Institute for Media
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University of St.Gallen

=mcm *working paper*

No. 2/2011

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The Visualization of Classification in Qualitative Research

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July 2011

To cite this paper:

Eppler, M.J., Mengis, J. (2011) Drawing Distinction: The Visualization of Classification in Qualitative Research. *=mcm working paper*, No. 2/2011, July 2011. St. Gallen: =mcm *institute*, University of St. Gallen. [Retrieved online at: www.knowledge-communication.org]

Drawing Distinctions:

The Visualization of Classification in Qualitative Research

Martin J. Eppler & Jeanne Mengis

Abstract:

Classifying empirical phenomena or theoretical contributions is a key step to building new knowledge, especially in the early stages of the research process. Classification can bring about multiple advantages, such as overview and comparison or identification of discriminating attributes. Yet it also poses several risks and constraints. Visualizing the drawn distinctions can make a classification accessible and versatile, which makes it easier to evaluate and compare with other classifications. It can augment the research process, including hypothesis formation, testing, interpretation, and reporting. However, there is to date no systematic overview of methods to represent qualitative classifications graphically. This paper fills that gap in the literature. We distinguish among four types of visual classifications, based on their differing ability to emphasize hierarchies or (lateral) group relations. We label these as compilations, configurations, layers, and trees. We analyze their benefits for the research process and point out risks to consider when using visualization for classification in qualitative social science research.

KEYWORDS**:** *Classification, taxonomy, typology, graphic representation, research*

1. Introduction

A key element of many social science research endeavours is the systematic classification of different phenomena or items in a domain or area. This can be done deductively, in the form of a theory-based typology, or inductively, through the creation of an empirically grounded taxonomy. The latter is practiced in quantitative research through cluster analysis, for example, a method through which subsets of a sample are identified on the basis of their similarity for a specific characteristic or variable. In qualitative research, *classificatory frameworks* are a widely used (Marradi, 1990; Nowotny, 1971), many of which have achieved high visibility in their respective scientific community, such as Bloom's classification of educational objectives (Bloom et al., 1956), Searle's classification of speech acts (Searle, 1975), Shrivastava's classification of organizational learning systems (Shrivastava, 1983), Holt's typology of consumption practices (Holt, 1995), or Shneiderman's taxonomy of information visualizations (Shneiderman, 1996) – to show the wide spectrum in which qualitative classifications are used. Classification is often integral to the way that scientists perceive, interpret, and organize a subject matter. It is an analytical tool that helps scholars compare and contrast items under observation, or structure a body of literature, for example in the context of a literature review. An example of this latter type of conceptual classification is shown in Figure 1. In their highly cited review article, the authors use this classification to segment and review empirical and non-empirical studies in the domain of Management Information Systems (Alavi and Carlson, 1992). In this example, the classification of articles has allowed the researchers to detect interesting anomalies and asymmetries in the field and derive future research directions.

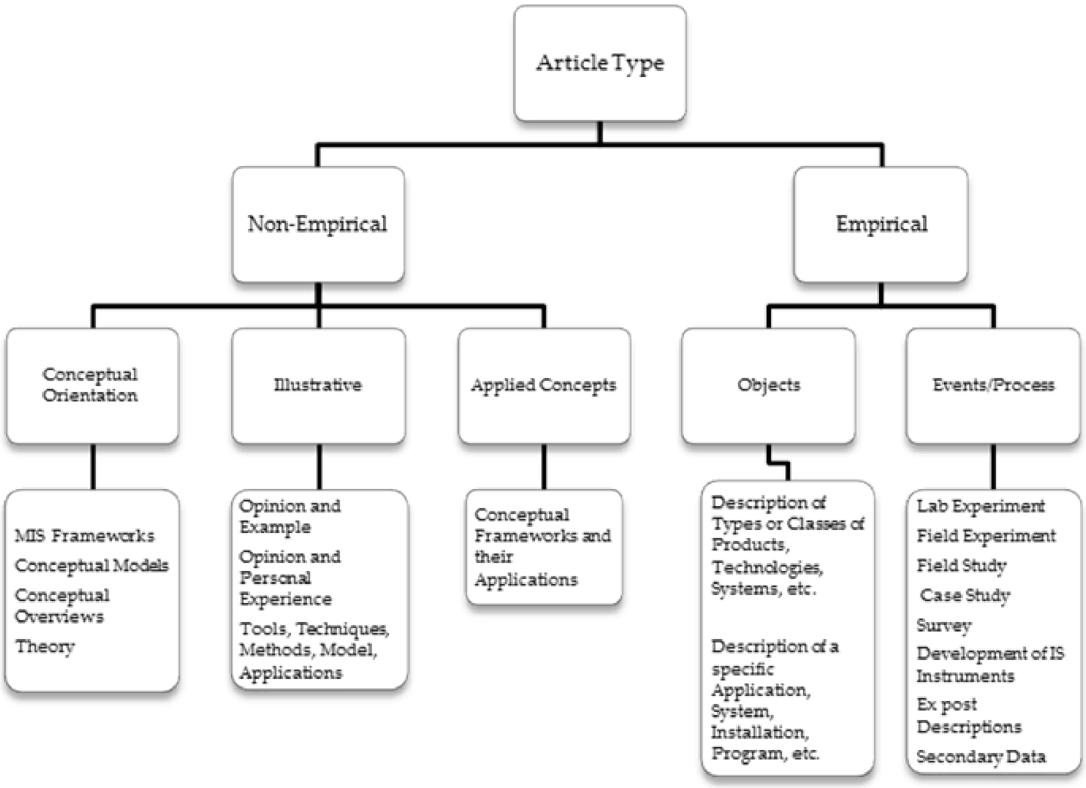

Figure 1: A classification of article types in the research domain of MIS by Alavi and Carlson (1992)

As Alavi and Carlson have done in the example above, many researchers take their classification one step further and represent it graphically, using a visual structure. Such graphic structures can show the hierarchy of groupings, emphasize underlying attributes of items, or highlight relations among groups (Card et al., 1999; Tufte, 1990). Many different graphic formats are employed for this purpose. They range from simple two-by-two matrices or tree structures to complex grids and coordinate systems, or may even include elaborate visual metaphors, such as stairs, pyramids, or buildings. Arguably the most famous graphic classification schema for research is Mendeleev's periodic table that systematically classifies the basic elements in chemistry in a u-shaped grid structure (the table organizes elemental atoms by the number of protons in their nucleus). Highly cited graphic classifications from the applied social sciences include Michael Porter's five-part classification of market elements (Porter, 1980), Mintzberg's classification of organizational configurations

(Mintzberg, 1979), or Rogers' seminal classification of innovation adopters (Rogers, 1995). This last (highly cited) typology distinguishes different kinds of behaviour when faced with a novel method or technology. Rogers uses the time delay in adopting a novel practice (and its visibility) as his classification principle and hence positions the four main types along a timeline. This particular graphic rendering of the classification emphasizes the relationship among the different types, specifically their sequence in the innovation diffusion process.

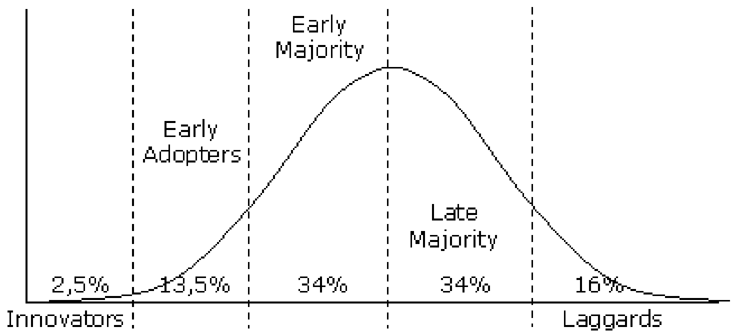

Figure 2: A classification of innovation adopters (Rogers, 2003: 281)

Despite the popularity of visualizing classifications, this approach – in our view – is not being used systematically and to its full potential. When it is used, its underlying logic or the rationale for choosing one visualization format over another is often left implicit.

In this article, we argue that the visualization of classification is of crucial importance when conducting research in the realm of social sciences. Yet, despite its importance, visualizing classifications is an insufficiently researched and discussed subject within social sciences. The few existing studies on visual classification have focused mainly on cognitive aspects, e.g. analysing the perception processes of images (Freedman *et al.*, 2003; Sigala & Logothetis, 2002)Ball and Smith, 1992) or on technical aspects, that is developing tools for visualising classifications (Ankerst *et al.*, 1999; Perronnin *et al.*, 2006; Seifert & Lex, 2009). We argue that we need to understand how a particular visual format affects the classification procedure used by a researcher. We need to examine how visual classification can support the various research activities and phases and, more particularly, which visual formats are suited for which type of classification. For example, whereas a matrix or grid forces the researcher to combine two or more attributes to form a group or type, a Venn diagram is ideal to create overlapping groups and enables the researcher to reflect on items that exhibit one, two, three or more attributes. These two formats can also be combined to leverage the advantages of both formats in a single image, as the classification developed in Young et al. (2006) and reproduced below illustrates. Based on case study research, Young et al. used this hybrid matrix/Venn structure to visually classify corporate blog types (see Figure 3).

