 1983, p. 171)

2.3. Classification of graphical genres

In the early era of graphical representations, it was easy to identify different graphical representations because of the limited number and types of graphical representations. The use of graphical representations has increased with the passage of time and so are the types of graphical representations. A graphical representation can be categorized according to form, domain or pedagogical function. All three aspects mentioned above are discussed in detail in chapter three. In order to achieve the skills of visual literacy, students must practice how to read different types of graphical representations. In order to do so, we need to identify which are existing types of graphical representations out there. Here are some established classifications of graphical representations.

2.3.1. Edward Fry's taxonomy of graphic literacy

Fry (1981) introduced this taxonomy to help teachers defining different types of visualizations. For instance, in the "Taxonomy of Graphs" (see Figure 6. Fry's Taxonomy of Graphs (Republished by Danos et al., 2009)), Danos (2009) categorized different types of graphical representations based on Fry's taxonomy of graphics. There are six major categories of graphical representations in this taxonomy and each category possesses some sub-categories. (1) Lineal Graph (line graphs) shows sequential data, such as story lines, timelines, flow charts, sports playoff brackets, or genealogy charts. (2). Quantitative graphs display numerical data, such as line graphs, bar or pie charts, or supply and demand curves (3) spatial graphs reveal area and location, such as floor plans, road maps, or contour renderings (4) pictorial graphs back on visual concepts, such as realistic paintings, cartoons, or abstract drawings (5) Hypothetical graphs presents the interrelationship of ideas, such as theoretical models or sentence diagrams (6) Omitted graphs intentionally leave out explanatory details, such as essay outlines, corporate logos, statistical tables, religious symbols, or decorative designs . (See Figure 6. Fry's Taxonomy of Graphs (Republished by Danos et al., 2009))

Image

Reproductions impossible pour des raisons de droits

Figure 6. Fry’s Taxonomy of Graphs (Republished by Danos et al., 2009)

This taxonomy can help the teachers and students to narrow down different types of graphical representations. Furthermore, Fry (1981) gave importance to combine different graphical representations to communicate the message effectively. This combination of different graphical representations can facilitate the learning process.

2.3.2. Carney and Levin‘s functional classification

Carney and Levin (2002) classified the graphical representations (pictures that serve in text processing) into five categories according to their function. Although, they used the term ‘picture’ in place of graphics but if we look at their examples of pictures, those pictures are not literally pictures and can be assumed as graphical representations in a broader context.

Table 4. Function of pictures by Carney and Levin

Function of pictures	Description
Decoration	Decroational pictures are often used to decorate the page. Title pages of books are common example of this type where main objective is to attract the readers from the appearance of title page. These pictures are used more for marketing purpose then educational.
Representational	Majority of the pictures we come across are representational ones which fully or partially repeat the message presented in text along with that picture. These types of pictures give a quick impression of the information presented in text to enhance the learning of the readers.
Organizational	Organizational pictures provide a useful structural framework for the text content (i.e. an illustrated map of a hiking trail, or an illustration showing the series of steps involved in performing cardiopulmonary resuscitation etc.).
Interpretational	Interpretational pictures help to clarify difficult text (i.e. representing blood pressure in terms of a pump system).
transformational	Transformational pictures include systematic mnemonic (memory enhancing) components that are designed to improve a reader's recall of text information.

Note. Adapted from (Carney & Levin, 2002))

Teachers and students frequently encounter these five types of graphical representations (pictures) in textbooks. This classification helps them to identify the type of picture and once they identified the type, the can devote their attention to comprehend that picture. For instance, two pictures can be dealt differently once identifying as decoration or representational ones. This classification invites our attention to the fact that not all the graphical representations (picture) are meant to enhance the learning but some pictures (i.e. decoration) are meant to serve as a tool to attract the readers.

2.3.1. Balchin's grouping of maps

Balchin also identified a large variety of graphical representations. However, in this categorization of graphical representations, a clear focus was on maps as he identified 38 different types of maps. We come across those maps frequently but they are not usually identified as individual types of maps. Other major categories are signs, symbols, diagrams, logos, photographs, orthography, flags and art forms.

Table 5. Categories of graphicacy by Balchin

Image

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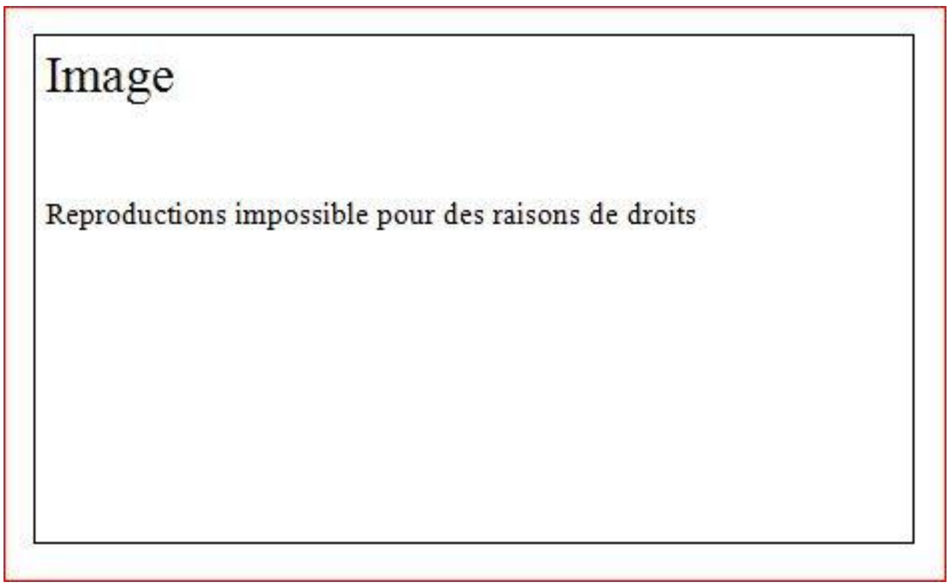
Source: Some obvious categories of graphicacy (Balchin, 1996)

2.3.1. Classification of drawings

Baynes (2008) recognized 49 types of drawings from different domains. He included some known graphical representations (i.e. maps, photographs, illustrations) with some non-popular type (i.e. mono print, axonometric, projection, orthographic projections etc.). If we look closely at these drawings and images (see Table 6. Types of images identified by Baynes), we can identify that majority of them are photographs, technical drawings, diagrams and sketches. The professionals from several domains (i.e. advertisers, architect, biologists, carpenters, chemists, civil engineers, football coaches, geographers, hair dressers, makeup artists, office managers, plumbers, timber merchants, surgeons, social workers, veterinarians, zoologists etc.) use these graphical representations.

Table 6. Types of images identified by Baynes



Source: Types of images identified by Baynes, 2008 as cited in (Danos et al., 2009, p. 74)

This classification invites us to think about another aspect that there are many visualizations which we encounter but those visualizations are not formally identified as individual types. Drawings are usually considered as one big category but Bayens identified more than 45 different types of drawings here. This classification can be useful for the teachers and students to distinguish each drawing individually to understand them effectively.

2.3.2. Jacques Bertin's classification of graphical representations

Bertin classified the graphical representations into three major categories; diagrams, networks and maps. We discussed this classification in Chapter 3.

2.4. Conclusions

In the light of three aspects – graphical representations in world curricula, milestones in the history of graphical representations and classification of graphical representations – presented above, we can conclude that graphical representations are part of curricula in many countries. Teaching and learning of visualizations is at different stages in different countries. For instance, U.S and Australia have been working to improve their students' graphicacy skills for a long time. On the other hand, developing countries like Pakistan are way behind in developing graphicacy skills in students. Secondly, several remarkable graphical representations have been published since the introduction of graphical representations in teaching and learning. Cartographers like Bertin and Tufte have published books on effective production and comprehension of graphical representations. But there are so many graphical representations published every year that it is hard to maintain their quality. We assume that the knowledge of different genres of graphical representations is essential for students to identify individual properties of each graphical representation and understand them faster. Several types of graphical representations are considered difficult and other as less difficult. For example, Bertin classified the graphical representations into four major categories whereas Bayens identified 49 types of drawings only.

This classification can be narrowed down or enlarged with different approaches. We conducted three studies in investigation of graphic comprehension and classification.

3. Teachers' thoughts on visualisations in culturally diverse settings

Note: This chapter is a part of a book. De Vries E. & Ashraf, M. (in press). Teachers' thoughts on visualisations in culturally diverse settings. In B. Eilam & J. K. Gilbert (Eds.) Science teachers' use of visual representations. Heidelberg: Springer.

Visualisations gain more and more importance in pedagogical material, in text books and in computer programs. Despite the co-existence of many different types of visualisations or graphical genres, learning research only has taken into account the distinction between text and pictures. The current study aims at unpacking what, at least in learning research, seems to be one single holistic indivisible category of visualisations. The presented approach focuses on teachers' thoughts on the existence of different types of visualisations and their presumed function in teaching and learning. Ten teachers from two different countries, France and Pakistan, and from two different subject matters, physics and geography, were interviewed. Amongst others, results showed that teachers are confident about student comprehension for generic categories such as tables, line graphs, and maps. However, the transparent nature of hybrid visualisations was called into question. This is an important finding given the fact that technological means have considerably enlarged the spectrum of visualisation possibilities.

3.1. Introduction

Visualisations are widely used in everyday life, in professional practice, in science and technology, as well as in teaching and learning. Indeed, graphical, as opposed to textual, ways of information presentation gain more and more importance in pedagogical material, schoolbooks and in computer programs for learning. Three viewpoints seem to have become particularly pervasive.

The first one is the idea itself that visual media are increasingly important in today's society. This viewpoint is also known as the visual or *pictorial turn* (Mitchell, 1994). Despite its appeal, some authors also criticized this idea pointing out that, in fact, there have been visual turns continuously throughout history. In any case, a noticeable increase of graphics can be observed in Western schoolbooks as well as in learning technologies. A thorough reflexion on the role of such a visual turn in pedagogical material could well be informed by a comparison of non-Western and Western school systems that vary in their susceptibility to this visual turn.

The second viewpoint is that information presentation within the visual medium mainly hinges on *resemblance* relations. Pictures are thought to represent by virtue of the visual similarity between the representation and what is presented. This is in contrast with language or text which is thought to represent by virtue of convention. The opposition between resemblance (natural relation) and convention (arbitrary relation) goes back to the debate in Cratylus on the justification of the choice of words to designate things. Furthermore, the distinction traces back to one of Peirce's triples, namely the three types of signs: icons (similarity), symbols (convention), and indices (contiguity). However, it would be extremely oversimplifying to equate graphics and resemblance on the one hand, and text and convention on the other. The dichotomy might well fall short in describing the observed variety of graphical formats, and moreover does not do justice to the complexity of semiosis as meaning making. As Rastier (2000) noted, the only way to establish the type of relation between a representation and that which is represented is through inspection of an *instance* of a semiotic process. As an example, a picture of dog might evoke a dog or evoke the concept of loyalty; in the first case it would be by virtue of a resemblance relation, in the second by virtue of convention. Many have in fact argued that meaning making from graphics is not solely based on resemblance relations (Goodman, 1976; Eco, 1976; Wittgenstein, 1993). In today's pedagogical material, as we will see below, the existence of different graphical genres or languages with different mixtures of similarity and convention for meaning making is commonplace. Schoolbooks and computer programs contain a variety of graphics and their particular format, or the way in which they should be interpreted, is rarely specified. We therefore propose to more closely study actual authentic visualizations used in textbooks and put them in relation to "pure" categories as described in the domain of information visualization.

According to the third viewpoint, related to the resemblance assumption, visual media possess *immediacy*. Compared to text, visualisations are acclaimed for their transparency, their concreteness, and their support for perceptual inferences (Larkin & Simon, 1987). Because of the assumed resemblance relations, the meaning of graphical material is thought to be instantly available without any interpretive activity. According to this widespread belief, graphics such as pictures, graphs, and diagrams are transparent. This also leads to the idea that understanding the graphical medium does not necessitate any interpretive skills. However, maybe well-designed general purpose everyday graphics do not need any thorough interpretative skills, but many domain-specific complex graphics do require extensive training and/or experience. In that case, the flipside of the coin is the need for particular skills or experience. Thus, just like reading and writing for texts, the ability to interpret and to construct visualisations seems to be an important skill. Roth, Pozzer-Ardenghi, and Young Han (2005) even argue for the necessity of developing "critical graphicay", i.e. the ability of constructing and deconstructing inscriptions, in other words to disentangle form, content, and purpose of representations (see also MRC, diSessa, 2004).

Moreover, one may consider educational settings to be a special case of communicational situations characterized by a knowledge disparity between participants. It begs the question of domain-specificity of visualizations within teaching and learning. For example, physics and geography might contain a different balance of the symbolic and the iconic modes of signification. We therefore are highly interested in soliciting the teachers' view from different subject matters.

Those three viewpoints motivated the idea to investigate teachers' thoughts on educational graphics. Differences in the availability of visualizations justify an international comparison, in our case between France and Pakistan. The great variety of graphics in schoolbooks as well as the multiplicity of the signification modes in play warrants the study of authentic graphics and their function in teaching. These functions may well go beyond just "showing" and "transmitting" content, or in Coleman's terms, go beyond merely drawing attention to whatever graphics are available: "Simply pointing to or referring to graphics is not a teaching practice sufficient to help students" (Coleman, 2010, p. 216). Finally, the immediacy principle, and the knowledge disparity in teaching and learning situations suggests the value of investigating graphics from both physics, supposedly more convention-oriented, and geography, supposedly more resemblance-oriented.

3.2. An international comparison between France and Pakistan

France and Pakistan are different from every point of view. France is a stable well-developed country whereas Pakistan is an under developing third world country with a lot of political and economic problems. France has a unique education system; Pakistan has an education system which is partially borrowed from the English school system. According to the World Bank 2010, France is spending 5.9% of its GDP expenditures on education whereas Pakistan's expenses on education are only 2.7 % of GDP. The performance of the French system is measured by the Pisa ranking (ranked 20st, PISA ranking 2009), Pakistan does not participate in these evaluation methods.

