

Knowledge visualization: Critique of the St. Gallen School and an analysis of contemporary trends¹

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Abstract

The purpose of this article is the analysis of leading European research in the field of knowledge visualization from the point of view of the accumulated theoretical base, practice of application, problems, and trends.

The need for digital business transformation for survival in the era of high-speed, mobile intelligent applications and big data has become apparent. However, understanding and interpretation of information can be performed only by humans. Modern managers cope with information “explosion” through visualization. Visualization helps them to understand, to compress and to demonstrate the ocean of numbers, words, and ideas. The number of works devoted to the theme of visualization is growing every year. There are numerous studies on the visualization of networks and relationships, and visualization of communication with a consumer. Fewer articles have been devoted to the visualization of knowledge in the implementation of business practices. At the same time, scientists are examining

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one specific area of application of visualization and only a few contribute to the theory of the subject and study it in a versatile manner. The latter include the works of researchers from the University of St. Gallen (Switzerland), which we call in this article the St. Gallen School.

We propose systematization of the following basic stages of research formation of the aforementioned School: 1) the preliminary stage, 2) the stage of empirical data accumulation, and 3) the stage of theory development. The School's contribution to the theory and practice of management was analyzed. Its contribution to theory includes the classification of visualization techniques, a description of visualization use in business, the development of the boundary objects theory, as well as a detailed description of experimental studies. Contribution to business practices means implementation of educational projects and the development of new visual models. The fragmented nature of research is identified: theoretical work is focused on how several visual models influence the implementation of certain business practices; empirical work often describes consulting projects, but do not provide an understanding of how to apply visualization techniques when there is no researcher-consultant.

Based on our analysis of the literature, we demonstrate that the major trend in information processing is focus on knowledge representation based on data, not data as such. The challenging areas related to applied research methods are highlighted as follows: lack of consistency, and lack of distinction between the concepts of "data visualization" and "knowledge visualization". Thus, there is a need to distinguish visualization of knowledge in a separate area of study.

Key words: knowledge visualization, knowledge communication, knowledge management, business trend, infographics, business research.

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Introduction

The necessity to transform business for survival in a rapidly changing world of informational overloads and ultra high speeds, mobile intellectual apps and big data has become evident. However, the comprehension and interpretation of information remains a human task. The interest in infographics and visualization assisting rapid understanding is no coincidence. Precisely through visualization, modern managers handle the information "explosion". Visualization helps grasp and comprehend, condense and clearly present an ocean of numbers, words, and ideas. Modern

knowledge management is inconceivable without extensive use of diagrams, graphics and schemas.

From among numerous modern works on information visualization, the authors selected works by researchers from St. Gallen University (Switzerland), dubbing them the St. Gallen School. These works focus on knowledge and data visualization in business. Notably, the leader of the St. Gallen School and head of the Institute for Media and Communication Management, Professor Martin Eppler, began his scientific journey from his dissertation on information overloads.

Visualization is also “social glue”, ensuring communication between different individuals and groups [1]. This means that visual methods work as a medium that sets general frameworks for communication.

This article analyses the works of the St. Gallen School according to the chosen topic, indexed in the Scopus and Web of Science databases. The analysis was conducted with regard to accumulated theoretical knowledge, use, issues, and modern trends in the area of knowledge visualization. Of the presented publications, works from the last 10 years were closely examined, including conference materials with a high citation index and journal articles. The reviewed publications’ extensive contributions to science and business practice makes it possible not only to trace the formative phases of St. Gallen School visualization, but also to draw conclusions about issues and development trends of this scientific area in general.

1. The main characteristics of the works of the St. Gallen School

Notwithstanding the multidimensionality of the works of the St. Gallen School, two main characteristics may be identified (*Figure 1*):

1) the breadth of the research area, which focuses on the study of the specificity of visual method application in business practice;

2) the orientation of research objectives towards knowledge visualization theory construction, which emerges in the authors’ commitment to the expansion of the theoretical base and the classification of known visualization methods.

The first characteristic is the largest, and is distinguished by breadth of coverage and practical orientation. The second characteristic sets the trends in research development in this area.

1.1. Area of research

As was already noted, the majority of the St. Gallen School works are dedicated to visualization in management. The authors show how visualization helps executives solve fundamental business problems, such as business model development, strategizing, multi-level communication, idea generation, team collaboration improvement, increasing knowledge exchange between people and companies, risk management, company core competency analysis, et al. (*Table 1*).