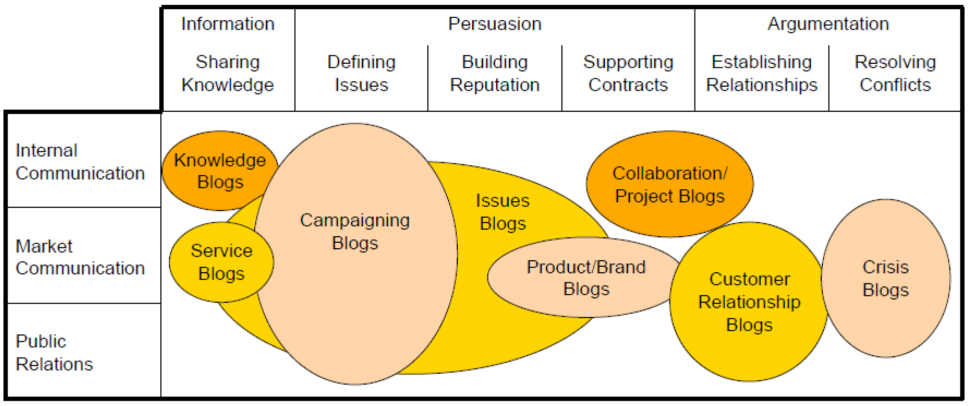

Figure 3: A qualitative classification of corporate blog types by Young et al. (2006)

But researchers may not be aware of these and other properties of diagrams when developing or presenting their classification. As a consequence, they may not fully benefit from the versatility that visualizations can provide for the development of their classifications. This is especially true when switching between different visual formats. The switching between alternative visual representations can give researchers the opportunity to detect inconsistencies or missing elements in their classification. It can lead them to modify, refine or extend their classification, among other benefits.

In this paper, we thus present a systematic overview of the formats available for depicting classifications visually. Our article is structured as follows. In the next section, we briefly define classification and describe its role as an element of the scientific method. Section three offers an overview of visual forms for classification, including illustrative examples. In section four we provide basic guidelines for the use of visual classifications in the research process. Section five is dedicated to the risks and limitations of using visualization for classification-oriented research. The final section summarizes our contribution and draws conclusions. In terms of limitations of this paper, we highlight the fact that we focus mostly on qualitative classifications and their graphic rendering and this within the realm of social sciences.

2. Classification as a Scientific Method

Classification, according to Bailey (1994), designates the ordering of entities into groups or classes on the basis of their similarity. The goals of classification are the minimization of within-group variance and maximization of between-group variance. Classification aims, in other words, for within-group homogeneity and between-group heterogeneity within a given domain. This task can be achieved in various ways. A *quantitative* approach usually consists of proceeding inductively and developing classes from empirical data. Cluster analysis is the most obvious example because it is a statistical procedure that is explicitly designed to place cases into similar groupings. Marketing researchers use cluster analysis to group consumers into various categories according to their spending habits, income levels, and lifestyle attributes (among other variables). These groupings can then be used to develop a formal taxonomy that can be further tested and applied practically. A classification may, however, also be developed conceptually, i.e., through a deductive, theory-based, or 'top-down' approach. This qualitative approach usually begins be developing a conceptual, classificatory framework (often of ideal types) into which identified items can then be placed. This latter type of classification is often referred to as a *typology*, while the former is usually labelled as a *taxonomy*, although numerous studies use both terms loosely or even interchangeably.

There are several noteworthy qualifications about the distinction between typology and taxonomy. Doty defines typologies as "*conceptually derived* interrelated sets of ideal types each of which represents a unique combination of the attributes that are believed to define the phenomenon" (Doty & Glick, 1994: 232). A taxonomy, according to Sanchez (1993), is simply an *empirically derived* grouping. While a typology may be oriented towards some normative end (such as market success in the case of a typology of business strategies), taxonomies tend to be purely descriptive. The goals of a taxonomy are to introduce structure into a body of facts, as well as to build a unified and homogeneous view of the domain of interest (Chandra, 2005: 247).

In contrast to mere categorization, classifications tend to be more systematic and stable, and lead to groups with clear boundaries and inclusion or exclusion rules (Jacob, 2004: 528). According to Bowker and Star (1999) classification refers to the spatio-temporal segmentation of the world. This segmentation, according to most scholars in the field, has to exhibit the following traits:

1. there are consistent, unique classificatory principles in operation;
2. the categories are mutually exclusive (non-overlapping);
3. the system is complete (all items can be placed in a group).

These are minimal requirements for a sound classification based on the original work of Sneath and Sokal (1973). Gregory (2006) goes further and states that a high quality classification must also be useful (i.e., it should aid analysis), contain meaningful and natural category labels and groupings, and consist of hierarchies that are appropriate (i.e., most important divisions are shown at the highest levels). In addition, the logic for placing elements in categories should be clear, as should be the characteristics that define each category. Likewise, Meyer (2007: 28) mentions validity, simplicity, relevance, and difference as key traits of a typology. The validity of a typology depends on the unambiguous definition of categorization criteria (referred to as classification principles above). It requires that a typology be consistent with established theories in a field. The criterion of simplicity refers to the conciseness and comprehensibility of a classification. A classification, in other words, should contain a limited number of categories that are easy to distinguish. The criterion of relevance implies that only the most influential items should be included in a typology. According to Meyer, focusing on the important has a higher priority than being complete in the case of a typology. Difference, finally, refers to the fact that a typology should highlight the major differences in views, while paying less attention to issues on which more agreement exists. The focus should be on contradictory assumptions and conflicting norms. In other words, only the aspects with a high discriminatory value should be considered. This is reminiscent of the definition of information as “a difference that makes a difference” (Bateson, 1972; Jacob, 2004).

Classifications have ontological and pragmatic implications, as categories not only serve analytic purposes, but also act as fundamental devices through which social order is created as they “organise persons, setting, events, or activities by whom they are employed or to which they refer” (Suchman, 1994: 182). Star (2005), for example, has discussed the pragmatic and material consequences of what science (but also religion) classifies as alive and dead on the legislations for abortion, assisted suicide, palliative care or even the collection of mortality data. Classifications hence do matter as research artefacts with at times wide ranging consequences.

As a research tool, classifications provide multiple *benefits* and there are various reasons why a researcher may want to develop a classification. As Nobel Laureate Herbert Simon wrote in his seminal book on the Sciences of the Artificial, “an early step toward understanding any set of phenomena is to learn what kinds of things there are in the set – to develop a taxonomy” (Simon, 1996: 219). The many analytical, creative and communicative benefits of classification are summarized and discussed in Bailey (1994), Bowker and Star (1999), Jacob (2004), Doty and Glick (1994), Gregory (2006), Sneath and Sokal (1973) and Meyer (2007). Based on their work, we can distinguish between simple classification benefits for *description* or representation and benefits for further *analysis* and evaluation of items or groups in a domain. In terms of representation (or communication) benefits, the following advantages of classifications are frequently mentioned:

- Parsimonious description of items in a group; structured overview of a domain, reducing complexity of an area
- Highlighting differences and similarities among items
- Highlighting under-explored areas
- Presenting an exhaustive list of dimensions
- Inventory and management of types

As an analysis (or evaluation) tool, a classification has the following advantages:

- Enabling new perspectives on a domain
- Facilitating comparisons among items
- Helping to understand relationships among items and groups
- Generating types as criteria for measurement and analysis
- Prediction of future instances of identified types

In spite of these numerous advantages, the classification approach has also been heavily criticized (Bowker & Star, 1999). The primary risks associated with classifications are their tendency to: render concrete those things that are in short-term flux, long-term evolution, or poorly understood; and to reify things that are not so neat and tidy in the first place. Classifications may have an inertia that marginalizes alternative viewpoints and under-emphasize important attributes. Chandra (2005) criticizes the loss of information because of the generalization inherent in classifications. Classifications can also lead to framing effects. These effects limit creativity and "thinking outside of the box" (or rather "outside the tree structure"). A classification may lead to stereotypical thinking and false dichotomies.

How can researchers best profit from classification? How can they do so while avoiding drawbacks and pitfalls? One answer is to make use of the versatility and conciseness of visualization. In the next section, we explore this possibility and show how to use diagrams to develop and present research-based classifications. The adequate use of visualization can improve the quality of classifications and help to avoid frequent classification errors, such as: mixing levels of abstraction; switching classification principles; including unrelated items; attributing elements to the wrong group; or generating an incomplete classification system; to name but a few common shortcomings of research-based classifications.