Although France has a secular education system, i.e. there is no religious education in the curriculum, students get one day off every week to take the religious education outside the school (Directorate General for Schools, 2010). Pakistan's official religion is Islam, and religious education is compulsory in the school curriculum. There are five levels in the educational system of Pakistan: primary (grades one through five); middle (grades six through eight); high (grades nine and ten); intermediate (grades eleven and twelve, leading to a Higher Secondary School Certificate); and university programs leading to undergraduate and graduate degrees programs. On the other hand, the French educational system contains three levels (DGS, 2010), level 1 (*premier degré*: nursery and elementary schools), level 2 (*second degré*: lower secondary *collèges* and upper secondary general, technological and vocational *lycées*), level 3 (higher education: university education). The French constitution states that it is the duty of state to provide free compulsory education for all children. France has both public and private schools, but even private schools have a contract with the state. Although school education in Pakistan is free too and the state provides textbooks to students, the parents have to pay a small amount of money every month. The state has a very low level of control over private schools. Lynd (2007) and DGS (2010) stated that 31% of students attend the private schools in Pakistan whereas only 17% of the students in France.

In Pakistan, most of the teachers working in public schools have at least a bachelor's degree in their teaching domain, and additionally, they have one year of professional education either by attending a teacher training institute or by distance education. However, teacher training is not obligatory for teachers in private schools (Lynd, 2007). Lapostolle and Chevaillier (2011) stated that French teacher education system is unique as compared to other European countries. Until the recent 2010 reforms in teacher education, the Ministry of Education used to recruit Bachelor's degree holders and provide two years training in French teacher training institutes (IUFM). The first year was devoted to prepare for a national competitive exam for recruitment as a teacher and the second year to professional teacher training. Since 2010, some major reforms took place: the academic requirement increased from a Bachelor's degree to a Master's degree for all teachers; universities are now in charge of initial teacher training; teacher training institutes (IUFM) merged into the universities. Further training, after obtaining a master, will be in-service teacher training by the Ministry of education upon recruitment. This change has brought many questions about the competencies of new teachers who will start teaching with almost no practical teacher training. Cros & Obin (2003) mentioned that salary of French teachers is quite unattractive as compared to other jobs in the country. Young graduates therefore prefer to work in private sector. Particularly in primary education, the majority of the teachers are graduated in humanities. The vast majority of French teachers are females and there is no policy for a gender balance approach because it is unconstitutional to recruit gender wise.

Agency for International Development (2006) stated that teaching and general performance of the teachers in Pakistan has been weak. Teacher training programs run by the government were not able to improve the teaching skills of the teachers so as to increase students' acquisition of knowledge. Several explanations have been coined. First, domain knowledge is poorly articulated with teaching strategies. Teacher training mainly focuses on theory and the practical aspects of pedagogy are neglected. Second, teachers hardly use learning aids and are not motivated to use even the low cost aids or any other modern equipment to enhance student learning. Teachers administer classes following a typical lecture method based on the textbooks provided by the state and demanding low levels of student participation. The performance of the teachers is monitored by their Annual Confidential Reports (ACRs). Finally, teachers are obliged to take part in many non-educational tasks e.g. election duties or vaccination programs. The state acknowledges these issues and policies are continuously prepared to tackle them i.e. improving teacher training programs, recruiting high qualified teachers on merit basis, etc. Whereas Sarwar and Hussain (2010) stated that main subjects taught during the teacher training programs in Pakistan are: educational psychology, teaching strategies, foundations of education, educational administration and supervision, curriculum development, and educational measurement and evaluation. Teacher trainers themselves generally lack the experience of teaching in the schools; thus teacher training is more theoretical than practical. The geography and physics teachers do not get particular teacher training based on the content domains.

French teachers often select, organize and construct their own teaching material, whereas Pakistani teachers use textbooks which contain mostly text, some tables, and very few maps (geography) and diagrams (physics). In France, there is no specific training about teaching with graphical representations. Geography teachers have the advantage of dedicated training in constructing and interpreting graphical representations as a core part of geography. Physics teachers have the advantage of domain-specific knowledge of scientific graphics, i.e. diagrams, schemas, and the like.

3.3. The visual medium as an educational toolbox

If we take it that resemblance, spontaneity, intuitiveness, and immediacy are not the only rules governing visual material, we should start by trying to distinguish educationally relevant categories of graphical material. To begin with, very diverse systematic taxonomies of visualisations would be possible depending on the particular classification criteria adopted: graphical form, pedagogical function, signification mode, or nature of the projection of world to visualisation. In this section, we alternatively classify according to form, content, and function.

3.3.1. Classifying according to graphical form

A classification according to the form of visualizations follows an objectivist viewpoint that there must be some specifiable relation between aspects of the represented and the representing world (see also Palmer, 1978). The objectivist viewpoint is also present in Tufte (1983, p. 13) who stated that the graphic display is the art of presenting complex information with clarity, precision and efficiency. According to Tufte, a graphic representation is thought to serve four purposes: description, exploration, tabulation, or decoration. The representational properties of the graphical medium have been extensively described in Jacques Bertin’s Semiology of Graphics (1967/1983) as one of the most renowned and foundational works in the domain of graphic designing and cartography. As the most important functions of graphics, Bertin mentions recording, communicating, and processing.

Regarding form, the first thing to be noticed is the fact that, whereas text fundamentally is organized in *time*, the structuring feature of the graphical medium is *space* (see also Bertin, 1967/1983). The resemblance relation in combination with spatiality makes the graphical medium most appropriate for depicting spatial relations (see Figure 7: A map in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 24).). The topology of objects in a scene, their positions and orientations from left to right and from top to bottom, is more easily inferred from a graphical representation because of the relatively straightforward mapping of the representation to the represented world (Larkin & Simon, 1987). This type of semiotic relation corresponds to one of Peirce categories, the “icon”, the two other ones being “index” and “symbol”. Note how the icon versus symbol distinction as an opposition of relations ruled by resemblance versus convention often gets blurred. For example, algebraic equations, as text, are organized in time (Bertin, 1983) and so are said to be ruled by convention. However, one can just as well reason from their *structural* (rather than visual spatial) resemblance relations to what they represent. As another example, some pictures, such as ideograms, may be called icons and symbols at the same time. For instance, the drawing of a heart could stand for a human heart, in which case it would be an icon, or stand for love, in which case it would be a symbol. Visual material in multimedia research typically relies on resemblance relations, *cf*. a drawing of a bicycle pump, a schema of a car engine, or a diagram of the formation of a thunderstorm. These multimedia studies therefore seem to discard alternative meaning making processes within the visual medium.

Bertin analyses how the spatiality of the plane, i.e. the flat surface in printed matter, in terms of the visual variables can be exploited for information visualization. The information is most often arranged in a table (see Figure 12). The properties of the plane are that it has two dimensions, height and width, on which one can establish one of three elements: a point, a line or an area. Therefore, one may use the size and the position of an element in the two-dimensional plane, and furthermore exploit the shape, orientation, color, texture and value for distinguishing between components. On the basis of form, Bertin distinguishes diagrams, maps, networks, and symbols.

- *Diagrams*. The graphic is a diagram "*when the correspondences on the plane can be established between all the divisions of one component and all the divisions of another component*" (Bertin, 1983, p. 50). In Bertin's terminology, a component can be understood as a variable. Therefore, the first group includes line graphs, bar charts, histograms, and scatter plots.
- *Networks*. "*When the correspondences on the plane can be established among all the divisions of the same component, the construction is a network*" (Bertin, 1983, p. 50). The second group includes all kinds of graphs, node-and-link diagrams, oriented graphs and charts of inclusive relationships.
- *Maps*. "*When the correspondences on the plane can be established: among all the divisions of the same component and arranged according to a geographic order, the network traces out a geographic map*" (Bertin, 1983, p. 51).
- *Symbols*. "When the correspondence is not established on the plane, but between a single element of the plane and the reader, the correspondence is exterior to the graphic." (Bertin, 1983, p. 51).

Bertin calls the latter category symbols because they appeal to some correspondence relation, i.e. an established convention, *outside* the graphic. The other three could be called icons for reasons of structural similarity. We could well say that this is a valid and appropriate, but to some researchers in the multimedia field, a counter intuitive interpretation of Peirce's triplet.

3.3.2. Classifying according to domain content

A fairly obvious way of classifying visualizations in teaching is to look at the domain content that is represented. The graphics used in different subject matters represent content of different nature and for a large part are derived from the expert practice within those disciplines.

- *Geography*. Textbooks in geography contain maps as spatial representations of data that have a spatial organisation. Cartography, the art of designing maps, is one of the oldest techniques of visualization and many techniques in the modern field of information visualization have their roots in cartography.
- *Physics and chemistry*. External representation takes up an important place in scientific practice (cf. Lynch & Woolgar, 1999). When used in science teaching, Disessa (2004) calls them "cautioned" representations to refer to the history of many graphical formats, such as electrical circuit diagrams, spectra, diagrams of forces, molecular structure diagrams, etc. Researchers like Airey (2009) even stress the fact that representations, together with activities and tools, make up the disciplinary discourse that needs to be acquired by students at university level. Representations in physics can a have a more concrete as well as a very abstract nature.
- *Mathematics*. Representations are extremely present in mathematics because, as Duval (1995) mentions, the abstract objects of mathematics can solely be apprehended through different external representations.

We could extend the list of disciplines, the examples are numerous: Tukey box plots in statistics, ultrasonography in medicine, technical drawings and CAD models in engineering, and Venn and Euler diagrams in logics. Having to learn the particular representational formats of a discipline is in contradiction with the immediacy idea of graphics. Particular graphical conventions have to be acquired simultaneously with the domain concepts. The main difficulty in recognizing this insight is the fact that once the convention is learned we no longer can distinguish it from our intuitions about a graphic. For example, the main intuition is that diagrams preserve topological information, but topological information has to be ignored when interpreting an electrical circuit diagram. Once we have learned the format, we seem to naturally disregard the topology of voltage or current sources, and of resistors, capacitors, inductors, and the like. Finally, there have also been other efforts to classify graphics according to the type of content. An example is the "periodic table of visualization methods" (Lengler & Eppler, 2007) which distinguishes between visualization methods such as flowcharts for processes and concept maps for conceptual content.

3.3.3. Classifying according to pedagogical function

Both Carney and Levin (2002) and Levin (1979) developed a taxonomy for the function of pictures in pedagogical material in their view. Pictures are based on visual resemblance, i.e. they preserve the form of objects and the topological relations between objects in a scene. According to Carney and Levin (2002), pictures instigate student learning of unfamiliar content through the familiarity of their format. They also mention how pictures may complete text. The five categories specify the function of a picture either in teaching or with respect to its relation to the text.

- *Decoration*. The function of decorational pictures is to embellish pages. The aesthetics of pedagogical material is not only advantageous from a commercial point of view. In teaching, pictures are thought to attract attention and to motivate. An example of a decorational picture would be a drawing of a pine tree with a text about a hiking trail.
- *Representation*. Pictures are said to serve a representational function when they stand for some or all of the content presented in the text. This is the most frequently used function of pictures in pedagogical material. A picture of the heart, coronary arteries and cardiac veins in a chapter about the circulation of blood would be a clear example of the representational function.
- *Organization*. Organizational pictures, such as a step by step guide of performing cardiopulmonary resuscitation, provide structure for the content presented in the text.
- *Interpretation*. Interpretational pictures aim at clarifying difficult text, e.g., representing blood pressure in terms of a pump system.
- *Transformation*. The last function refers to transformational pictures. These pictures include systematic mnemonic components that are designed to improve a reader’s recall of text information.

Schwartz and Danielson (2012) pointed out that Carney and Levin’s five functions do not cover all functions of graphics and the majority of the graphics serve more than one function i.e. a graphic can be organizational and decorational at the same time. Roth, Pozzer-Ardenghi, and Young Han (2005) also presented a taxonomy comprising four functions of graphics: decorative, illustrative, exploratory and complementary. Finally, Marsh and White (2003) proposed a very detailed taxonomy with 49 functions that graphics can serve in relation to text. There are 11 major functions: decorative, elicit emotions, control, reiterate, organize, relate, condense, explain, interpret, develop and transform.

3.3.4. Contexts and crossovers

The three ways of classifying graphics according to form, content, and function, seem to be relatively straightforward. However, no one would argue that their categories are exhaustive and mutually exclusive. Whenever inspecting authentic real world examples, as we will be doing below, one realizes the inherent awkwardness of these classifications. The context of a particular graphic, and the prior knowledge of the interpreter, cannot be abstracted away. For example, how to classify a poster of the London Underground on the wall of an English as a foreign language class?

3.4. Prevalence of graphics in textbooks

As a first step, we attempt a systematic categorization of the graphics in some French and Pakistani Geography and Physics schoolbooks. Table 7: Summary of the category definitions shows a summary of category definitions taken from dictionaries, encyclopedias and books about information visualization.

Table 7: Summary of the category definitions

Label	Definition	Source
Map	"A graphic is geographic "map" when the elements of a geographic component are arranged on a plane in the manner of their observed geographic order on the surface of the earth".	Bertin, 1983, p. 285
Diagram	"A simplified drawing showing the appearance, structure, or workings of something; a schematic representation"	Oxford online dictionary
Schema	"Showing the main form and features of something, usually in the form	Cambridge dictionary

	of a drawing, which helps people to understand it”	online
Line graph	“Line graphs compare two variables. Each variable is plotted along an axis. A line graph has a vertical axis and a horizontal axis. A line graph is often used to visualize a trend in data over intervals of time – a time series – thus the line is often drawn chronologically”	MSTE Carolyn's Unit on Graphing
Illustration	“Any type of picture or decoration used in conjunction with a text to embellish its appearance or to clarify its meaning”	Columbia Electronic Encyclopedia
Pie chart	“A circle which is divided from its center into several parts to show how a total amount is divided up”	Cambridge dictionary online
Flow chart	“It’s a type of diagram that represents an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting these with arrows. This diagrammatic representation can give a step-by-step solution to a given problem”	Wikipedia encyclopaedia
Pictogram	“Pictogram is a visual presentation of data using icons, pictures, symbols, etc., in place of or in addition to common graph elements (bars, lines, points etc.)”	businessdictionary.com
Bar Graph	“A chart with rectangular bars with lengths proportional to the values that they represent. The bars can be plotted vertically or horizontally”	Wikipedia encyclopaedia
Table	“An arrangement of facts and numbers in rows or blocks.”	Cambridge dictionary online
Hierarchy Graph	“A system in which people or things are arranged according to their importance”	Cambridge dictionary online
Image	“A representation of the external form of a person or thing in art”	oxford dictionary online

These definitions occupy different positions on a resemblance – convention dimension. For example, when the resemblance relation concerns spatiality, it often does not need explication, i.e. for maps, the projection of spatiality to spatiality is in the definition and is intuitive. However, when the resemblance relation concerns proportionality, such as relative lengths of the bars in a bar graph to relative values of a variable, it needs to be explicit in both the definition and in a legend. It contains a conventional component.

Table 8: Frequency of different types of graphics in four different schoolbooks

	France		Pakistan		
	Geography	Physics	Geography	Physics	Total
Diagram	1	250	0	281	532
Image	206	123	0	23	352
Line graph	7	226	0	37	270
Map	159	3	66	0	228
Table	47	67	84	27	225
Schema	25	45	0	11	81
Bar chart	16	3	12	0	31
Pie chart	10	3	8	0	21
Pictogram	1	1	0	0	2
Flow chart	1	0	0	0	1
Total	473	721	170	379	1743
N of pages	281	335	240	358	1214
N of graphics/page	1,7	2,1	0,7	1,1	1,4

All graphics in four text books of geography and physics from France and Pakistan were categorized (see Table 8). Table 8 clearly shows differences regarding the presence of graphical representations in French and Pakistani textbooks. First of all, French textbooks (both geography and physics) contain many more graphics than Pakistani. In addition, graphical representations in French textbooks entail color, whereas Pakistani textbooks mostly contain black and white graphical representations. Finally, French textbooks comprise a larger variety of graphical representations than Pakistani textbooks. Table is the only type of graphical representation which exists in all four textbooks. These differences can largely be traced back to the differences in the available financial and technological means reserved for schoolbooks in both countries. When financial and technological resources are scarce, the type of graphical representations is reduced to the indispensable for particular domain contents. As can be read off from the table, the Geography content domain minimally requires maps and tables and for the Physics content domain, diagrams, line graphs and tables are essential. The low number of graphics in Pakistani textbooks is not likely to originate from national government policies. In Pakistan, the National Bureau of Curriculum and Textbooks (NBCT), also known as the curriculum wing, formulates rules and regulations regarding textbooks. The National Textbook and Learning Materials Policy and Plan of Action (Govt. of Pakistan, 2007) does not pay any specific attention to visual or graphical material (see also Khalid, 2010).

3.5. Exploring teachers' thoughts

The current study aims at an inventory of existing knowledge on visualisation types through an exploration of teacher conceptions on the pedagogical use of visualisations. There were three main objectives of this study. The first interrogation concerns teachers' awareness of different types of visualizations. If graphics are conceptualized as the tools of the pedagogical trade, than teachers should have a relatively homogeneous way of designating graphics. Our second aim is to see whether teacher impressions are domain-dependent. In domains with different uses of graphics, such as geography and physics, do teachers have different notions about authentic graphics? And third, we aim to explore the degree to which teacher impressions might be culture-dependent. The underlying idea is that in countries with varying degrees of technological development, this would emerge from teachers' ideas about graphics.

The study involved an inventory of teacher conceptions through a detailed, semi open-ended interview. Such interviews allow the researcher to get insight information (Patton, 2001) and provide an opportunity to the participants to discuss their interpretations of different concepts. The target population consisted of in-service higher secondary school teachers of physics and geography from France and Pakistan irrespective of age, gender, qualification and residential background. Snowball sampling (Patton, 2001) method was applied for the sample because of the difficulties to gain access to teachers in both countries. Five French and five Pakistani secondary school teachers in geography and physics were interviewed in their home country.

A closed quantitative interview (Cohen, Manion, & Morrison, 2000) was used as research tool. The interview consisted of seven questions for each of eight different visualisations chosen from geography and physics text books from Pakistan and France. The questions concerned teacher impressions about categorizing graphics, the function of graphics in teaching, and student's comprehension. The interviews were conducted in schools or in the homes of the teachers according to their preference. The sessions ranged from 40 to 90 minutes. The interviews were recorded with formal permission of the teachers. All interviews were transcribed for analysis. The transcripts were scored with the help of an analysis grid. An open coding method was adapted to identify teachers' answers on categorizing graphics, functions of graphics and on teachers' assumptions on student comprehension. Each statement in the transcripts was read in the light of this analysis grid.

3.5.1. Teacher's labelling of graphics

All eight visualisations received more than one category name within the set of nine teachers. One teacher gave idiosyncratic responses and was left out. The most used categories labels were “diagram”, “table”, “map” and “line graph”.

Figure 7: A map in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 24).

Most teachers thought of the first graphic (Figure 7: A map in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 24).) as a map. Some specified that it could be considered a *planisphere* (world map in French). Thus, the peculiar circles and arrows on the map did not prevent most teachers from calling it a map. Two teachers distinguished themselves from this general tendency, one Pakistani Physics teacher called it an illustration and one Pakistani Geography teacher called it a graphic.

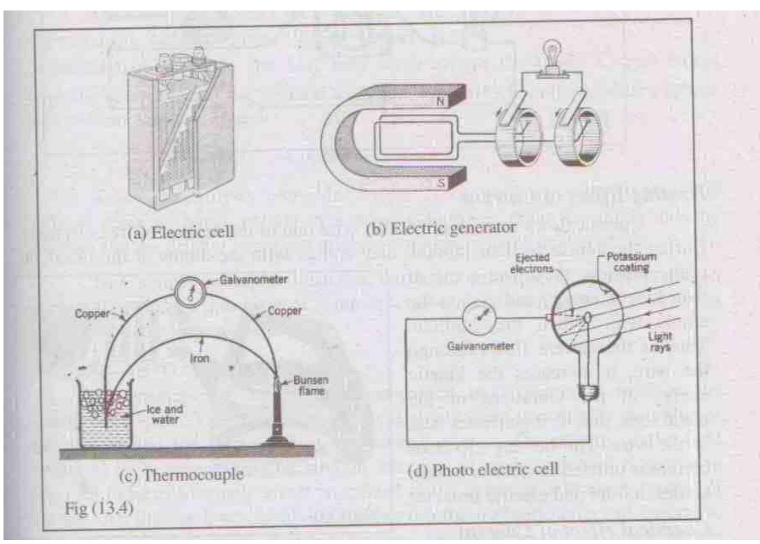


Figure 8: A depiction in a Pakistani physics text book (Khattak & Khattak, 2009, p. 53).

Most teachers thought of the second graphic (Figure 8: A depiction in a Pakistani physics text book (Khattak & Khattak, 2009, p. 53).) as either a diagram or a schema, and less frequently as a figure or simply a graphic. In fact, the graphic contains resemblance based-graphics and abstraction-based graphics. Therefore, very general labels seem to be appropriate for the teachers.

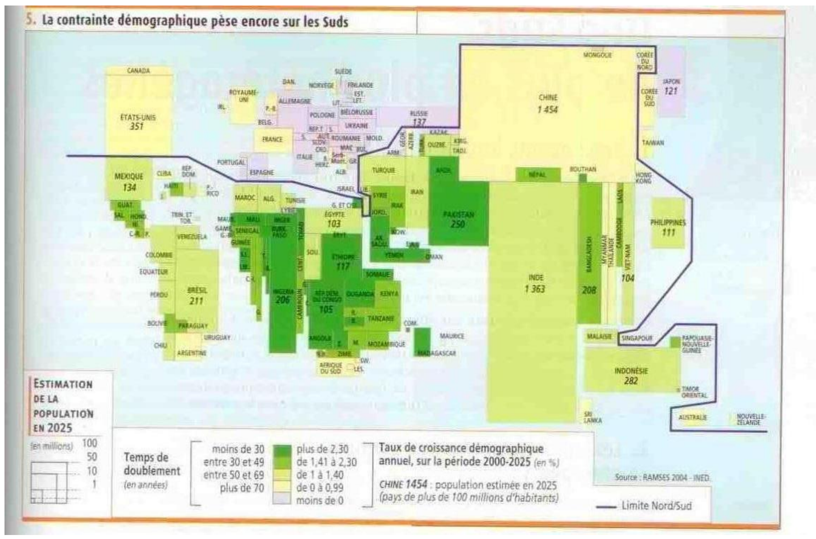


Figure 9. A hybrid of a map and a histogram in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 55).

The third graphic (Figure 9) can be considered to be a hybrid between a map and a bar chart or histogram. This mixture was also evident in the teachers' responses. Most teachers simply thought of it as a map, but other labels, such as bar diagram or histogram, were also used.

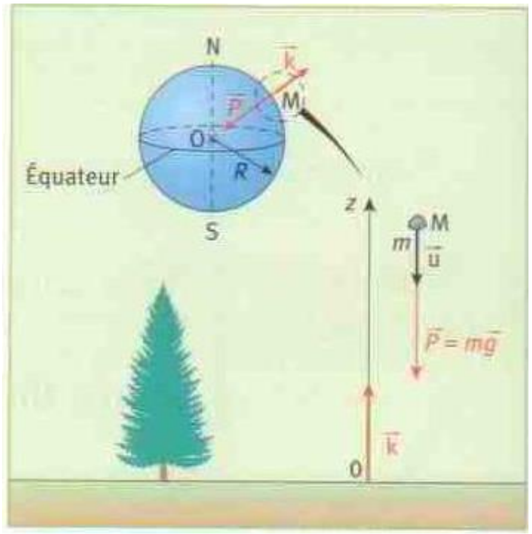


Figure 10. A graphic in the physics domain in a French physics textbook (Parisi, 2002, p. 150).

Four teachers labelled the fourth graphic (Figure 10) a diagram, but other labels, such as model, sketch, and even map, were also used. In effect, the graphic relies on resemblance, i.e. in the drawing of a tree, but also contains more abstract drawings and equations.

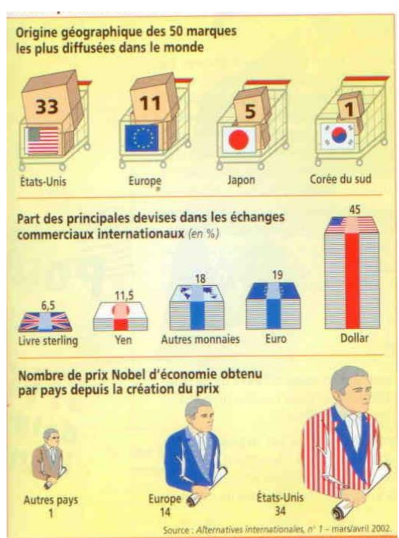


Figure 11. A diagram in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 123).

This fifth graphic (Figure 11) can be considered to be a bar chart with pictogram, or symbols according to Bertin's definition. Teachers did not use the labels pictogram or symbol, or even icon to refer to this graphic. Very general terms were used, such as figure, visual, image, and the like. Note that, whereas the graphic was taken from a textbook, it was originally not designed for instructional material.

Table 17.1 Approximate Elastic Moduli of some Materials

Material	*Young's modulus Y (Pa)*	*Bulk modulus B (Pa)*	*Shear modulus S (Pa)*
Aluminium	7.0×10^{10}	7.5×10^{10}	2.5×10^{10}
Brass	9.0×10^{10}	6.0×10^{10}	3.5×10^{10}
Copper	11×10^{10}	14×10^{10}	4.4×10^{10}
Crown glass	6.0×10^{10}	5.0×10^{10}	2.5×10^{10}
Iron	21×10^{10}	16×10^{10}	7.7×10^{10}
lead	1.6×10^{10}	4.1×10^{10}	0.6×10^{10}
Nickel	21×10^{10}	17×10^{10}	7.8×10^{10}
Steel	20×10^{10}	16×10^{10}	7.5×10^{10}

Figure 12. A table in a Pakistani physics textbook (Khattak & Khattak, 2009, p. 194).

The sixth graphic (Figure 12) was identified as a table by all but one Pakistani physics teacher who labelled it a model.

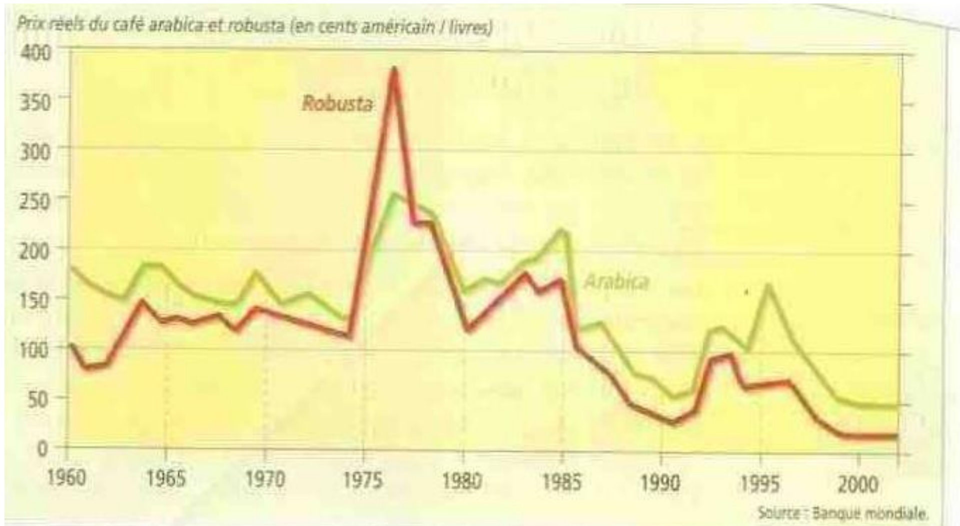


Figure 13. A line graph in a French geography textbook (Jalta, Joly, & Reineri, 2004, p. 55).

Several labels were used for the seventh graphic (Figure 13) but all can be assimilated to a line graph (curve graphic, graph). One French physics teacher called it a scatter plot.

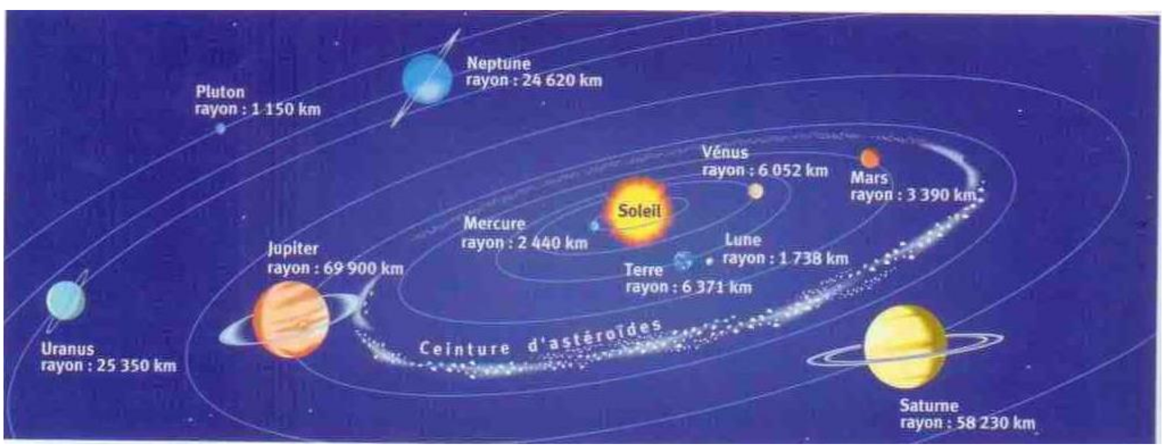


Figure 14. A hybrid of a decorational and a representational function in a French physics textbook (Parisi, 2002, p. 184).