4. The Visualization of Classification

Classifications are not only resources for organising thought; they are also material in as much as they are "inscribed, transported and affixed to stuff" (Star, 2005: 175). Whilst the materiality of classifications is often understood as their quality of having pragmatic implications on the ground (Star, 2005; Suchman, 1994), classifications are also material for the physical qualities of their representations. Taxonomies are rarely represented exclusively through text, as scholars frequently use a combination of text, diagrams, symbols, and drawings to map sets and their relations (see the Linnaean taxonomy from 1735 as an interesting example: Linnaeus, 1758).

The visual representation can facilitate the comprehension of the abstract structure of a classification. In particular, visualisations such as diagrams are facilitation devices for structural inferences, i.e. inferences about the qualities of parts and the relations among them (Tversky, 2005). By mapping abstract information in space, qualities of the classification (e.g. the relative importance of sets, the strength or the dependency of a relation) can be understood through distance, direction, or size.

The visual depiction of groupings based on similarity can take on many forms and shapes. They range from traditional tree structures to elaborate logic or set diagrams (such as Venn or Euler diagrams) and also include multi-dimensional scaling planes or cubes (Cox & Cox, 2008) and classifications based on parallel coordinate clusters (for an overview, see:

Hoffman & Grinstein, 2002). While a few visualization formats for classification are not easily applied in the social sciences (such as cladograms that depict the evolution of an object, particularly a biological organism), a large variety of them are. There are many (two- and three-dimensional) shapes that can be used to point to distinctions and relations between groups or classes. A key difference between visual formats in this context is the way they emphasize *hierarchical* orders (e.g. based on levels of abstraction) and (lateral) *relation*ships between singular classes (such as similarity, relative importance, or size).

In the following discussion of our survey of visual classification formats, we will build on this distinction of whether (and to what degree) each visual format emphasizes hierarchy or other (lateral) relations among groups and we will present four kinds of visual classificatory representations found within social sciences: compilations, configurations, layers, and trees (see Figure 4).

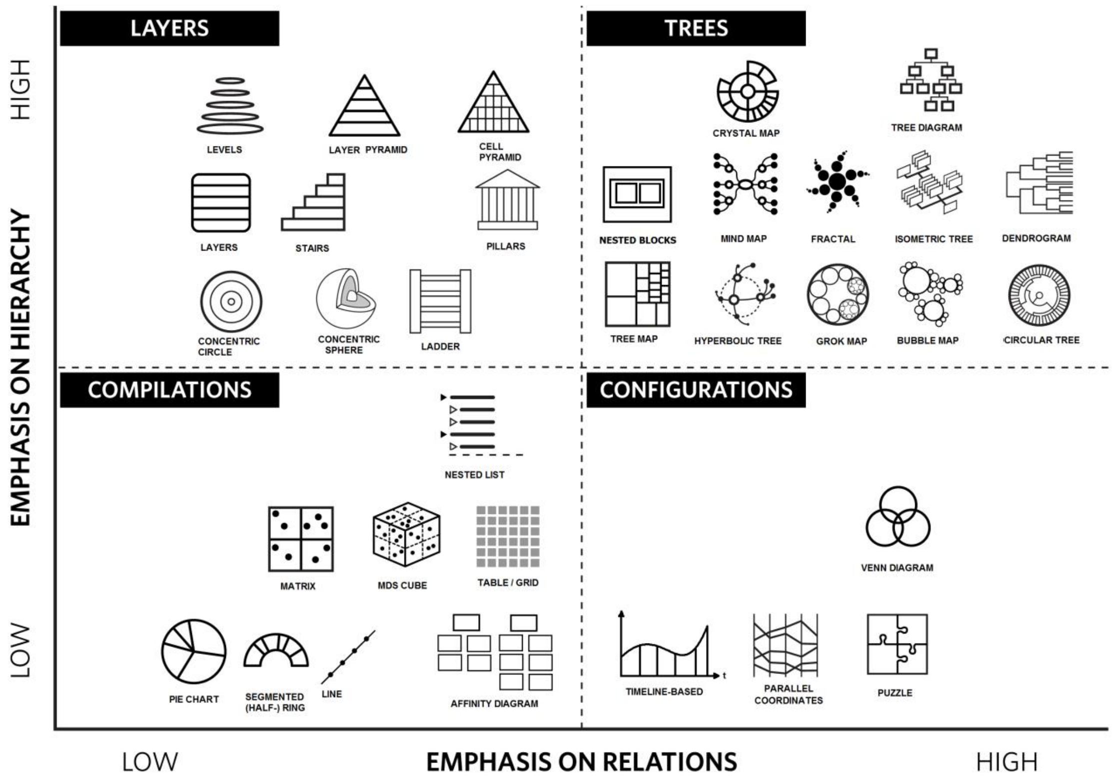

Figure 4: An overview on different graphic representations of classifications

Compilations: A first group of visualizations to be used for representing classifications provide no hierarchic structure nor emphasize relationships between elements or their groups. They allow for a relatively unstructured compilation and aggregation of items based on their similarity and do not impose an explicit relational structure between these items. Typical representatives of this group are segmented wholes (such as a segmented line, pie or arc/ring charts).

Configurations: With the term configurations we group visualizations that do not provide a hierarchy, but emphasize (to varying degrees) relationships among groups or classes. A configuration is a particular arrangement of items that has an explicit structure which facilitates comparisons between items or groups, or shows some overall pattern among the groups. There are, however, never more than two levels in these visualizations – the groups and their items. Typical forms in this group are Venn or timeline diagrams. Also a metaphoric structure such as the jigsaw puzzle points to relationships between elements whereby the metaphor domain conveys an additional insight about the groups' relations (i.e., their interdependence).

Layers: There are also groupings that mainly emphasize hierarchy which we label Layers. Simply put, layers group items hierarchically without revealing additional relationships between the groups. The pyramid would be one simple example of visualizations in this group.

Trees: Trees are those visual representations that show both hierarchy (in terms of levels of abstraction) and relationships, such as relative size of a group (as with a tree map) or closeness of groups (as with a dendrogram). Treemaps, for example, convert the traditional top-down hierarchy tree structure into a graphic based on encapsulation, where the size (or colour) of each square enables the viewer to compare it to other items or entire group. The example in Figure 5 (developed by Microsoft Research and described in Dodge and Kitchin, 2001: 171-173) shows a classification of computer-related internet discussion forums. Besides distinguishing groups and sub-groups, the visualization also shows the number of entries (or postings) in each group through the relative size of each respective rectangle. A simple tree diagram would not reveal this important aspect of the classification that allows comparing and contrasting items in the classification.

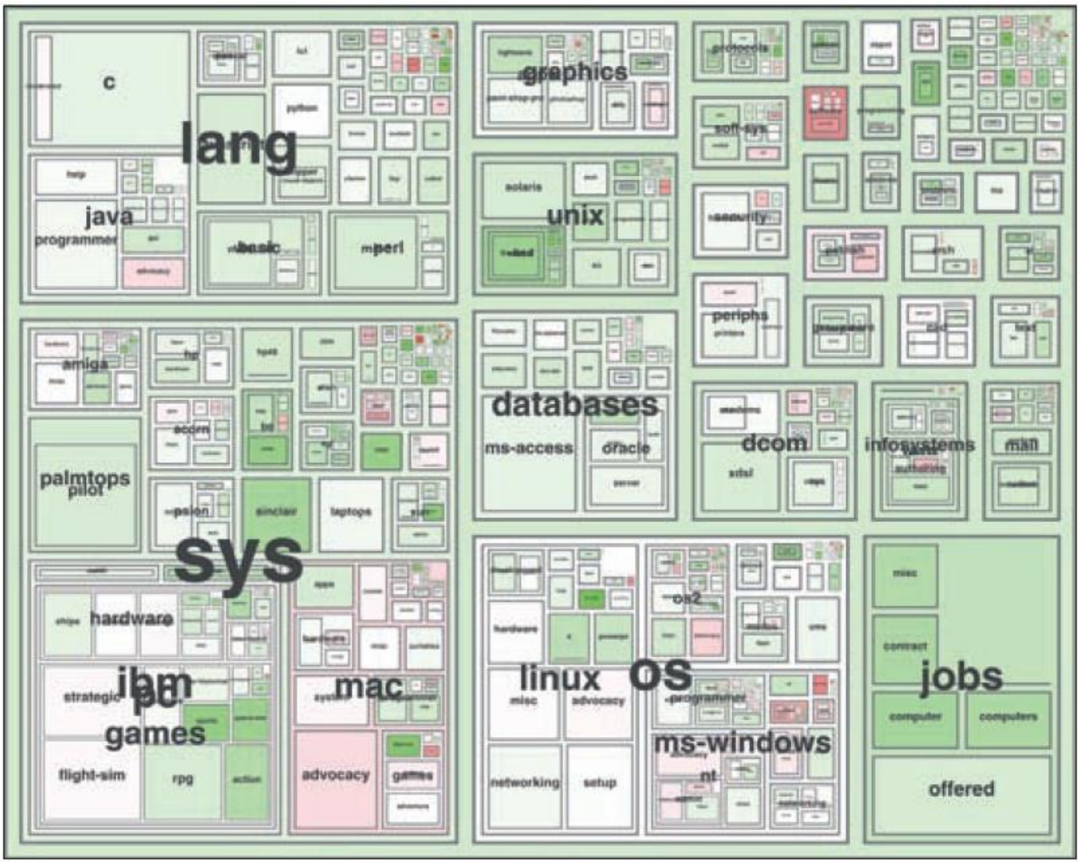

Figure 5: A visual classification of computer-related Internet discussion forums based on the Treemap visual format (from: Dodge and Kitchin, 2001: 172).