The eight graphic (Figure 14) was labelled a map, a diagram or a graphic.

The results of teachers' labelling of the graphics are summarized in Table 3. From this table, as well as from the foregoing, we observe several things. First of all, although some categories seem to be more clearly established, such as "map", "line graph", and "table", there seems to be no rigorous vocabulary to designate different types of graphics, at least not in the set of teachers we interviewed. Furthermore, there is no clear distinction between what might be called resemblance based graphics (figure, image, visual, sketch) and convention based graphics (line graph, diagram, table). Although we would like to think of the set of different graphical formats as an educational toolbox, no shared glossary can be identified. Teachers, as experts in the transmission of knowledge, do not seem to think of graphics in a systematic way that goes beyond the general public. Let us exploit the analogy: what to think about a craftsman who does not have names for the different tools of the crafts? If these results are considered generalizable, then we must come to the realization that visualisations, at least as they appear in today's textbooks in Western and non-Western societies, cannot be considered an integral part of a teacher's toolbox.

Table 9. Teachers' labeling of educational graphics

	Graphic								
Given labels	1	2	3	4	5	6	7	8	Total
Map	6		5	1	1			2	15
Diagram		5		4	2			3	14
Table						8			8
Line Graph							6		6
Schema		2							2
Illustration	1								1
« Planisphere »	1								1
Figure		1			1				2
Histogram			1						1
Hologram			1						1
Bar diagram			1						1

Image					1				1
Visual					1				1
Organigramme					1				1
Model				1		1			2
Scatterplot							1		1
Sketch				1				1	2
Graphic	1	1	1	1			1	2	7
Other				1	2		1	1	5

3.5.2. The function of graphics

From Carney and Levin's five pedagogical functions, the decorational function was largely discarded for the eight graphics by teachers from both countries and both content areas. Teachers did not think of any of the graphics as being functional in motivating or attracting students. The most important function of graphics, as indicated by teachers, is to present specific information on a topic and furthermore, for students to be able to study subject matter. These two combined correspond to Carney and Levin's representational function of graphics. In addition, the line graph in Figure 7 was also thought to serve a comparison function between text and graphics.

Whereas Pakistani teachers seem to encourage memorizing data presented in tables for future recall, French teachers initiate exercises using tables so students will interact with the data. Moreover, Pakistani teachers adhere to traditional lectures with few opportunities for student participation. French teachers try to engage students in collaborative activities for understanding graphical representations. Finally, Pakistani teachers stay closely to text books provided by the government. Teachers in France, on the other hand, exploit multiple resources, such as the internet, multiple textbooks and journals in order to vary graphical representations. Some French teachers also develop their own graphical representations.

3.5.3. Confidence in student comprehension

Teachers from both countries and both content areas expect that students will easily understand the eight selected graphical representations. The teachers' rationale for their anticipation of student understanding lies in the knowledge that students have encountered graphical representations of the same genre. Several teachers indicated that these kinds of graphics are routinely used in teaching. They mentioned that students, as they habitually study such graphical representations, are used to them.

Some of the teachers were somewhat less confident about student comprehension of the map-histogram hybrid displayed in Figure 3. They think the graphic will be difficult for students to understand because "it is complicated" and "needs to be explained by the teacher". In looking for explanations, we might attribute this to the fact that the graphic is a hybrid of a map and a histogram. More precisely, it mixes two different resemblance relations, a spatial-geographical one of the topology of the countries on the surface of the earth and a logical-statistical one of correspondence relation between the surface of the rectangles and the magnitude of the displayed variable.

3.6. Conclusions

Let us briefly relate back to the three viewpoints evoked in the introduction. Regarding the first one, the presumed visual turn, it led us to compare two countries that show different economic circumstances and technological development for graphics in textbooks. We question presumed relations between culture and education on the one hand, and teachers' thoughts about graphics in teaching and learning on the other hand. The economic circumstances explain differences in the presence of graphics in textbooks. Far more graphics are present in textbooks in France than in Pakistan. However, it is interesting to note that, in spite of tremendous differences in educational system, teacher training, pedagogy and textbooks, teachers exhibit quite similar thoughts regarding the use of graphics in teaching and learning. Abundance in graphics in Western textbooks does not, for the moment, lead to the emergence of a systematic approach to the transmission of knowledge using the visual medium. We found no hints to the presence of more sophisticated conceptions about the role of graphics, such as those described by Ainsworth (2006), or by diSessa (2004), or even relations between graphical formats and functional taxonomies. The notion of a semiotic educational toolbox remains illusory.

The second viewpoint concerned the fact that, although the visual spatial medium is often equated with resemblance relations, both similarity and convention may rule visualisations. Looking at genuine authentic graphics in textbooks from different countries and in different content domains makes one realise that graphics do still seem to be one opaque category. Very many different graphical genres co-exist, as well as very many different labels, but no unique mapping between genres and labels. The question arises as to the importance of the words used to label a particular type of graphical representation in relation to particular suggested interpretation strategies, i.e. a picture for superficial examination, a schema for analyzing, a crosstable for structuring. The association between a goal or need, and a tool for satisfying that need, is crucial in many expert domains. Craftsmen for example interact using a number of different designations to refer to different tools of their trade. From a set of similar looking tools, they recognize pliers, pincers, snips, shears and wrenches and may be asked to explicit what they are used for. Further research would be needed to explore educational graphics and visualizations as a conceptual field with a variety of goals, needs, tools, and interpretative activities. This is also important given the fact that technological means have considerably enlarged the spectrum of visualisation possibilities. The design of visualisations for learning therefore involves finding the balance between full exploitation of new visualisation techniques and the anticipation of their pedagogical appropriateness.

Finally, the third viewpoint involved the need or, on the contrary, the superfluity of graphical competency, graphical literacy or graphicacy. The assumption that information is readily available from graphics by virtue of immediacy was firmly anchored in teachers' thoughts. Across countries and domains, sheer exposure to graphics in the past, habitually encountering graphical material in textbooks, is allegedly sufficient for understanding even complicated graphics. Future research should inquire into the veracity and the nature of teachers' and learners' representational knowledge in general and for pedagogical purposes. Furthermore, future work should tackle the question of teaching of representational knowledge in teacher training and in school curricula.

4. An exploration of the card sorting technique with Students

Understanding of graphical representations is a subject in itself. Use of graphical representations is increasing day by day in all domains. So, it becomes more important to identify different genres of graphical representations individually to understand them. There is no limit of graphic categories; from Bertin's four categories of graphical representations to Baynes's 49 types of graphical representations. The current study aims at to discover the Masters students' knowledge of different genres of graphical representations. Twenty students of the class of Masters in education participated in this study. We used the card sorting technique and asked the students to classify 50 graphical representations. They were instructed to classify those 50 graphical representations into clusters and gave a title to each cluster. Results showed that students' knowledge of graphical representations is limited to the familiar graphical representations they have seen or used earlier. The atypical graphical representations were considered difficult to classify.

Introduction

In our first study, we investigated in-service teachers' comprehension and pedagogical techniques about graphic representations. The results showed that the teachers were unfamiliar with the different types of graphical representations that they come across in their teaching practice. In this second study, the participants are Master 1 students in Education who may considered to be future teachers.

4.1. Categorizing graphical representations

As we stated earlier, the principle objective of graphical representation is to illustrate and present the information concisely in such a way that it becomes understandable for readers at a glance. Graphical representations help to clarify complex information. There are many categories of graphical representations and the number pf these categories is expanding on a daily basis. We assume that understanding different categories of graphical representations requires comprehending different layers of graphical representations. In the context of delivering a message, graphical representations are different from text and mathematics. It is essential to understand how a reader extracts the information from a graphical representation and what steps should be followed to understand its meaning. Damrong (2003) stated that graphical representations contain information at various levels and that extracting information from graphical representations is a two-step process: factual and inferential.

Factual information is the concrete kind of information which every graphical representation contains. The following steps are the sub-steps for extracting factual information from a graphical representation.

a) Type of Graphical representation: The first step is identifying the type of graphical representations. Usually different types of graphical representations are used to present different types of information. There are no rules that a specific genre of graphical representation can be used to present only a specific type of information. Furthermore, if a reader can identify the graphical genre, this does not prove that he or she can understand the graphical representation as a whole.

b) Title: The second step is reading the title. Usually, the title gives an overall idea of the content of a graphical representation. The title can often be found at the top of the graphical representation.
c) Captions and Legends: Captions usually describe the source of data and legends explain which symbol or color signifies which part of data. Tufte (1983) suggested that a legend should be presented aside the graphical representation so that the reader can see the graphical representation and legend at the same time without going backwards and forwards.
d) Facts: The fourth step is to explore the facts and compare the information.

Following these steps, the reader should be able to extract the factual information presented in a graphical representation. Factual information is only one part of graphic comprehension; the second part is inferring the implicit information from a graphical representation.

Some graphical representations like line graphs or bar graphs are considered easy to understand but other graphical representations require readers to make inferences. The extraction of inferred information asks for deeper thinking skills. There are three major steps to understand the implicit information (Damrong, 2003).

a) Objective: The reader must have an objective while he or she is reading the graphic.
b) Prior knowledge: Prior knowledge related to the topic of a graphical representation facilitates the reader to successfully infer the implicit information. Prior knowledge can be based on a reader's formal or informal education.

c) Application of knowledge: The reader should be able to apply his or her prior knowledge on a graphical representation to draw conclusions. Once a reader applies his or her prior knowledge, the reading of a graphical representation becomes easier (Damrong, 2003, p.8).

This study is an exploration of the Master students' capabilities of identifying different genres of graphical representations.

4.2. Research questions

There were three research questions investigated in this study:

1. How do Master students categorize graphical representations?
2. Do they follow an expert a priori categorization?
3. And finally, what are the characteristics of difficult to categorize graphical representations?

4.3. Method

4.3.1. Selection of graphical representations

We used 50 graphical representations from the domain of geography, physics, chemistry and mathematics, etc. All 50 graphical representations used in the study are available in the appendix 2. These graphical representations were taken from High school textbooks of history, geography and physics from France, Pakistan and Australia. Beside textbooks, some of the graphical representations were taken from international newspapers like The New York Times, Le Monde, etc. These graphical representations were chosen to provide a relatively varied set containing graphical representations from different genres discussed in Table 7: Summary of the category definitions. All these graphical representations were individually printed in color format on A4 pages.

4.3.2. Participants

Twenty Master 1 students in Education of the University of Grenoble participated in this study. These Master students are considered pre-service teachers in France. This study will serve as a continuation of our first study in which we investigated in-service teachers' comprehension of graphical representations.

4.3.3. The card sorting technique

The card sorting is a reliable, inexpensive and user-centered technique which involves sorting a set of cards into groups that make sense. The technique involves giving participants a set of cards containing subject matter. The participants are asked to sort the cards into homogenous groups and give a title to each group.

William (2012) considers Aristotle's classification of plants and animals as a first use of the card sorting technique. Monchi, Petrides, Petre, Worsley and Dagher (2001) stated that card sorting became prominent with "The Wisconsin Card Sorting Test" of neuropsychology in which they tested the ability to display flexibility in the face of changing schedules of reinforcement. In social sciences, early card sorting was used as an indicator of the functions of memory, mental processes and imagination. According to Spencer (2009), the card sorting is frequently used for brainstorming for exploring participants' point of view about a topic or to investigate what goes together and what does not.

There are three types of the card sorting techniques:

- Open sorting: users constitute their own categories
- Closed sorting: categorizations are predefined
- Hybrid sorting: a combination of both open and closed sorting

In open card sorting, the participants receive the cards without any pre-established grouping and are asked to sort cards which are alike for them into groups.

Here is an example of the three major steps involved in open card sorting.

Image

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Figure 15. Major steps in open card sorting (Sinyakov, 2013)

In closed card sorting, participants receive the cards and they have to place the cards into pre-established primary groups (see Figure 16).

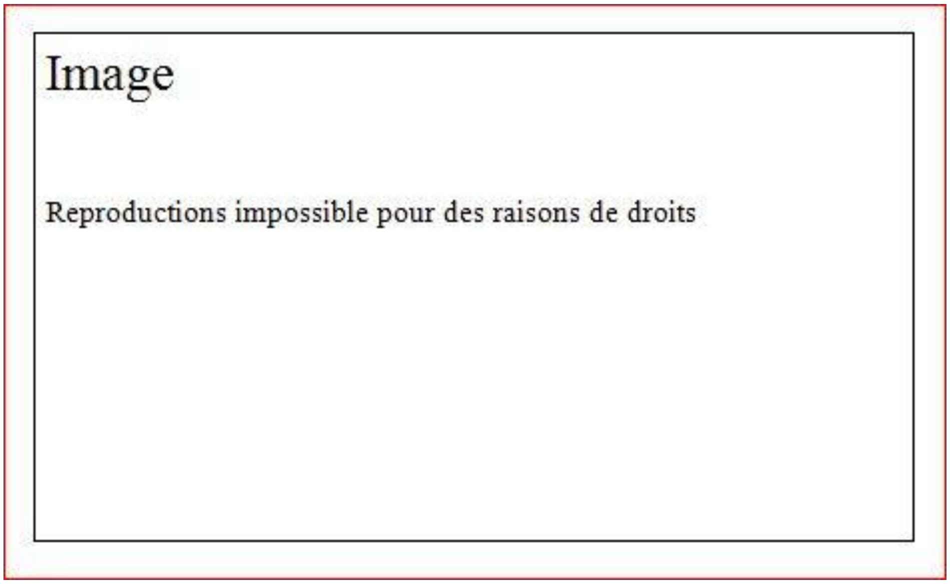

Figure 16. Closed card sort (Sinyakov, 2013)

The Card sorting can be conducted with groups or individuals with cards presented either in physical format or virtually on screen. According to William (2012), the results of the card sorting are presented in the form of cards frequently grouped together by the participants and the labels of the groups given to those groups. Usually three types of findings occur as a result of a card sorting activity

I. Terminology (what were the terms used by the participants for a specific cards)
II. Relationships (What were the similarities or relationships between items categorized together)
III. Categories (what were the categories and how were categories labeled by the participants)

4.3.4. Experimental setup

We used the open card sorting technique for our studies because open card sorting is considered the best choice as it provides maximum liberty to the participants. The participants create their own names for the categories which not only disclose how they categorize the cards, but also what terminologies they employ for the categories. Open sorting is frequently used to discover patterns in participants' classification. In our studies, we used 50 graphical representations as cards to conduct the card sorting study. Here are the instructions of our first card sorting study. These instructions are available in the appendix as well.