A dendrogram representation, another type of tree structure, fosters the understanding of relations by positioning closely related items or groups in close vicinity and placing relatively unrelated items at a greater distance. As an example from our own research, figure 6 shows a dendrogram of stakeholders involved in managing natural hazards in Switzerland. This dendrogram is the result of a card sorting exercise where interview partners have grouped stakeholders according to their (perceived) similarity. The dendrogram reveals, for example, that federal ministries or offices are seen as clearly distinct from research institutes by the interview partners. The diagram also shows stakeholders that are ‘outsiders’, i.e. institutions or people that have never been grouped with other groups (such as architects or the media). This quantitative technique and tool (card sorting with cluster analysis) was used within the realm of a qualitative method – the interview. Unlike a normal tree diagram it gives more information regarding the (perceived) strength or homogeneity of groupings in a classification. Although its hierarchic levels are less salient than in a standard tree diagram it provides more information for examining relations among groups and items.

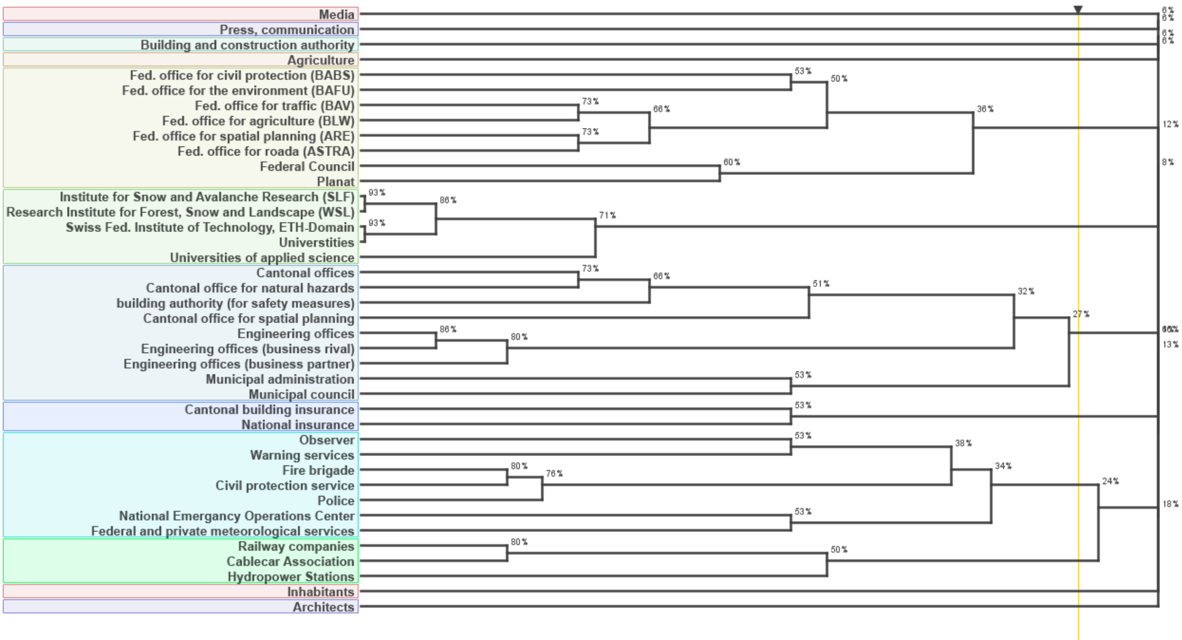

Figure 6: An example of a dendrogram as a result of card sorting exercise during expert interviews (own illustration)

The positioning of the different visualization formats in our framework is still tentative and ultimately depends on the actual use and adaptation of a graphic classification template to a particular research context. It should thus not be over-interpreted or read with expectations of high accuracy. Nevertheless, the grouping provides an informative first segmentation of the various visual forms available to represent classifications graphically. In the next section we present guidelines on how these different visual representations can be put to use.

4 Guidelines for the Use of Graphic Classifications in Research

Each type of classification scheme has a bearing and lends itself to particular research activities and techniques, but not to others. Also, not each visualization format is suited to represent each classification scheme. It is therefore important to understand when to apply each of the four types of visual classifications discussed above.

A first consideration for choosing a visual classification is the *nature of the research and the activities and phases it implies*. For example, the analytical approach may be inductive or deductive, or the nature of the research observations may be qualitative or quantitative. These different types of research orientations and activities can each be supported by specific visual classification formats. For example, while dendrograms or multi-dimensional scaling cubes are more useful for inductive, quantitative purposes, top-down tree diagrams or nested lists can be more useful for deductive qualitative work. This implies, also that the various steps in social science research, such as developing the theoretical domain, collecting data, exploring and later more systematically analysing data, consolidating conceptual models, and reporting classifications and research results, can be supported each by specific visual practices of classification. In the following, we will discuss how visual classification techniques can support these distinct research steps (which depending on the more qualitative or quantitative orientation of the research may proceed in different sequences).

Theory Development Phase: Visualizing Classifications to Organize Items, Develop Ideas and Compare Theories

A classification is often part of a larger theory and its development often goes hand in hand with reviewing the relationships between the classification scheme and its theoretical background. Visualization may help the researcher understand how the classification scheme complements the larger theory and how it fits within this larger context. Also, using visual techniques in developing classification schemes may reveal problems or inconsistencies of a theory earlier and prior to theory testing. The following five examples illustrate this role.

Thought Experiments. Many theories are developed as researchers think through complicated problems using hypothetical tests. These "thought experiments" (Kuhn, 1977) often come in the form of unusual, even extreme cases that challenge an existing theory because they seem to pose an exception or a conundrum. Unfortunately, however, thought experiments can easily lapse into abstract "word puzzles", as the debate about the merits of a theory hinge on rhetorical devices and slippery wording. By visualizing a thought experiment, researchers are invited to reflect on a theory in more concrete and tangible terms. Evasive language becomes less of a problem as fragmented variables can be reconsidered in a system view with multiple components (Reiner, 1998). Instead of merely speculating regarding the ideal types present in a domain, a visualized classification enables the researchers to externalize and thus better scrutinize his or her thought experiment.

Brainstorming. Brainstorming, in the most basic sense, is the generation of ideas and associative trains of thought around an issue or an interesting avenue of inquiry (for an overview, see: Lichtfield, 2009). This can be the rote itemization of ideas, such as a bulleted list. Yet, brainstorming can also be used collectively and by building more consciously on visual support: the emerging ideas are presented visually and manipulated on-the-fly into groups or interconnected maps (Van der Lugt, 2003). The low-tech visualization approach to this involves writing ideas onto cards or sticky notes. The notes can be grouped by placing them into piles, arrays, clusters, and the like (as so-called affinity diagrams). Cards are mapped onto a large piece of paper or whiteboard, and then connections and annotations are drawn. The resulting classificatory schemes and maps can form the basis for elaborate theories. A high-tech approach involves using software that facilitates brainstorming by simulating ideas visually (Wang et al., 2010) or by making the idea capture process more efficient. Computer support also allows more ways to group and link ideas, and reporting the resulting ideas in greater detail (see also: Dennis & Williams, 2003).

Theory Comparison. Theories are often difficult to compare because they were built using different terms, concepts, assumptions, and intellectual frameworks. This is particularly the case when comparing theories from different schools of thought, academic disciplines, and occupational practices. Visualization helps researchers draw connections between these seemingly different theories by offering a standard set of tropes to map theories (the equivalent of a standard vocabulary without having to haggle over word usage and definitional meaning). Visualization can also help with the technical intricacies of drawing connections between very different classification schemes. For example, many institutional classification schemes used by public bureaucracies and industry associations come with equivalence tables and tree diagrams. These tables and trees allow teams to make comparisons between the classification schemes found within different countries or industries (e.g., equivalence tables to compare national standardized industrial classification and occupational schemes). In other words, these visualization methods help translate terms and concepts across domains of practice, administration, or theory. In this way, visual classifications can act as boundary objects (Henderson 1991) that help to overcome the barriers of one single theory.