« Le regroupement : il est demandé aux participants de regrouper les cartes « qui se ressemblent », de «construire des familles » et de noter le résultat du tri dans un tableau. Ils peuvent dédoubler une carte afin de la faire apparaître dans différents groupes. Les participants doivent ensuite donner un nom à chacun des groupes construits. Ils peuvent enfin décider de rassembler des groupes afin de constituer une catégorie plus large qu'ils doivent également nommer ».

Here is the translation of those instructions for the convenience of the readers.

Grouping: We ask you to make groups of cards "that resemble each other", to "build families" And to note down the result of that classification in the table below. You can categorize a card in multiple groups. The participants have to give a title to each of the groups they built. At the end, they may decide to join some groups together to form a "group of groups" which they also give a name.

4.4. Results

4.4.1. A priori categorization

Before conducting the study with Master students, two raters categorized the 50 graphical representations keeping in mind the definitions listed in Table 7. The categorization was done in two steps. The first step involved individual categorization by two raters and the second step involved a discussion of the differences in categorization. A Cohen's kappa test was computed to check the reliability. The resulting kappa of .67 indicated that there were certain differences in categorizing diagrams, schemas, illustrations and pictograms. Diagrams and schemas were merged to resolve the differences. A Cohen's kappa test was recomputed which resulted in a value of .75. The remaining differences were discussed to decide inter-subjectively on the final categorizations. Table below is the result of a priori categorization after intersubjectivity.

Table 10. A priori categorization after intersubjectivity

Given labels	**Card Numbers**																				
Diagram/schema	2	4	8	9	13	14	15	19	20	21	22	23	33	35	42	43	44	45	46	47	49
Maps	1	3	11	16	24	25	26	27	28	29	30	38	41								
Line Graph	7	12	18	36	39	50															
Chart (pie & bar)	5	31	34	37	40																
Table	6	10																			
Illustration	17	32	48																		

4.4.2. Student categorization

A hierarchical cluster analysis with SPSS using Ward's method was conducted to find clusters. Burns and Burns (2008) stated that cluster analysis reduces the data into manageable subgroups and demonstrates the inter-relationships between variables. Furthermore, the Ward's method is different from other methods because it uses an analysis of variance approach to calculate the distances between the graphical representations. Following Burns and Burns (2008) method, we formulated an agglomeration schedule (Table 11) which provides every possible number of clusters from 1 to 50 (the number of cards in the study). The coefficient column was rewritten to find out the changes. Addition of that change column revealed the ideal number of clusters. In this case, suitable number of clusters is six because after that, we can notice clear distance among two cases in column "change". The dendrogram below may provide more support to the agglomeration schedule.

Table 11. Re-formed agglomeration table

Number of Clusters	**Agglomeration last step**	**Coefficients this step**	**Change**
2	1029,600	709,412	320,188
3	709,412	499,606	209,806
4	499,606	380,051	119,555
5	380,051	298,194	81,857
6	298,194	219,700	78,494
~~7~~	**~~219,700~~**	**~~174,478~~**	**~~45,222~~**
8	174,478	144,942	29,536
9	144,942	129,025	15,917
10	129,025	114,359	14,667
11	114,359	102,423	11,936
12	102,423	90,923	11,500
13	90,923	80,958	9,964

We can notice in column change that the distance between six clusters (78,494) and seven clusters (45,222) is bigger than the distance between the other solutions. After finding out that six is the optimal number of clusters, we re-performed the cluster analysis on SPSS with the predefined six clusters (see Figure 17).

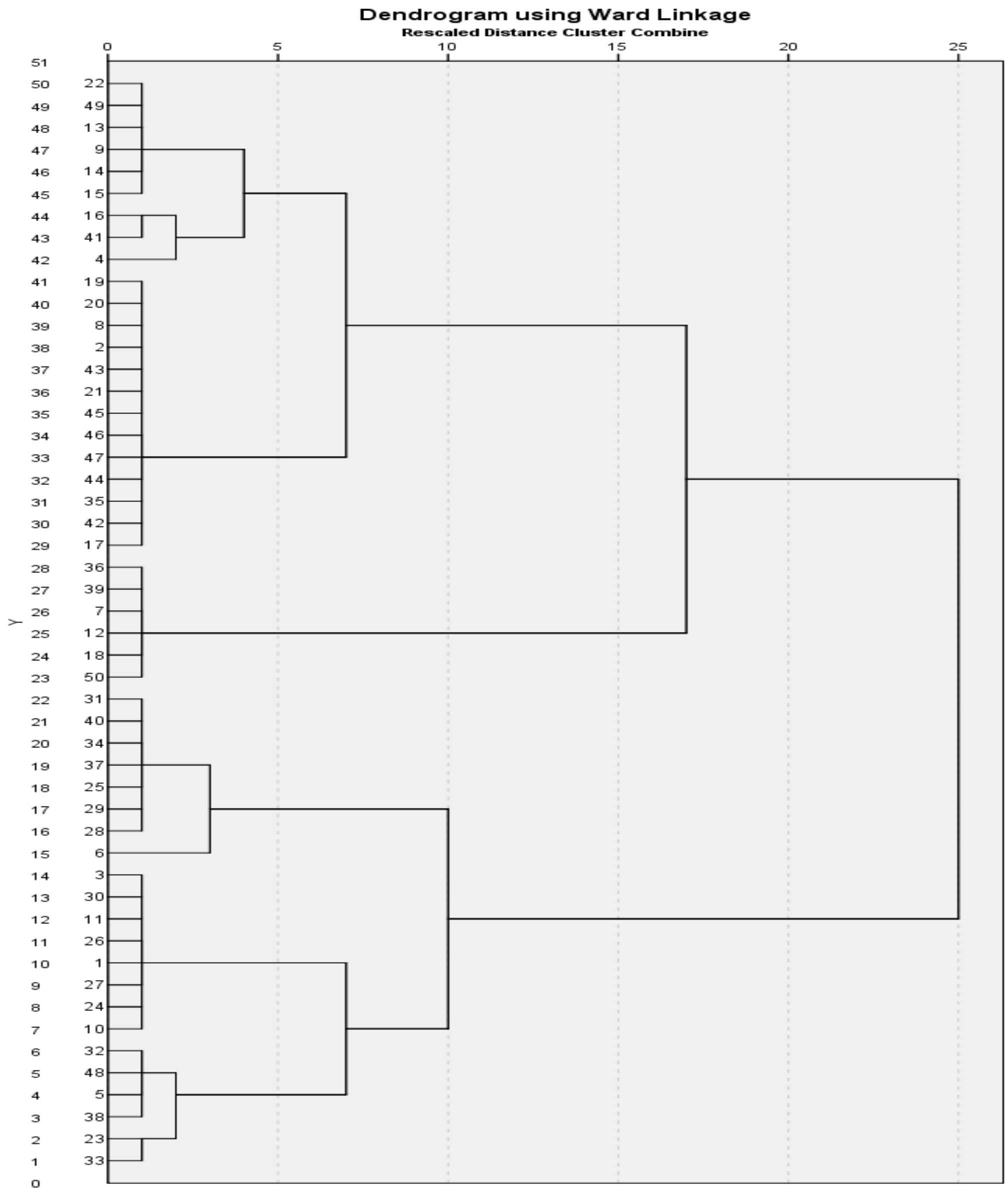

Figure 17. Dendrogram of clusters

The dendrogram above shows that there are six main clusters. We prepared a cross table to compare the students' categorization with the a priori categorization. This cross table will allow us to find the trends in the students' categorization.

Table 12. Cross table of a priori and student categorization

	Student categorization						
	4	3	1	6	2	5	Total
Diagram / Schema	19, 20, 21, 2, 8, 43, 45, 46, 47, 44, 35, 42	13, 14, 15, 22, 9, 4, 49				23, 33	21
Map		16, 41	3, 30, 11, 26, 1, 27, 24	25, 29, 28		38	13
Chart (pie & bar)				31, 37, 40, 34		5	5
Line Graph					36, 39, 7, 12, 18, 50		6
Illustration	17					32, 48	3
Table			10	6			2
Total	13	9	8	8	6	6	50

The cross table above gives an overview of the student and the a priori categorizations. We analyzed the each cluster individually.

4.4.3. Cluster 1

Image

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The

Figure 18. Graphics of student cluster 1. gives an overview of the graphical representations in this cluster. It contains 13 graphical representations which is the largest cluster of this card sorting study. These 13 graphical representations have in common that they were taken from the domain of physics, biology and geography. They contain diagrams of equipment, of phenomena or of processes. The majority of this type of graphical representations can be found in early school books. Therefore, it can be assumed that the students were familiar with these graphical representations.

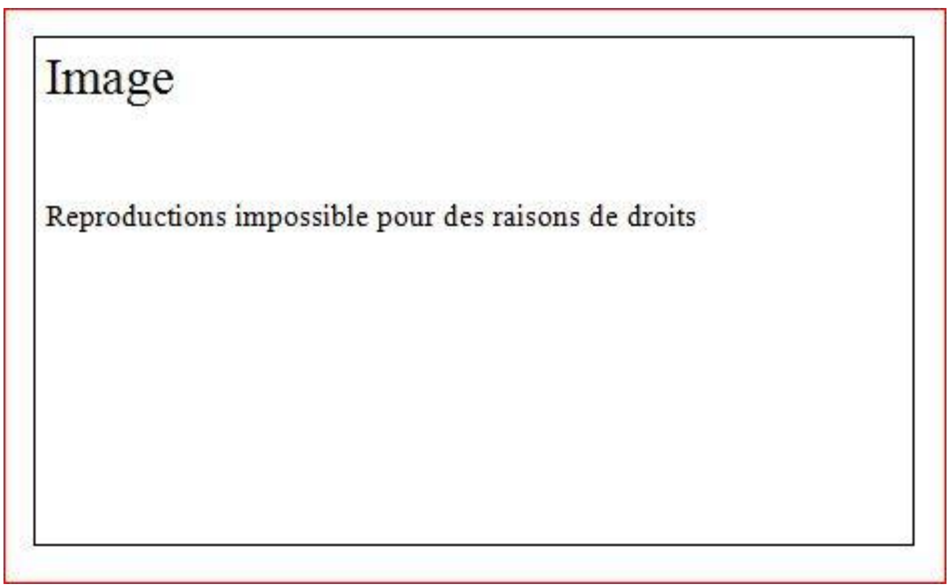

Figure 18. Graphics of student cluster 1.

In the a priori categorization, these graphical representations were categorized as diagrams except graphic 17. In the a priori categorization, graphic 17 was classified as an illustration. The main difference seems to be that this latter graphical representation is not based on an actual data or apparatus. This explains the expert categorization as an illustration.

4.4.4. Cluster 2

Cluster 2 contains eight graphical representations (see Figure 19). All the graphical representations of this cluster were taken from the domain of geography. We can call this a cluster of maps as these graphical representations were called maps in the a priori categorization.

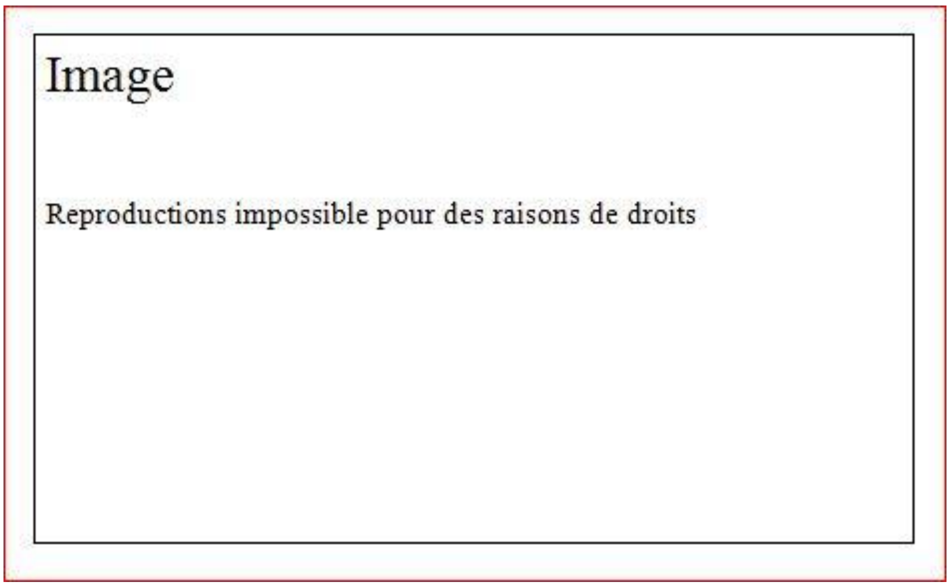

Figure 19. Graphics of students cluster 2

This is the second cluster in which the students categorized most of the graphics as they were categorized in the a priori categorization. Seven out of eight graphics were categorized together in the a priori categorization too. In the a priori categorization, these graphics were called maps except for graphic 10 which was labeled as a bar graph. Since graphic 10 contains geographical data, students might have categorized this graphic with the others for they are similar in domain content. In fact, at the end of card sorting task, some students explicitly mentioned that they categorized the graphics according to the content domain.

4.4.5. Cluster 3

This cluster contains six graphics (see Figure 20). This can be called the cluster of line graphs because these graphics possess the qualities of line graphs. Since the 18th century when Playfair introduced line graphs, this type of graphics have been used in all kinds of domains. Line graphs are one of those types of graphical representations which can be found in school and university textbooks.

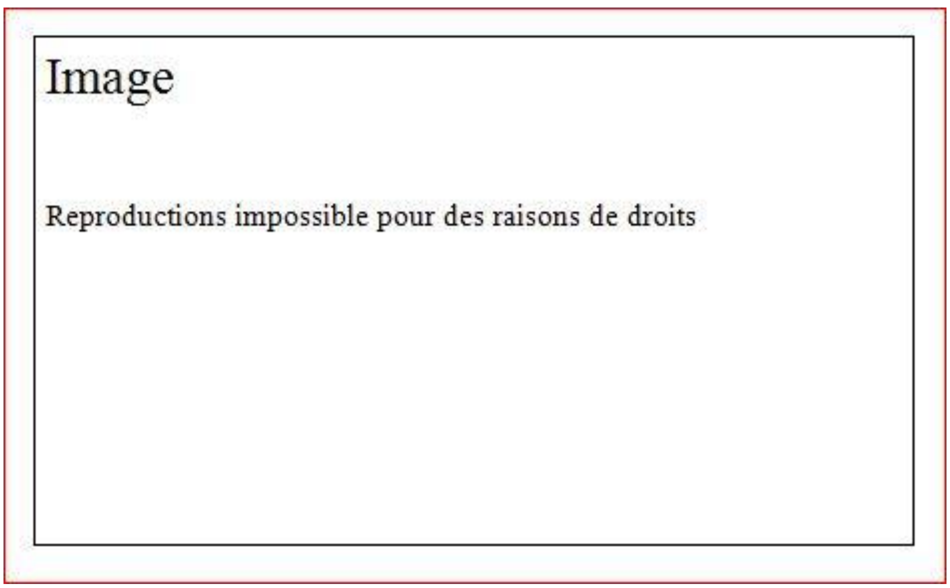

Figure 20. Graphics of student cluster

The students categorized these six graphics together in one cluster. In a priori categorization, these graphics were also categorized together. Table 12. Cross table of a priori and student categorization shows that this was the only cluster where the students' and the a priori categorization completely coincide. The possible reason can be the students' familiarity with these types of graphics and identification of these types of graphical representations is straightforward

4.4.6. Cluster 4

This cluster contains nine graphical representations (see Figure 21). The graphics in this cluster have in common that they contain different parts which are interconnected by lines.

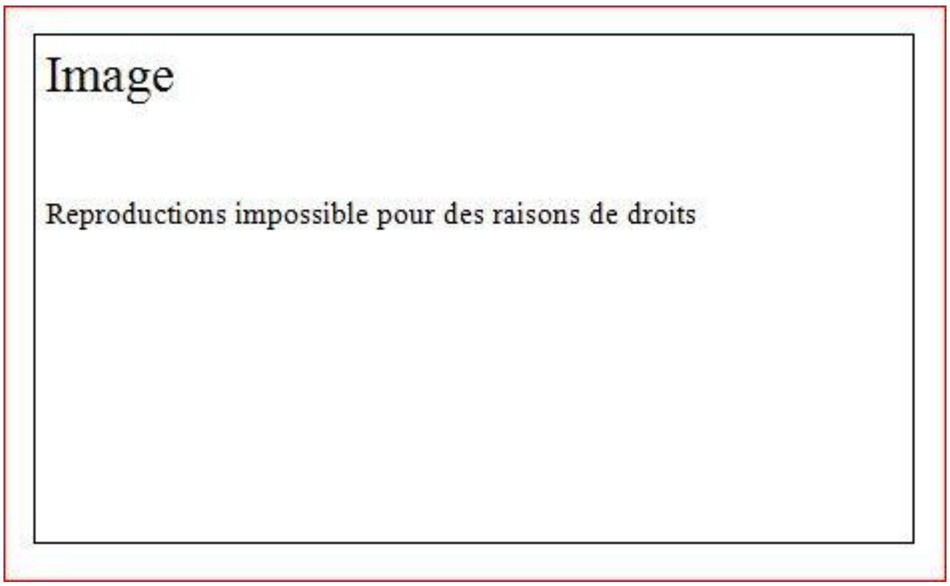

Figure 21. Graphics of student cluster 4

In the a priori categorization, seven out of these nine graphics were categorized as diagrams whereas graphics 41 and 16 were categorized as maps. The possible reason of the students' categorization of graphics 41 and 16 in this cluster is that both these graphics have similar appearance and lines as the other graphics in the cluster. Bertin (1983) would have classified these graphical representations as networks.

4.4.7. Cluster 5

This cluster contains six graphical representations (Figure 22). It can be noticed in Table 12 that this is the one cluster in which the a priori and the students' categorization completely differ.

Image

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Figure 22. Graphics of student cluster 5

In the a priori categorization, these graphics were classified in various categories. Graphic 33 and 23 were categorized as diagram/schema. Graphic 32 and 48 were categorized illustrations. Graphic 38 was labeled as a map and Graphic 5 as a chart (pie & bar).. Possible reasons of the student categorization of these graphics into one cluster can be the structure of these graphics. These graphics seem to share a rather abstract format and they have icons which connect different parts.

4.4.8. Cluster 6

This cluster contains eight graphical representations and we can call it a cluster of miscellaneous types of graphics (see Figure 29).

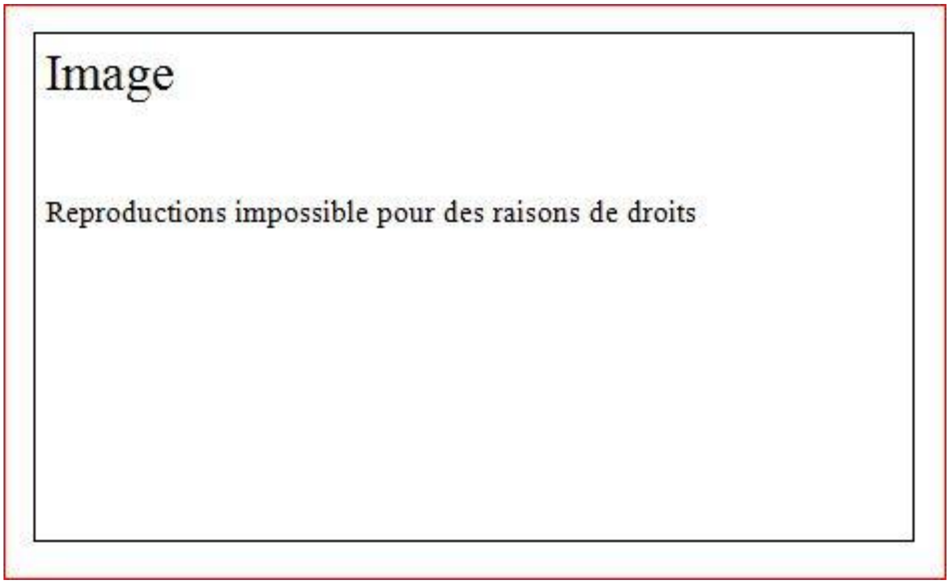

Figure 23. Graphics of student cluster 6

In the a priori categorization, graphic 31, 34, 37 and 40 were categorized as charts (pie & bar), graphics 25, 28 and 29 as maps and graphic 6 as a table. Contrary to the a priori categorization, the students categorized all these graphics together. One common aspect in all these graphics is that they are comparing different elements within the graphics. Furthermore, six out of eight graphics in this cluster were taken from the domain of geography. It is possible that the students categorized these graphics together keeping the subject domain in mind.

4.5. Discussion & Conclusion

The first question referred to the way Master's students categorize graphics. It is found that the students' knowledge of graphical representations is limited to the familiar graphics they have seen or used in their earlier education. They identified the graphics like typical maps, line graphs, diagrams etc. For example the clusters of maps, diagrams and line graphs contain those common types of graphics and the students' categorized majority of them following the a priori categorization.

Second question was that do they follow an a priori categorization? We can conclude that in case of majority of the graphics, the students and the a priori categorization coincide. For example, in cluster one, the students categorized 13 graphics together and 12 of them were categorized together in the a priori categorization too. In cluster two, seven out of eight graphics was categorized together following the a priori categorization. All six graphics of cluster three was categorized together both in a priori and the students' categorization. The cluster number three which contains six graphics, was the only cluster in which the students' and the a priori categorization completely coincide. But in the rest of the clusters, the student categorization showed some differences with the a priori categorization. And finally the third question was what are the characteristics of difficult cases in categorizing? There are some graphics which can be characterized as atypical. These were the graphics which were discussed in a priori categorization during intersubjectivity. Graphics 17, 23 and 33 are examples of atypical graphics. We assume that readers do not come across these types of graphical representations very often. So, we can conclude from the students' categorization that the atypical graphical representations were difficult to categorize.

Teaching of graphics together with the text is assumed important so that students can identify, comprehend and interpret graphics. After conducting this study, we noticed that 50 graphics took too much time in categorization and it would be difficult to conduct a final study with a large group of participants. We conducted our final study using 17 graphics which were designated by the participants as the most difficult to understand and to interpret.

5. Classifying graphic genres using card sorting technique

Classification of graphics is an aspect of investigating the basic knowledge about graphic genres. Classification process does not explain which part of a graphic was understandable for the reader and which was not? But a reader can't identify the genre of a graphic without having prior knowledge about graphics. We used open card sorting technique to question eighty four Master students' understanding of graphical genres. Among others, the results showed that the students had limited knowledge about atypical genre of the graphics. The sciences students particularly had difficulty in categorizing the abstract type of graphics.

5.1. Introduction

Graphical representations have been used in teaching and learning for a long time. They are considered to be a tool to enhance the learning process. Comprehension of the content from textbooks demands several skills and graphicacy is one of the important skills. Understanding the subject matter requires the background knowledge about the subject matter and we can assume that the skill of graphicacy makes the learning process more effective.

Mosenthal & Kirsch (1990) stated that despite the extensive use of graphical representations, comprehension of graphical representations and their structure is understandable for a small population only. Research in different countries has shown that students lack sufficient skills to develop, understand and interpret graphical representations. Gallimore (1990) stated the school students in UK are not trained enough to understand graphics. The National Assessment of

Educational Progress (NAEP, 1985) also stated that students in the U.S are lacking adequate training to understand graphical representations. Curriculum developers should pay more attention to sufficient training of graphicacy.

Well prepared graphical representations can lead towards better understanding of the text as well as badly developed ones can mislead. The majority of the graphical representations are developed to present the data in such a way that the reader can get the information in a single glimpse. Sometimes, the graphic developers pay so much attention to the decoration in the graphic itself that they forget its primary objective. The role of a good graphic is not to decorate the text but to effectively transmit data. A simple graphic can be very helpful to understand and transfer information. That ight be the reason why Wainer (1984) described three simple rules in his article "*How to display data badly*" that are 1) show the data; 2) show the data accurately and 3) show the data correctly.

Teachers and students sometimes face difficulties in understanding graphical representations because sometimes they are difficult (Kirsch & Jungeblut, 1986; Askov & Kamm, 1982; Askov, Kamm, & Klumb, 1977). In many cases, the teacher and the students are not familiar with the graphical representations. So, it's important to train teachers for proper use of graphical representations and to use more graphical representations in teaching to familiarize students with graphics. Teachers sometimes assume that students are capable of understanding the graphical representations. Gillespie (1993) enforces the point of view that the teachers should always devote some time for graphic reading and interpretation in the classroom.

Those studies mentioned above motivated us to investigate the students' comprehension of graphical representations. The majority of the previous studies were conducted with school students and teachers but we conducted this study with Master students. Our study will not investigate the whole paradigm of graphic comprehension but we will focus only on the knowledge of the students about graphic genres.

5.2. Research Questions

The three questions for this study were the same as in the previous chapter:

I. How do Master students categorize graphical representations?

II. Do they follow an expert a priori categorization?

III. What are the characteristics of difficult to categorize graphical representations?

5.3. Method

5.3.1. Participants

Master students' from various French university institutes for teacher training participated in this second card sorting study. Overall eighty-six Masters' students (fifty-nine students of education and twenty-six students of the sciences i.e. physics, computer sciences and biology etc.) took part in this study. These participants were those who responded to our request for volunteers to participate in the study. The participants participated in two different ways: forty five students were approached in the universities and forty one students participated via online card sorting. Although the study was conducted in two different ways,; online and on paper, there were no differences in graphic representations and instructions of the study. We will explain later in the experimental setup how we conducted the online card sorting.

5.3.2. Graphical representations

We employed 17 graphic representations for this study. All these graphics were a part of our first card sorting study in which we used 50 graphics. These graphics were taken from textbooks history, geography and physics from France, Pakistan, Australia and from international newspapers. In the first study, we identified these 17 graphic representations as the most difficult to understand and interpret. The set of graphics (see Table 13) contains different genres of graphics, such as maps, diagrams, charts, illustrations, and bar graphs.

Table 13. The graphics used in 2nd card sorting study

Image

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5.3.3. Experimental setup

Once again, we used open card sorting for this second study. We asked the thirty-one Education students and fourteen Science students to categorize the 17 graphics showed above. All 17 graphics were printed individually on a sheet and each participant was handed a deck of graphics including the page of following instructions:

Note: The instructions were in French for the convenience of French students and we translated them into English for the convenience of the readers. Original instructions are presented in the appendix 2.

"I am a Ph.D. student in educational sciences at the University Pierre Mendes France of Grenoble. The subject of my thesis is the use and understanding of graphics in teaching and learning situation. I would like to explore the students' conceptions about it. I will ask you some questions about use of the graphics. There are two parts of this study; in first part, you have to develop graphic families which are alike for you from the given 17 graphics. In second part, you have to give a few reasons why did you put a specific graphic in a specific group".

For online participants, we prepared an online study on a site www.websort.net. This website is user friendly and especially designed for online card sorting. We used the same 17 graphics and instructions for the online study which we used for on paper study.

5.4. Results

To evaluate the categorizations by the students, we conducted a cluster analysis with SPSS using Ward's method which we already explained in our first card sorting study. The agglomeration schedule (Table below) provided every possible number of clusters from 1 to 17 (the number of graphics). We took the central column named coefficients.

Table 14. Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	4	14	32,000	0	0	13
2	1	6	98,000	0	0	10
3	12	17	174,000	0	0	12
4	10	15	254,000	0	0	6
5	8	16	370,000	0	0	13
6	7	10	500,667	0	4	12
7	3	5	633,167	0	0	10
8	2	11	768,667	0	0	11
9	9	13	930,167	0	0	11
10	1	3	1102,417	2	7	14
11	2	9	1282,417	8	9	14
12	7	12	1483,750	6	3	15
13	4	8	1696,250	1	5	15
14	1	2	1973,875	10	11	16
15	4	7	2412,931	13	12	16
16	1	4	2936,353	14	15	0

We rewrote it in Table below which helped us to see the changes in the coefficient. We added a new column named change to establish the ideal number of clusters. In this case, six is the suitable number of clusters and the dendrogram below will provide more support to the agglomeration schedule.