Visual Analogies. Many insights in the development of new theories come from drawing analogies or combining ideas from different areas of inquiry and disciplinary fields. Visualization can help to make these analogies more vivid and make the connections and equivalence between different areas of inquiry clearer. Moreover, visualizations such as visual metaphors (Carroll, 1994) can become a lever that inspires the generation of ideas and organizes those into familiar categories of other domains. An example is the Lets Focus software application that allows individuals and groups to generate theories and classification schemes using visual metaphors and interface elements, such as puzzles, pyramids, or temples (lets-focus, 2011). These analogies also help researchers better explain the resulting theory to a lay audience by drawing connections to commonplace items that most people have first-hand experience with.

Exploring Connections. Many visual techniques are specifically designed for drawing connections between ideas, variables, and concepts. Mind-mapping allows researchers to explore linkages (causal and otherwise) between various nodes (Daley, 2004). For example, in the interest to develop multivariate quantitative theories, researchers map variables according to causal connections into coherent logic models (theories) prior to testing. Whilst the logic model could be described verbally, researchers almost always choose to express it with a diagram (e.g. path diagrams). For qualitative mapping, the software company TheBrain Technologies produces various mind-mapping applications that allow researchers to map-out subjects along a hyperbolic plain (that is, a three-dimensional plain with a curved surface, thus allowing concepts and linkages to move into the foreground or background) (TheBrain, 2011). This helps researchers juggle a large number of ideas (sometimes numbering in the thousands) while developing classification schemes and theories.

Data Collection Phase: Visual Classifications as Observational Aids

When researchers enter the field, they often use tools that improve the accuracy and reliability of their observations (e.g., standardized questionnaires and field guides). Visual classifications can contribute to the process of how researchers solicit, record, and make sense of empirical observations (Couper *et al.*, 2004; Crilly *et al.*, 2006).

For example, the ethnographers Jan Chipchase and Fumiko Ichikawa (2005) spearheaded a research project to determine people's carrying behaviors when it comes to mobile phones. Their study took place across several countries and involved a large team of researchers to conduct on-the-street survey interviews. The number of places in which mobile phones can be carried is finite and thus they were organized into categories. To make recording easier, the paper questionnaires that researchers filled out made extensive use of visual archetypes. For example, purses, backpacks, and pockets were illustrated as response options in the survey questionnaire. This speeds cognition and the filling out of a questionnaire, something which is vital to on-the-street interviews where the time of completion for questionnaires is a determinant of people's willingness to respond to the survey. Visual classifications can also be used as a means to elicit information and reflections from respondents, which are otherwise difficult to obtain. Crilly et al. (2006), for example, experimented with the use of diagrams for graphic elicitation during interviews. They exposed interviewees with diagrams and found that this significantly improved the communication between the researcher and the interviewee by providing a shared conceptual foundation. Finally, visualization can also be used inductively with informants in cases in which the researcher aims to avoid imposing classification schemes on the studied communities, a main concern in cognitive anthropology (see: D'Andrade, 1995). During interviews, for example, informants can be asked to visually depict their ordering of things and explain the image verbally to the interviewer. The image can provide a structure to the interview without yet imposing the conceptual structures of the researcher transpiring through his/her questions (cp. Spradley, 1979).

Exploratory Phase: Detecting Patterns and Categories of Emerging Visual Classifications

Many researchers do not start with a fully fledged theory and instead adopt a more inductive approach. Faced with large amounts of empirical observation, they aim to detect patterns and to form theories and testable hypotheses through inductive reasoning. Various research approaches and techniques have evolved specifically for developing classification schemes for such *exploratory research*. For example, in the realm of qualitative empiricism, *grounded theory* is a method of grouping observations into concepts and concepts into categories (Glaser & Strauss, 1967). As another example, in the realm of quantitative research, exploratory data analysis is used to observe patterns in data and assign labels to emerging groups. In these cases, visualization can be used as part of the category development process (see, for example: Perer & Shneiderman, 2008). 'Compilations' are particularly useful for this explorative phase as it leaves relationships between entities and classes still relatively unarticulated and loose. The researcher can inductively map qualitative data around similarities and differences without imposing a rigid structure of relationships between classes. The visualization allows the researcher to map out a subject and, in so doing, juggle more observations and concepts simultaneously.

As an example, the company SAS has built visualization tools into its JMP Statistical Discovery Platform (Sall et al., 2007), a set of software applications to aid exploratory data analysis in a wide variety of disciplines (such as genomics, neuroscience, finance, and public policy analysis). The software uses visual displays to help with pattern recognition. This can include compilations such as juxtaposed visual displays (which can be animated to show a time dimension) that attempt to identify patterns across more than two variables at a time. This allows a researcher to perceive patterns in data that may suggest categories that might not have been obvious by using non-visual methods. Moreover, the software turns data into more relational visual classifications, such as a tree map (see Figure 5).

Another example of a visual technique used for exploratory analysis is the cluster analysis technique, used to group cases into categories based on a set of variables. The statistical software used to generate these categories reports results using conventional alpha-numeric read-outs (Aldenderfer and Blasfield, 1984: 75). Yet, the technique also produces a visual classification scheme in the form of a dendrogram (see Figure 6). The dendrogram gives the researcher a much faster (efficient) way of figuring out how the categories emerged given that the statistical procedure is an iterative process (of minimizing within-group differences and maximizing between-group differences). This information can be determined by looking through large amounts of alpha-numeric read-outs. However, the dendrogram is better suited for comparison of categories across iterations in the categorization process, for showing the grouping and splitting of categories, and for summarizing the composition of the final categories.

Systematic Analysis and Theory Testing Phase: Visual Classification in Confirmatory Research and Data Analysis

Visualization may not only help with exploring data, but also for purposes of conducting more systematic analysis and for empirically testing a theoretical model or classification. Drawing connections between theory and data may be rather laborious and researchers often make use of visualizations, such as tables and graphs to better make sense of the data and develop their findings. A few examples will help to illustrate how this may be done with the help of visual classifications.

Sorting, Mapping & Matching Data. Identifying correspondence between data points and categories can be done more efficiently with visual methods that map or match data to a classification scheme. This can be an essential operation in theory testing. Visualization may also suggest ways in which a theory needs to change that might not be obvious from alpha-numeric print-outs.

Aggregating Findings. Raw data is usually in a form that is not sufficiently aggregated to draw findings. Various aggregation and summary methods exist. Among them are visualization methods that show patterns within the data for theory testing purposes. This makes it easier to determine whether findings support or refute a given theoretical model. For example, most statistical packages will offer an array of tables, grids, coordinate systems, and graphs as default visual options related to classification.

Exceptions & Outliers. One of the most common checks in research involves checking to see if cases or clusters of cases constitute outliers. These are extreme cases that can skew findings. In terms of classification, outliers and major exceptions can exaggerate certain classes or suggest the need to make qualifications to an explanation of findings. In any case, anomalous cases need to be kept track of and visualization methods are often an efficient way of identifying these cases. This is also possible in qualitative studies where, for example, case studies are allocated to the cells of a (grid-based or coordinate system) typology. This can reveal that many real-life cases happen to be in a particular area of the typology or that certain areas in a visual typology remain empty (have no real-life equivalent). Such results may lead the researchers to revise their theory or extend it to account for missing cases.

Consolidation Phase: Discovering Errors of Clarity, Omission, and Duplication in Classification Schemes

When a classification scheme has been developed, or is under development, it is necessary to check for classes and cases that may not fit well within the scheme. A case may not be well represented by any category or it may fall within more than one category. Also, fuzzy wording may make it difficult to place cases in some categories or the scheme as a whole. This can lead to reliability problems when multiple researchers are working on a project and - because of the labels' ambiguity – are placing cases within the scheme in a non consistent way (the problem of *inter-rater reliability*). Visualization can help identify such problems. The following are some examples of using visual classification as a checking tool.

Validity Check. A researcher may have expressed a classification scheme in words and have become reasonably comfortable with it. However, the written form can allow for imprecise and to some extent improper definitions, without this to be noticed by the researcher. When he/she tries to visually display the scheme, these problems become obvious. The visualization process forces the researcher to express the scheme in a more explicit and clear form and he/she can thus see more easily if a specific category does not fit the classification scheme or if another category is missing. This is possible as the visual language requires concreteness, specificity and clear-cut distinctions. At the same time, the types of relationships between categories can be more critically reflected and new problems can come to light by describing a visual verbally. Moving between verbal and visual descriptions is thus a key practice for strengthening the validity of a classification.

Coherence Check. Using words alone, it is sometimes difficult to understand how a classification scheme fits together. If a scheme is intended to be a continuum, then it should clearly signal this through its shape as well (for example as a double-headed arrow). If a scheme is intended to be exhaustive, then a visualization should expose gaps (e.g. matrices showing one or two quadrants empty). Moreover, visualization serves as a coherence check in some cases by forcing researchers to articulate the way in which categories relate. Categories may have to link with each other (e.g. use 'configurations' or 'trees' such as mind maps), or to fit together to create a complete picture (e.g. use 'configurations' such as visual metaphors), or form a hierarchy or incremental formation (e.g. use 'layers' or 'trees' such as cell pyramids or hyperbolic trees).