Table 15.Re-formed agglomeration table

No of Clusters	Agglomeration last step	Coefficients this step	Change
2	2936	2412	523
3	2412	1973	439
4	1973	1696	277
5	1969	1483	212
6	1483	1282	201
7	1282	1102	180
8	1102	930	172

Note. A clear demarcation point seems to be here at cluster six.

In the table above, we tried to identify the suitable number of clusters. After rewriting the coefficient downwards, we can notice a remarkable difference at level seven. After finding out that 6 are the best number of clusters, we re-performed the cluster analysis asking SPSS to perform the cluster analysis with six clusters only. Here is the dendrogram table

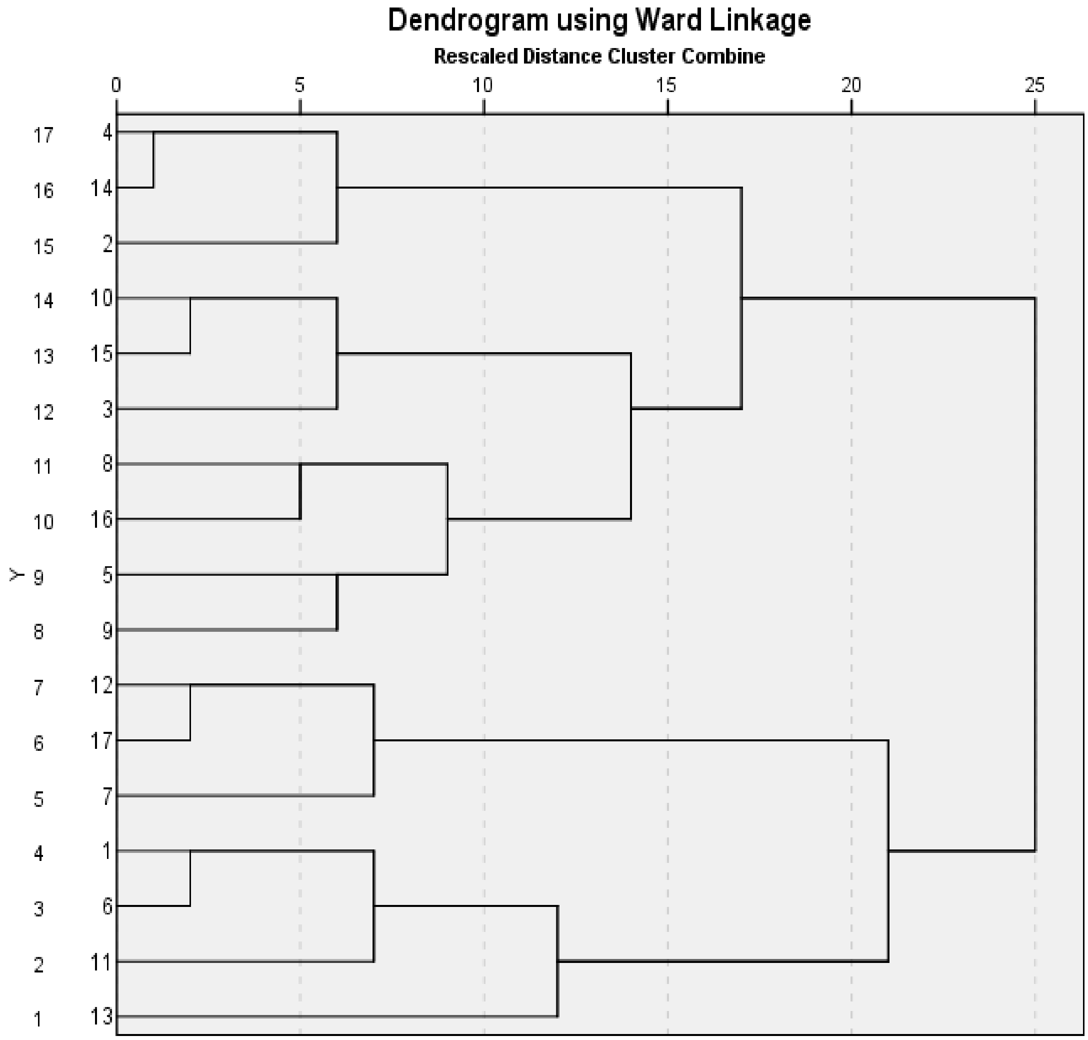

Figure 24. Dendrogram using ward linkage

We created below a table of those six clusters to get a clear view of the graphics categorized in each cluster.

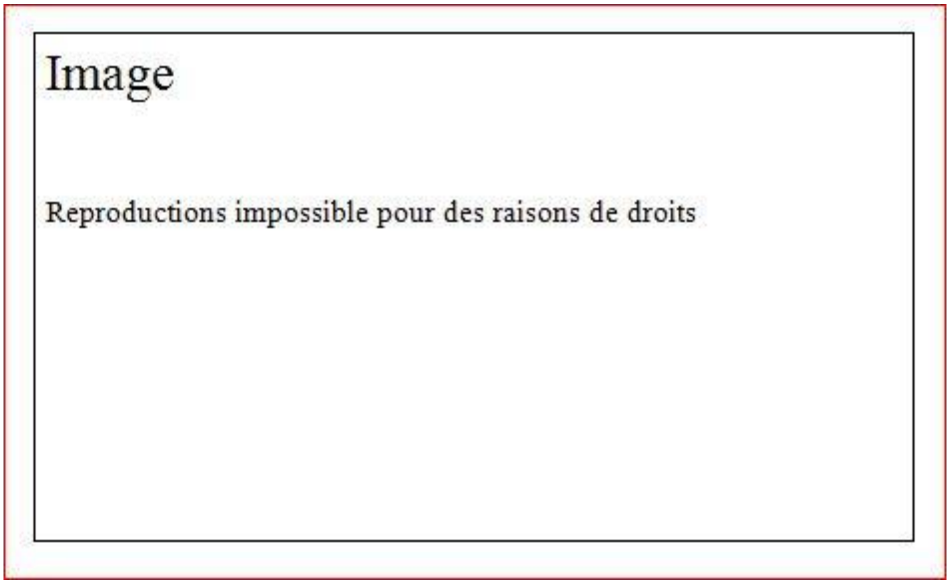

Figure 25. Final classification of graphics

The table above shows the graphics in each of the six clusters. Afterwards, we created a cross table of students' categorization and the a priori categorization of the previous chapter to compare both categorizations. This cross table showed the positions of each graphic individually and in the clusters.

Table 16. Cross table of a priori and student categorization

	Student Clusters						
A priori clusters	3	1	4	5	2	6	Total
Diagram/schema	15, 20, 21, 43	4, 8, 35			23	33	9
Illustration			17, 32, 48				3
Maps				3, 16, 29			3
Bar graph					5, 37		2
Total	4	3	3	3	3	1	17

We analyzed each cluster in the light of the cross table and the students categorizations.

5.4.1. Cluster 1

This cluster contains three graphical representations (see Figure 26. Graphics of student cluster 1). Two of these graphics were taken from the domain of geography and one from physics.

Image

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Figure 26. Graphics of student cluster 1

In our first card sorting study, two of these graphics (8 and 35) were also categorized together. Table 16 clearly shows that in this final categorization, the students' categorization coincides with the a priori categorization. All three graphics were classified as diagram/schemas in the a priori categorization. One common aspect in all three graphics of this cluster is that all of them are depicting the positioning of different objects within the graphic. Fry (1981) classified this type of graphics as spatial graphics in his taxonomy of graphics. On the other hand, Bertin (1983) classified this type of graphics in his category of diagrams.

5.4.2. Cluster 2

This cluster also contains three graphical representations (see Figure 27). Two of these graphics (5 and 23) were also categorized together in our first card sorting study. All three graphical representations in this cluster were taken from the domain of Geography.

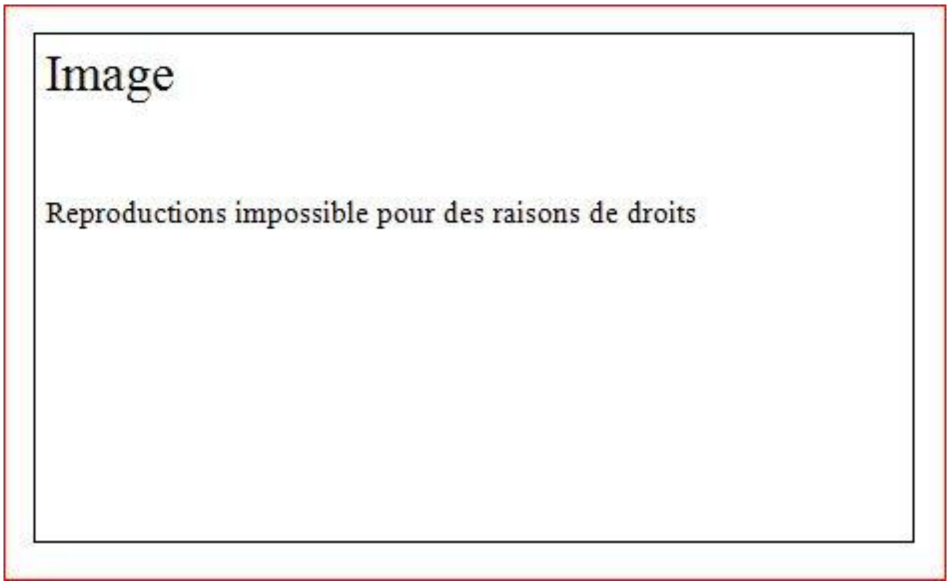

Figure 27. Graphics of student cluste 2

In the a priori categorization, two of these graphics (5 and 37) were categorized as bar graphs whereas graphic 23 was categorized as a diagram/schema. But the students categorized all three graphics together. Graphic 23 could be a bar graph but it violates the rules of conventional bar charts because the largest quantity is divided in two at each step (e.g. 5 million becomes 3.5 and 1.5 million). Bertin (1983) would have categorized all three graphics in the category of diagrams.

5.4.1. Cluster 3

This cluster contains four graphical representations (Figure 28). Three of these graphics (20, 21, and 43) was categorized together in our first card sorting study too. In the a priori categorization, all four graphics were categorized as diagrams/schemas.

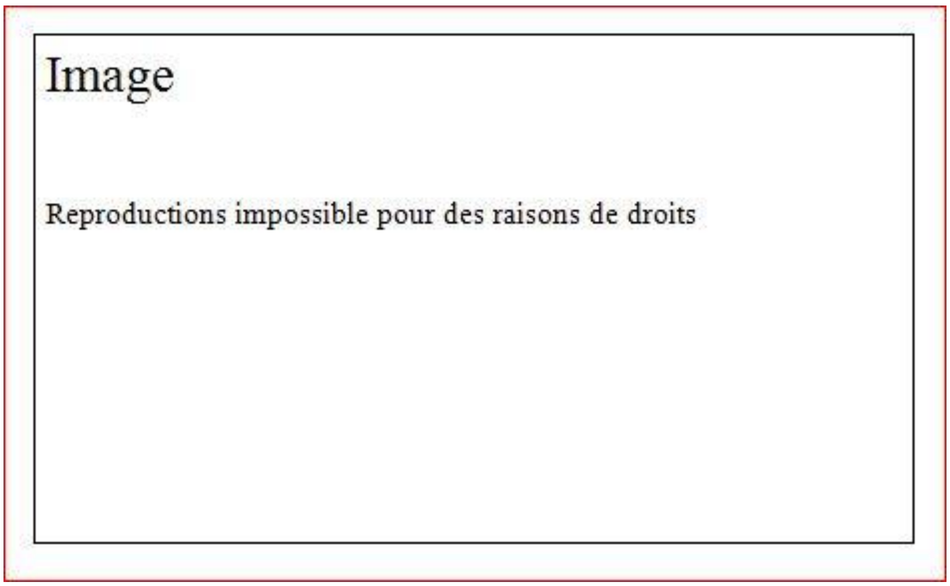

Figure 28. Graphics of student cluster 3

Although all four graphics are not from the same domain, Table 16 clearly shows that both the a priori and the student categorization completely match for this cluster. Bertin (1983) also would have categorized these graphics in his category of diagrams.

5.4.2. Cluster 4

This cluster contains three graphical representations (Figure 29). Two of these graphical representations (32 and 48) were also categorized together in our first card sorting study. All three graphics were taken from international newspapers.

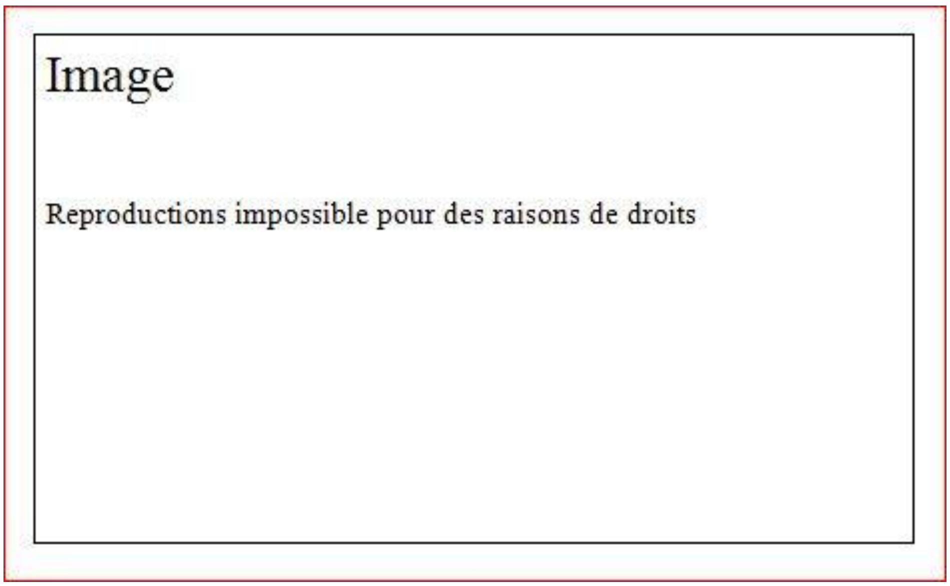

Figure 29. Graphics of student cluster 4

Table 16 shows that both the a priori and the student categorization match in this cluster. In the a priori categorization, all three graphics were categorized as illustrations. Fry (1981) categorized this type of graphics as pictorial abstract graphics. On the other hand, Bertin (1983) categorized this type of graphics as diagrams.

5.4.3. Cluster 5

This cluster contains three graphical representations (Figure 30). Two of these graphical representations (3 and 29) were taken from a French Geography textbook and graphic 16 was taken from a website.