Impossible Categories. A classification scheme may be defined in such a way that, by definition, cases cannot fall within a particular category. That may not be obvious until data is plotted into a diagram and certain cases cannot be positioned within a visual category or certain categories remain empty. These situations can indicate a lapse in logic or the use of an inappropriate visual.

Duplicate Categories. A classification scheme may seem to be discretely worded; that is, worded with no overlap or duplication. Overlaps are not necessarily a problem in classification schemes and many types of classification schemes and visual classification methods are premised on overlapping categories (e.g., Venn Diagram, Additive Clustering) (Arbie, 1977). However, if the overlap is unintended (and the intention was to create a discrete classification scheme), then visualization may help to identify overlaps. Moreover, classification schemes can have the problem of duplicate categories. For example, two categories may be labeled with synonyms or closely worded terms. When the scheme only has a few categories, this duplication should be obvious. However, when schemes have dozens of categories, it becomes challenging to identify duplicate categories. In such situations, visualization may help, as duplicate categories cannot be situated cleanly in a graphic.

Reporting Phase: Communicating Classification Schemes and Research Results Visually

In many cases, visualization can communicate a classification scheme (or research results involving the scheme) more effectively and accurately. Reporting does not simply start with the conclusion of a research project, but preliminary results and emerging classification schemes are shared throughout its development, mainly with the academic community, but also with respondents (in form of feedback) or the public at large (this is particularly the case in participatory research designs such as Action Research, see: W. F. Whyte, 1991). Visual classifications can facilitate this interaction, as the structure of the classification (e.g. the types of relationships among classes) or its contribution can be understood more easily. This allows the audience to identify flaws and problems of the classification and to contribute through feedback to its further development. In order for this to be possible, the researcher needs to clarify the purpose behind the visualized classification: does he/she want to provide an overview, focus on particular details, or enhance the movement between zooming in (on details) and zooming out (on the overall classification structure) (Nicolini, 2009). According to the main purpose different types of visualizations will need to be considered. For example, tree maps (Figure 5) are useful to zoom in and out between various levels of concreteness and abstraction, whereas a visual metaphor (such as a temple) signals the functional relationships between the groups or items in a visual classification. Several articles on Bloom's taxonomy of educational objectives, for example, use the image of a staircase to present the groups in the classification and to emphasize the different levels of objectives and their sequence. The Center for Excellence in Learning and Teaching at Iowa State University has even transformed this staircase-based classification into a virtual artefact, thus allowing readers to explore its components in an interactive way (see Figure 7). This is an example of how the visualization of a classification can facilitate the transfer process from research to teaching (see http://www.celt.iastate.edu/teaching/RevisedBlooms1.html; for an immersive, walk-through version of this taxonomy visualization see **Fehler! Hyperlink-Referenz ungültig.**). Below, we further differentiate these advantages of visual classification for this final phase of the research process.

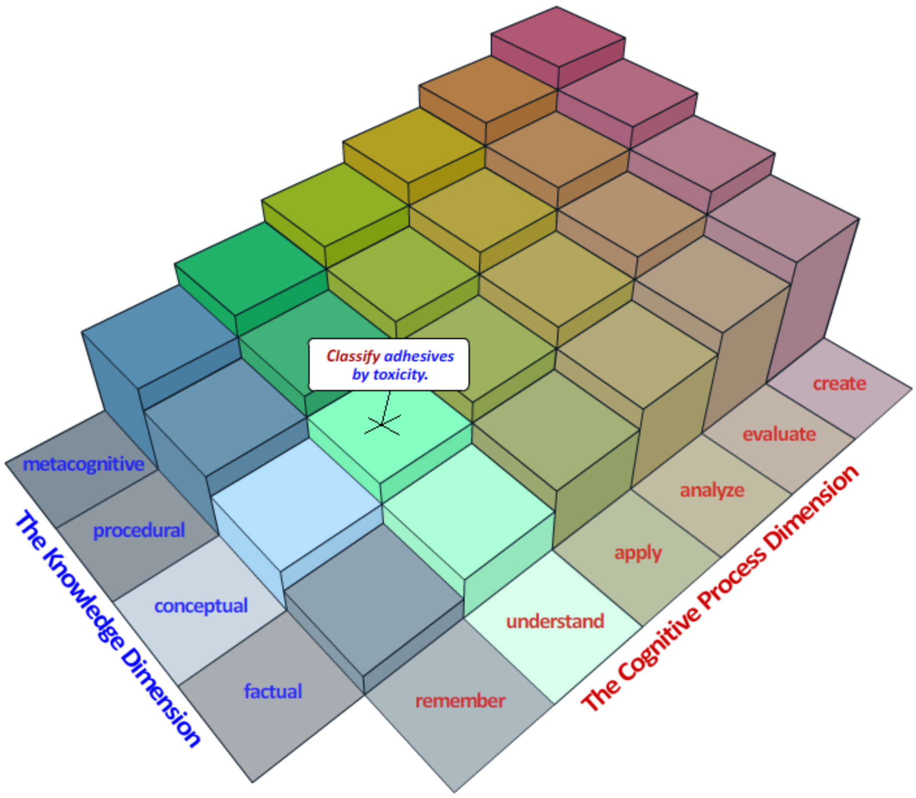

Figure 7: Bloom's taxonomy of learning objectives as an interactive visual metaphor for learning purposes (by Rex Heer at: http://www.celt.iastate.edu/teaching/RevisedBlooms1.html)

Categorization/Model Display. When reporting research to a broader audience, it is often easier to show classification schemes (and other aspects of theory) using visual means. This helps the audience see a broader coherence that is often difficult to convey with words alone. The audience can also see how the various parts of the classification scheme fit together.

Illustration. When reporting, it is often necessary to offer an illustrative example in order to better convey an intended meaning. Visualization of a class or classification scheme can do this in a way that better animates the concept in people's minds because of the use of imagery.

Data Reporting. Finally, the most obvious and widespread use of visual classification is to display the ultimate results of a study. In such cases, the more simple and tidy visualization methods (such as matrices, pyramids, or simple tress) are ideal for conveying straightforward messages about findings. Visual methods that provide too much detail or clutter (such as circular trees, crystal maps, or fractals) create the potential for valuable findings to become lost or place too much of the analytical burden on audience members.

We have argued so far that visual classifications can support the research process in multiple ways and we have qualified how visualization can be used for the various phases of the process. The above discussion has also pointed out that the choice of a visualization format not only depends on the type of research and the activities and phases it involves, but also on the *aims* that a researcher pursues with his or her research and the communication with the *audience*. For the latter, the researcher also has to take the audience and its foreknowledge into account. Some visualization techniques – such as parallel coordinates, dendrograms, or treemaps – require familiarity with the conventions or mathematical models underlying the visualization and are thus not useful for visual novices or a mathematically less educated audience. Similarly, visualizations based on metaphors may be culture-dependent, which can lead to misunderstandings if the visual classification is intended for an audience outside one's culture of reference (Sabrina Bresciani & Eppler, 2010). Depending on the audience' cognitive style (verbally or visually oriented), the researcher also has to consider how to integrate text and graphics and which of the two should dominate to represent a classification. In fact, those people who are verbal-linguistic in the way that they perceive information and are not "visual thinkers" (Kozhevnikov et al., 2005), prefer traditional classifications. For those people, the tight integration of the visual classification with its verbal description is particularly important.

So far, we have focused mainly on the affordances and benefits of visualization for developing and communicating classifications and for conducting research activities. Researchers who visualize classifications, however, should also be aware of the *risks* and limitations of this approach. We describe such potential drawbacks in the next section.

5. Limitations and Risks of Visualizing Classifications

As with any analytical technique, there are limitations and risks associated with visualization in the classification context. Most of these risks are inherent to visualization (cp. Sabrina Bresciani & Eppler, 2009), although a few are posed by common misuses or misunderstandings of visualization techniques. In the following, we will discuss some of these "marquee" risks and major limitations that researchers ought to consider carefully when working with visualization for classification schemes. In particular, we will address the fallacy of misplaced concreteness, the problem of reduced flexibility, of force fitting, the issue of the "miscellany" category, the risks of over-simplification, of exaggerating similarity or difference, and finally briefly outline media limitations of visual classifications.

Reinforcing the Reification Fallacy/Fallacy of Misplaced Concreteness

Treating an abstract concept or classification scheme as a concrete, real entity is a type of fallacious reasoning. This is called the *fallacy of reification* or, using Whitehead's term (1929), the *fallacy of misplaced concreteness*. Visualization can lead to greater risk of this fallacy occurring because it makes the intangible seem more tangible. Normally, reifying the ideation process and making ideas more tangible is a strength of visualization (Sfard, 1995). It is however not so when it causes the viewer to forget the conceptual nature of the classification scheme. This problem can occur, for example, when a two-by-two typology is presented that consists of four ideal types. Such a format may create the illusion that all real-life occurrences neatly fall into one of the four distinguished types.

Reducing Flexibility/Locking in Classifications

A classification scheme may have to evolve over time. Throughout the process of a research project, the researcher becomes more familiar with the subject and this familiarity allows him to see more nuances and make more subtle conceptual distinctions. Equally, the subject itself may evolve. For example, a classification of occupations within an economy will have to change as new occupations emerge. Through the reification of the ideation process into a tangible visualization, ideas not only become more concrete and tangible (the reification fallacy mentioned above), they also become more stable and lose their flexibility (cp. Henderson, 1991; J. K. Whyte *et al.*, 2007). This can undermine the evolution of classifications because their visual format may not easily accommodate adding, subtracting, and combining categories. It can be difficult, for example, to change the visual organization (e.g. adding a category to the already five categories represented on a pentagon), the spatial dimensions (e.g., the length of a list) or spatial resolution (e.g., the density of points). The relatively stable structure of the visual format can prove particularly problematic when a classification scheme is still under development and yet has to be finalized. It is thus important to work with alternative visual formats for as long as possible to avoid this lock-in effect. Using visuals for classificatory purposes in such a versatile way is also an approach that helps researchers switch perspectives and view their data from different angles.

The Problem of Visual Force Fitting

When an established classification scheme encounters a novel instance that is not easily accommodated, it may be necessary to change the scheme. When such adjustments become necessary, but the researcher insists on situating the new case within the inadequate scheme, this is called the *problem of force fitting* (Meyer and Booker, 2001: 51). There is a case of forced fit that is specific to visualization: the situation whereby a novel instance seems to fit logically into a classification scheme but does not fit well within the chosen graphic format. This is usually a sign that the visual format used is inadequate for the categorization or of poor design. Not addressing such an issue and instead forcing a case or item into a poorly fitting graphic framework implies that an opportunity for advancing the theoretical reasoning around the classification has been lost.

The Problematic Handling of Miscellany in Visuals

Some classification schemes have a rest, miscellaneous, or "trash can" category and it is often the place where disparate cases or outliers are placed. Placing a large number of cases within such a category can be problematic since it can be an indication of inadequacies in the classification. On the other hand, some subject matter may have large numbers of outlying cases that may still not be relevant to most forms of analysis (one could think of the case of the platypus in zoology). In such instances, a miscellaneous category is a suitable method of including these outliers. Unfortunately, the visual format does not allow for accommodating outliers or 'awkward' cases very well. It requires more clear-cut categories building up a coherent whole and thus does worse with large numbers of disparate outliers than verbal classifications. Whilst this is rather unproblematic for most analytical uses, it becomes more so when outliers are an important aspect of the phenomenon and are forgotten in view of the lacking miscellaneous category.

Trivialization and Over-simplification of Subject Matter by Visuals

Sometimes, the choice of visual style, or the selection of a particular type of graphic, can undermine the seriousness of the subject matter (cp. Ware, 2004). For example, the use of a two-by-two matrix may be chosen as the preferred mode for visualizing a classification because it is simple and accessible, but then is not adequate for the complexity of the represented phenomena. Also, the visualization may lead to the mistaken impression that distinctions are more clear-cut than they actually are (cp. Shimojima, 1996, on visualisations' risk to be overspecific).

More generally, classification is always a form of reductionism (that is, simplification). This is not, in itself, a problem as long as: (a.) the researcher does not forget that the underlying cases may, at some point, require a more fine-grained treatment (or more detailed classification scheme); and (b.) the simplification serves the appropriate analytical goal. Classification schemes that are not detailed enough (i.e. are overly simplistic) cause problems. In many cases, visualization bears the risk that it further simplifies the classification scheme, which can easily result in over-simplification (Nicolini, 2007).

Exaggeration of Similarity and Difference

A further challenge of visual classifications is related to how they deal with similarity and difference within and between classes. Classes have fuzzy boundaries as features are not simply absent or present, but can also vary in degree. In hierarchical classifications, for example, subclasses not only are distinct, but also similar, as they share interdependent features and a super-ordinate category into which they can be grouped (cp. with studies conducted in cognitive anthropology, e.g. Campbell, 1958). Because similarities and differences vary in degree, less prototypical cases are often difficult to allocate and could belong to one class or another (Taylor, 2003). For this reason it is important that a classification scheme gives indications about *the degree* of within-group similarities and differences, or about the degree of between-group similarities and differences (as it is the case in a dendrogram or in concentric circles). A challenge with the visual format is, however, that it mostly represents boundaries between classes as clear-cut and may suggest something else about similarities and differences than the verbally described classification. For example, a classification scheme may include categories that contain very different cases, but the visualization gives the mistaken impression that the category is relatively homogenous. Also, the categories in the scheme may differ in the degree to which they are homogenous, yet the visualization may suggest that each category is similar (even perfectly symmetrical) in this regard. Introducing shading or color-coding may reduce this danger in some application contexts.

Media Limitations

As a final risk of using visualization to represent classifications, we turn our attention to the medium in which a research-based classification is normally presented, that is print. Quite often, the medium used to communicate a classification scheme is poorly suited to a particular visualization. For example, hyperbolic trees, tree maps, and Grok Maps can be expressed using printed media of sufficient size and resolution. However, all of these methods of visual classification were originally designed for interaction on a visual display. When researchers use these methods in media that they are unsuited for, the benefits of visualization are reduced and many problems may result.

Considering these seven risks in the graphic rendering of a classification can consequently help to profit more fully from the aforementioned benefits.

6. Conclusion

In this paper, we have outlined the crucial role that graphic representations can play in the development, refinement, validation and communication of research-based classifications. We have given a tentative overview on possible graphic forms that can be used by researchers to construct or convey their taxonomies or typologies. We have also outlined how the functions of graphic representations of classification change according to the research step supported by them. Another contribution of our work has been the identification of key advantages and risks that come about through the use of visuals in the classification context.

One main implication of this paper is that we have articulated a re-classification imperative: Researchers should resist a premature closure in their choice of a graphic schema for their classification. They should keep their options open according to their ongoing observations and insights. Furthermore, we urge researchers to consider the benefits of visualization on the way that classifications are formed: While some visualizations invite the researcher to combine classification criteria (such as a matrix or a Venn diagram), they may de-emphasize different hierarchical levels. Conversely, some visualizations may enable a tree-like structure and neglect overlapping areas or groupings based on mixed criteria. The intent of this article is to sensitize researchers to these (often implicit) issues of the graphic representation of a classification. We acknowledge that our list of graphical forms is not exhaustive and is only a first step towards improving the way that classification graphics are used in the social sciences. We also acknowledge that our positioning of these forms along two axes (hierarchy and relationships) is a first, rough segmentation that must be subject to subsequent analyses and refinement.

In future research, we would consequently like to more systematically compare the different graphic forms for classifications (in terms of their respective functions and limitations) and describe their features more formally (such as their level of complexity, their biases, their affordances, etc.), as well as match them more accurately with different research scenarios or needs.

References

Alavi, M., Carlson, P. (1992) A review of MIS research and disciplinary development, *Journal of Management Information Systems*, 8(4), 45–62.

Aldenderfer, M. S., Blasfield, R. K. (1984) *Cluster Analysis*, Thousand Oakes (CA): Sage.

Ankerst, M., Elsen, C., Ester, M., & Kriegel, H.-P. (1999, 15-18 August). *Visual classification: An interactive approach to decision tree construction.* Paper presented at the Fifth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, San Diego (CA).

Arbie, P. (1977). Clustering representations of group overlap. *Journal of Mathematical Sociology, 5*, 113-128.

Bailey, K. D. (1994). *Typologies and taxonomies: An introduction to classification techniques*. Thousand Oakes (CA): Sage.

Bateson, G. (1972). *An ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*. Chicago: University Of Chicago Press.

Bloom, B., Englehart, E., Furst, W. H., & Krathwohl, D. (Eds.). (1956). *Taxonomy of educational objectives (cognitive domain)*. New York: David McKay Co.

Bowker, G. C., & Star, S. L. (1999). *Sorting things out. Classification and its consequences*. Cambridge (MA).

Bresciani, S., & Eppler, M. J. (2009). The risks of visualization: A classification of disadvantages associated with graphic representations of information. In P. J. Schulz, Hartung, U., Keller, S. (Ed.), *Identität und vielfalt der kommunikationswissenschaft* (pp. 165-178). Konstanz (Germany): UVK Verlagsgesellschaft GmbH.

Bresciani, S., & Eppler, M. J. (2010). Glocalizing visual communication in organizations. In B. Bertagni, M. La Rosa & F. Salvetti (Eds.), *Glocal working* (pp. 233-251). Milan: Franco Angeli.

Campbell, D. T. (1958). Common fate, similarity, and other indices of the status of aggregates of persons as social entities. *Behavioural Sciences, 3*, 14-25.