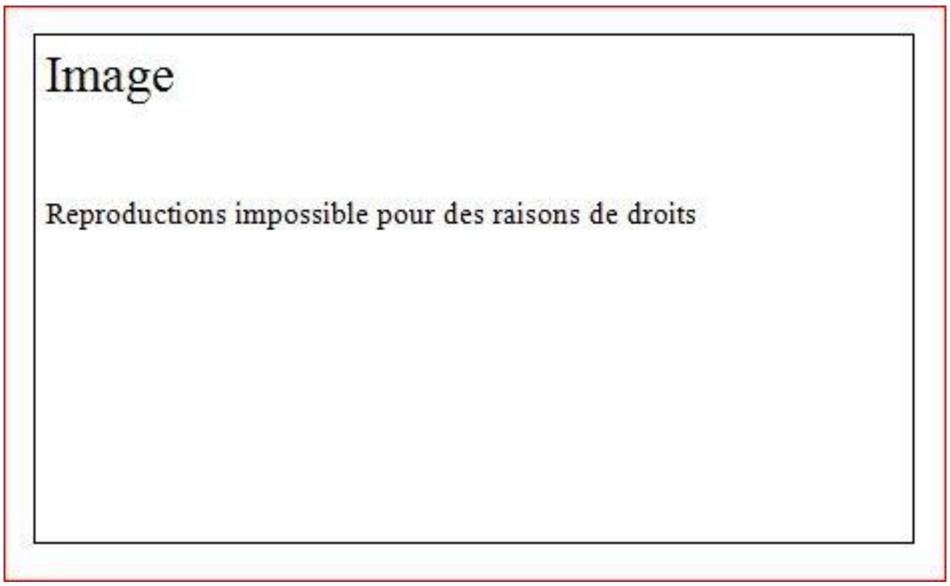

Figure 30. Graphics of student cluster 5

In the a priori categorization, these three graphics were also categorized together in the cluster of maps. Table 16. Cross table of a priori and student categorization shows that both the a priori and the students' categorization coincide in case of this cluster. Bertin (1983) also categorized this type of graphics as maps.

5.4.4. Cluster 6

This cluster contains only one graphical representation (Figure 31). In our first card sorting study, the students categorized it in various clusters.

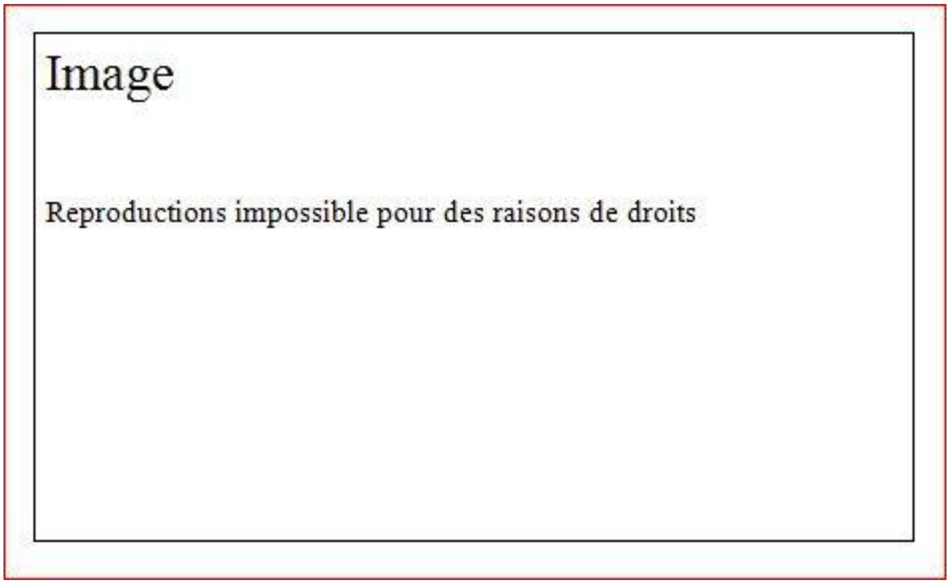

Figure 31. Graphic 33 (An image of NASA Pioneer Plaque, NASA, 1972)

Graphic 33 falls into the category of diagram/schema in the a priori categorization. In fact, one can categorize this graphic in various categories. One could say that it has characteristics of illustrations (a man and a woman), of a map (sun and nine planets) and of diagram/schema because of its high level of abstraction.

5.5.Discussion

The first question was ‘how do Master’s students categorize graphics? A hierarchical cluster analysis using Ward’s method showed that the students categorized the 17 graphics into six clusters. However, the card sorting technique has its limits and it does not show the process of categorization. Card sorting can provide the clusters and graphics frequently categorized together but can’t provide the reasoning of those categories except asked separately.

The second question was whether the student categorizations would resemble the a priori categorization. Table 1 showed remarkable similarities between the two categorizations. For example, student cluster 4 coincided with the a priori genre of maps and student cluster 5 was identical to the a priori genre of illustrations. Figure 32 shows the a priori category of maps. According to Bertin, “A graphic is geographic ‘map’ when the elements of a geographic component are arranged on a plane in the manner of their observed geographic order on the surface of the earth” (Bertin, 1983, p. 285). However, each of these three graphics has a particular property that makes it less of a map. Graphic 3 actually could also be categorized as a bar chart. Graphic 16 could be categorized as an illustration and graphic 29 actually displays the surface of Mars rather than the earth. Despite these properties, these graphics were categorized as maps in both students’ and the a priori categorizations.

Image

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Figure 32: Map cluster, graphics 3, 16 and 29

Finally, in the a priori categorization, nine out of 17 graphics were categorized as diagram/schemas, whereas the students categorized these nine graphics into four clusters. Within these four, the second largest (three graphics) cluster contained diagrams with a depiction of the earth, which indicates a domain specific criterion. In sum, we can conclude that the student categorizations resembled the a priori categorization.

The third research question inquired about the characteristics of difficult cases in categorization. Figure 33 shows the two graphics which seem to stand by themselves in Table 16. Cross table of a priori and student categorization. Graphic 23 was categorized with bar graphs in the students' categorization, but it was identified as a diagram/schema in the a priori categorization. As we mentioned in cluster 2, it violates the conventions of bar charts because the largest quantity is divided in two at each step (e.g. 5 million becomes 3.5 and 1.5 million). Finally, in the students' categorization, cluster six contains only graphic 33 which falls into the diagram/schema a priori category. Looking more closely, one could say it has characteristics of illustrations (a man and a woman), of maps (the sun and nine planets) and of diagram/schemas because of its high level of abstraction.

Image

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Figure 33: Graphics 23 and 33

5.1.Conclusion

It was noticed that graphics genres are expanding rapidly but that students frequently encounter traditional graphics only. New genres of graphics are being published in textbooks, newspapers etc. but the teachers are hesitant to introduce those graphics to their students. It can be assumed that teachers and students sometimes face difficulties in understanding graphical representations because either the graphical representations are difficult or students are not familiar with them. Regular use of new genres of graphics in teaching and learning will oblige the teachers and the students to explore them. Furthermore, it is suggested that the teachers should consider different genres of graphic as individual entities. For further investigation, it would be interesting to examine the teaching of graphics in teacher training institutes.

6. Conclusion and General Discussion

This chapter includes general discussion of main results of all three studies. Theoretical and practical implications were also discussed. Thereafter, the chapter ends with limitations and recommendations

6.1.Main results

The studies in this thesis are based on two parts: teachers' comprehension and teaching of graphics and Master students' categorization of graphical genres. The first part, described in chapter 3, is on teachers' thoughts on visualizations in culturally diverse settings. Chapter 4 and 5 are two studies with Master students using the card sorting technique to explore their comprehension of graphic genres.

Before discussing the main results, here is a brief summary of all three studies.

The first study (chapter three) was conducted in the context of intercultural comprehension of graphical representations. High school teachers from France and Pakistan were questioned about teaching and learning of graphics in schools. Despite the cultural, economic and technological differences and different teacher training approaches, teachers' approach of dealing with graphics had great resemblance. Teachers were interrogated about genre, function and students' comprehension of graphics in teaching and learning situations. The teachers clearly identified between maps, line graphs and tables as compare to resembling graphics (i.e. figure, sketch and image etc.). Although graphical representations are widely considered to be a mean of attracting the audience towards the subject matter. The teachers did not agree, but rather considered graphics to be a tool to merely deliver the subject matter. And finally, teachers thought that the majority of the graphics were understandable for students as students had already seen those kinds of graphics. The hybrid kinds of graphics were considered difficult for students.

In second study (chapter four), 20 Master students from the domain of Educational sciences were questioned about the comprehension of different graphical genres. 50 graphical representations were taken from textbooks from France, Australia and Pakistan and from some international newspapers. These graphical representations consisted of the most common genres, such as maps, diagrams, line graphs, bar graphs, pie charts etc. Card sorting was employed to investigate students' classification of graphics. Hierarchical cluster analysis showed that students categorized the graphics into six categories. It was found that the students identified common types of graphical representations (i.e. maps, line graphs, diagrams etc.). In case of some graphics, the a priori and the students' categorization coincide. For example in cluster one, students categorized 13 graphics together and 12 of them were categorized together in a priori categorization too. We can conclude that the students' categorization matched the a priori categorization in case of common genres of graphics (i.e. maps, line graphs, networks and pie charts etc.)

In the third study (chapter five), we investigated 84 Master students' comprehension of graphical genres. We used 17 graphical representations in this study. Those 17 graphics were classified as the most difficult ones in the second study. It was found that majority of the student clusters coincided with the a priori categorization. There were two graphics which were categorized differently by the students as compared to the a priori categorization. Both of those graphics were unconventional or atypical. It was noticed that the graphical genres are expanding but the students and the teachers are not familiar with those new genres.. Teachers and students sometimes face difficulties in understanding graphical representations because either the graphical representations are difficult or they are unfamiliar. A practical implication is that regular use of new genres of graphics in teaching and learning should allow obliging the teachers and the students to explore them.

6.1.1. Graphics in textbooks

We discussed in chapter two that graphical representations are part of curricula over the globe. Irrespective of cultural, geographical and economical differences, graphics can equally be found in textbooks everywhere. In our first study, we employed graphical representations from French and Pakistani textbooks of Physics and Geography. Table 8 clearly shows differences regarding the presence of graphical representations in French and Pakistani textbooks. First of all, French textbooks (both geography and physics) contain many more graphics than Pakistani ones. In addition, graphical representations in French textbooks entail color, whereas Pakistani textbooks mostly contain black and white graphical representations. Finally, French textbooks comprise a larger variety of graphical representations than Pakistani textbooks. Tables are the only type of graphical representations which exists in all four textbooks studied. These differences can largely be traced back to the differences in the available financial and technological means reserved for schoolbooks in both countries. When financial and technological resources are scarce, the type of graphical representations is reduced to the indispensable for particular domain contents. As can be read off from the table, the Geography content domain minimally requires maps and tables and for the Physics content domain, diagrams, line graphs and tables are essential. The low number of graphics in Pakistani textbooks is not likely to originate from national government policies. In Pakistan, the National Bureau of Curriculum and Textbooks (NBCT), also known as the curriculum wing, formulates rules and regulations regarding textbooks. The National Textbook and Learning Materials Policy and Plan of Action (Govt. of Pakistan, 2007) does not pay any specific attention to visual or graphical material (see also Khalid, 2010).

6.1.2. Teaching of graphics

Graphical representations are considered to be a tool to facilitate text comprehension but complex graphics may make it more difficult to relate them to the text. Gillespie (1993) stated that many students are incapable of understanding and interpreting graphical representations. Teachers must work on attracting students toward graphical representations and use graphics from textbooks as examples. Teachers' awareness of different genres of graphical representations in pedagogical practices could not get much attention of the researchers. Geography is the only domain in which teachers are taught to develop, understand and interpret graphical representations. It is obvious from the examples of curricula from different countries in the beginning of this thesis that graphical representations are essential part of school programs. The results of our first study with in service teachers showed that even Geography teachers from both France and Pakistan were hesitant about some genres of graphics. We found that despite remarkable differences in educational system, teacher training, pedagogy and textbooks, the teachers' exhibit quite similar thoughts regarding the use of graphical representations in teaching and learning.

6.1.3. Knowledge of graphics genres

We discussed several times different research on comprehension of graphical representations but very few research is found on comprehension of graphical genres. Students have to deal with many graphical representations in almost all domains but graphical representations come with limited or no instruction. We concluded from our first study that even teachers sometimes do not bother to explain graphics entirely. The main focus of teachers remains on text and students have to either work on graphics themselves of skip them. Betrancourt, Ainsworth, de Vries, Boucheix and Lowe (2012) also argued that graphicacy should get more attention in schools because even students who have used different graphical representations can face difficulty dealing with a depictive type of graphics.

We assembled the graphic categorization of the two studies with the classification of graphical genres discussed in the theoretical chapter. It is found as a result of both studies that diagrams, maps, line and pie graphs were those types of graphics which were classified clearly both in the a priori and the students' categorization. Bertin (1983) categorized those illustrations, bar charts and diagrams in a large category called diagrams. Fry (1981), on the other hand, called illustration type graphics "pictorials". Whereas, Carney and Levin (2002) categorization was aimed at to distinguish the graphical representations on the basis of their function and not the type. Thus, from their point of view, the majority of the graphics used in the studies in this thesis can be called the representational graphics. We can conclude on the basis of the discussion above that there is no ultimate resolution on the classification of graphical genres. Graphical representations can be classified in many ways following different approaches or convictions.

6.2.Limitations

There are some limitations of the studies conducted in this thesis.

We used card sorting for two studies, but this technique has the limit of not giving the reasons for classification. Consequently, we could not find the reasoning of the students classification of graphical representations. Multiple techniques should be used along with card sorting to study the reasons of graphical classification and to improve comprehension of graphics.

The participants of our studies were volunteers and we had no over different variables, such as the age of the participants, their gender or their domain of study, etc.

6.3.Recommendations

Reverse card sorting is another way to find whether participants categorize graphics in the same way as experts. In reverse card sorting, the participants have to rearrange the cards into a pre-established structure of categories and subcategories.

Future research should inquire into the veracity and the nature of teachers' and learners' representational knowledge in general and for pedagogical purposes. Furthermore, future work should tackle the question of the teaching of representational knowledge in teacher training and in school curricula. Further research would be needed to explore educational graphics and visualizations as a conceptual field with a variety of goals, needs, tools, and interpretative activities.

7. Bibliography

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