Card, S. K., Mackinlay, J. D., & Shneiderman, B. (Eds.). (1999). *Readings in information visualization: Using vision to think*. San Diego (CA): Academic Press.

Carroll, N. (1994). Visual metaphor. In J. Jintikka (Ed.), *Aspects of metaphor* (pp. 189-218). Dordrecht: Kluwer Academic Press.

Chandra, C. a. T., A. (2005). Supply chain system taxonomy: A framework and methodology. *Human Systems Management 24*(4), 245-258.

Couper, M. P., Tourangeau, R., & Kenyon, K. (2004). Picture this! Exploring visual effects in web surveys. *Public Opinion Quarterly, 68*(2), 255-266.

Cox, M. A. A., & Cox, T. F. (2008). Multidimensional scaling. In C. Chen, W. Härdle & A. Unwin (Eds.), *Handbook of data visualization* (pp. 315-347). Leipzig: Springer.

Crilly, N., Blackwell, A. F., & Clarkson, P. J. (2006). Graphic elicitation: Using research diagrams as interview stimuli. *Qualitative Research, 6*(3), 341-366.

D'Andrade, R. (1995). *The development of cognitive anthropology*. Cambridge: Cambridge University Press.

Daley, B. J. (2004, September 2004). *Using concept maps in qualitative research.* Paper presented at the Concept Maps: Theory, Methodology, Technology, Pamplona (Spain).

Dennis, A. R., & Williams, M. L. (2003). Electronic brainstorming: Theory, research, and future directions. In P. B. Paulus & B. A. Nijstad (Eds.), *Group creativity: Innovation through collaboration* (pp. 160-178). New York: Oxford University Press.

Doty, D. H., & Glick, W. H. (1994). Typologies as a unique form of theory building: Towards improved understanding and modelling. *Academy of Management Review, 19*(2), 230-251.

Freedman, D. J., Riesenhuber, M., Poggio, T., & K., M. E. (2003). A comparison of primate prefrontal and inferior temporal cortices during visual categorization. *Journal of Neuroscience, 23*(12), 5235-5246.

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory.Strategies for qualitative research*. Mill Valley (CA): Sociology Press.

Gregory, S. (2006). The nature of theory in information systems. *MIS Quarterly, 30*(3), 611-642.

Henderson, K. (1991). Flexible sketches and inflexible data bases: Visual communication, conscriptive devices, and boundary objects in design engineering. *Science, Technology, & Human Values, 16*(4), 448-473.

Hoffman, P. E., & Grinstein, G. G. (2002). A survey of visualizations for high-dimensional data mining. In U. Fayyad, G. G. Grinstein & A. Wierse (Eds.), *Information visualization in data mining and knowledge discovery*. London: Academic Press.

Holt, H. B. (1995). How consumers consume: A typology of consumption practices. *Journal of Consumer Research, 22*(1), 1-17.

Ichikawa, F., Chipchase, J., & Grignani, R. (2005, November, 15-17). *Where's the phone? A study of mobile phone location in public spaces.* Paper presented at the IEE Mobility Conference 2005, Guangzhou (China).

Jacob, E. K. (2004). Classification and categorization: A difference that makes a difference. *Library Trends, 52*(3), 515-540.
Kozhevnikov, M., Kosslyn, S., & Shephard, J. (2005). Spatial versus object visualizers: A new characterization of visual cognitive style. *Memory & Cognition, 33*(4), 710-726.
Kuhn, T. S. (1977). A function for thought experiments. In T. S. Kuhn (Ed.), *The essential tension: Selected studies in scientific tradition and change* (pp. 240-265). Chicago: University of Chicago press.
lets-focus. (2011). Let's focus - drawing attention. Retrieved 23.05.2011, from http://www.lets-focus.com/
Lichtfield, R. C. (2009). Brainstorming reconsidered: A goal-based view. *Academy of Management Review, 33*(3), 649-668.
Linnaeus, C. (1758). *Systema naturae* (10th ed. Vol. 1): Holmiae, Salvii.
Marradi, A. (1990). Classification, typology, taxonomy. *Quality & Quantity XXIV, 2*(May), 129-157.
Meyer, R. (2007). *Mapping the mind of the strategist. A quantitative methodology for measuring the strategic beliefs of executives.* Erasmus University, Rotterdam.
Mintzberg, H. (1979). *The structuring of organizations*. New York: Prentice Hall.
Nicolini, D. (2009). Zooming in and out: Studying practices by switching lenses and trailing connections. *Organization Studies, 30*, 1391-1418.
Nowotny, H. (1971). The uses of typological procedures in qualitative macro-sociological studies. *Quality & Quantity XXIV, VI*(1), 3-37.
Perer, A., & Shneiderman, B. (2008, April 5-10). *Integrating statistics and visualization: Case studies of gaining clarity during exploratory data analysis.* Paper presented at the 26th Annual SIGCHI Conference on Human Factors in Computing Systems, Florence (Italy).
Perronnin, F., Dance, C., Csurka, G., & Bressan, M. (2006, May 7-13). *Adapted vocabularies for generic visual categorization.* Paper presented at the Computer Vision - 9th European Conference on Computer Vision, Graz.
Porter, M. (1980). *Competitive strategy*. New York: The Free Press.
Reiner, M. (1998). Thought experiments and collaborative learning in physics. *International Journal of Science Education, 20*(9), 1043-1058.
Rogers, E. (1995). *The diffusion of innovations*. New York: Free Press.
Sall, J., Creighton, L., & Lehmann, A. (2007). *Jmp start statistics. A guide to statistics and data analysis using jmp* (4th ed.). Cary (NC): SAS.
Sanchez, J. C. (1993). The long and thorny way to an organizational taxonomy. *Organization Studies, 14*(1), 73-92.
Searle, J. (1975). A taxonomy of illocutionary acts. In K. Gunderson (Ed.), *Language, mind and knowledge (minnesota studies in the philosophy of science)* (pp. 344-369). Don Mills (Ontario): Maceachern.
Seifert, C., & Lex, E. (2009, 15-17 July). *A novel visualization approach for data-mining-related classificaction.* Paper presented at the 13th International Conference on Information Visualization, Barcelona.
Sfard, A. (1995). Reification as the birth of metaphor. *For the Learning of Mathematics, 14*(1), 44-55.
Shimojima, A. (1996). *On the efficacy of representations.* Unpublished PhD Dissertation, Indiana University (USA).
Shneiderman, B. (1996, September 1996). *The eyes have it: A task by data type taxonomy of information visualizations.* Paper presented at the IEEE Symposium on Visual Languages, Los Alamos (CA).
Shrivastava, P. (1983). A typology of organizational learning systems. *Journal of Management Studies, 20*(1), 7-28.
Sigala, N., & Logothetis, N. L. (2002). Visual categorization shapes feature selectivity in the primate temporal cortex. *Nature, 415*, 318-320.
Sneath, P. H., & Sokal, R. R. (1973). *Numerical taxonomy: The principles and practice of numerical classification*. San Francisco (CA): Freeman.
Spradley, J. P. (1979). *The ethnographic interview*. New York: Holt, Rinhart and Winston.
Star, S. L. (2005). Categories and cognition: Material and conceptual aspects of large-scale category systems. In S. J. Derry & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration: An emerging cognitive science*. Mahwah (NJ): Lawrence Erlbaum Associates Inc.
Suchman, L. (1994). Do categories have politics? The language/action perspective reconsidered. *Computer Supported Cooperative Work, 2*, 177-190.
Taylor, J. R. (2003). *Linguistic categorization*. New York: Oxford University Press.
TheBrain. (2011). Thebrain: Mind mapping software, brainstorming, gtd and knowledgebase software. Retrieved 23.05.2011, from http://www.thebrain.com/
Tufte, E. (1990). *Envisioning information*. Cheshire: Graphics Press.

Tversky, B. (2005). Chapter 10: Visuospatial reasoning. . In K. J. Holyoak & R. G. Morrison (Eds.), *Handbook of reasoning* (pp. 209-249). Cambridge (UK): Cambridge University Press.

Van der Lugt, R. (2003). Brainsketching and how it differs from brainstorming. *Creativity and Innovation Management, 11*(1), 43-54.

Wang, H.-C., Cosley, D., & Fussell, S. R. (2010, February 6-10). *Idea expander: Supporting group brainstorming with conversationally triggered visual thinking stimuli.* Paper presented at the 2010 ACM conference on Computer supported cooperative work, Savannah (GA).

Ware, C. (2004). *Information visualization* (2nd ed.). San Francisco (CA): Morgan Kaufmann.

Whitehead, A. N. (1929). *Process and reality*. New York: Macmillan.

Whyte, J. K., Ewenstein, B., Hales, M., & Tidd, J. (2007). Visual practices and the objects used in design. *Building Research & Information, 35*(1), 18-27.

Whyte, W. F. (Ed.). (1991). *Participatory action research*. Thousand Oaks (CA): Sage.