A few empirical studies of knowledge visualization methods are presented in *Table 2*. In particular, articles [7–11, 14–16, 21, 22] present the results of a number of empirical investigations focused on the study of the specificity of using a separate visualization method and its influence on a specific business objective (in

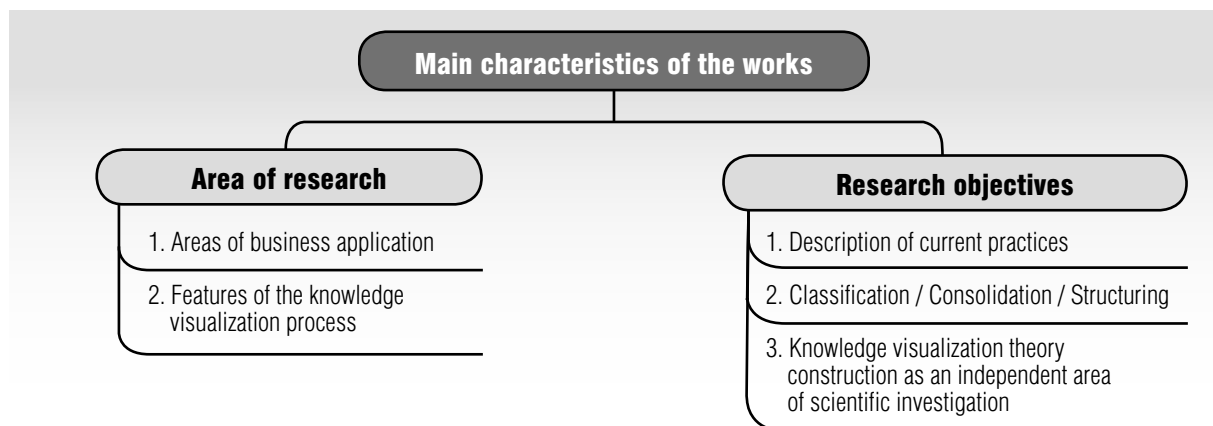


Fig. 1. The main characteristics of the works of the St. Gallen School in the area of knowledge visualization

Table 1.

List of analyzed papers

Ref.	M. Eppler's co-authors	Year	Title
PRELIMINARY PHASE			
[2]	R. Lengler	2007	Towards a periodic table of visualization methods of management
[3]	R.A. Burkhard, et.al.	2007	Visualization Summit 2007: Ten research goals for 2010
[4]	–	2007	Toward a visual turn in collaboration analysis?
[5]	R.A. Burkhard	2007	Visual representations in knowledge management: Framework and cases
EMPIRICAL DATA ACCUMULATION PHASE			
[6]	R.A. Pfister	2012	The benefits of sketching for knowledge management
[7]	F. Hoffmann	2012	Does method matter? An experiment on collaborative business model idea generation in teams
[8]	S. Bresciani, M. Tan	2011	Augmenting communication with visualization: Effects on emotional and cognitive response
[9]	F. Hoffmann, S. Bresciani	2011	New business models through collaborative idea generation
[10]	A. Comi	2011	Assessing the impact of visual facilitation on inter-organizational collaboration: An experimental study
[11]	N. Bischof	2011	Caring for clarity in knowledge communication
[12]	S. Bresciani	2009	The benefits of synchronous collaborative information visualization: Evidence from an experimental evaluation
[13]	M. Aeschmann	2009	A systematic framework for risk visualization in risk management and communication
[14]	K.W. Platts	2009	Visual strategizing. The systematic use of visualization in the strategic-planning process
THEORY CONSTRUCTION PHASE			
[15]	L. McGrath, S. Bresciani	2016	We walk the line: Icons provisional appearances on virtual whiteboards trigger elaborative dialogue and creativity
[16]	E. Alexander, S. Bresciani	2015	Understanding the impact of visual representation restrictiveness on experience sharing: An experimental assessment
[17]	E. Alexander, S. Bresciani	2015	Knowledge scaffolding visualizations: A guiding framework
[18]	S. Kernbach, S. Bresciani	2015	Slip-sliding-away: A review of the literature on the constraining qualities of PowerPoint
[19]	S. Bresciani	2015	The pitfalls of visual representations: A review and classification of common errors made while designing and interpreting visualizations
[20]	A. Comi	2014	Diagnosing capabilities in family firms: An overview of visual research methods and suggestions for future applications
[21]	R.A. Pfister	2014	Beyond projection: Using collaborative visualization to conduct qualitative interviews
[22]	R.A. Pfister, N. Bischof	2014	Best of both worlds: Hybrid knowledge visualization in police crime fighting and military operations
[23]	S. Bresciani	2013	Visualization in management: From communication to collaboration. A response to Zhang

Table 2, works [7–11, 14] pertain to the empirical data accumulation phase, while works [15, 16, 21, 22] to the theory construction phase). Around half of the specified works are dedicated to subjects such as communication and collaboration. They can also be supplemented through decision-making, work with consumers, new product development, etc. Together

with dozens of existing visualization methods, we obtain an extensive field for study. However, this approach is fragmentary and does not give an understanding of the system of interrelations inside this informational field as a whole. The majority of researchers in the area of visualization have unfortunately chosen precisely this approach.

Table 2.

Empirical research of knowledge visualization methods

Ref.	Type of research	Visual method	Business objective	Research method	Result
[7]	Quantitative	Templates and other boundary objects	Creativity and team cooperation	Experiment, 3 teams of managers	Templates are capable of directing teamwork. The use of physical objects and sketches did not yield significant results
[8]	Quantitative	Interactive visualization	Communication and organization	Experiment, a group of professionals	Communication can be directed and improved through interactive visualization, which entails brief and apt expression of ideas
[9]	Quantitative	Business models	Team development of a new business model	Experiment, 3 teams of managers	The use of a digital model of a business template significantly increases perceived collaboration, but reduces creativity
[10]	Quantitative	Interactive visualization, posters	Collaboration between teams of different companies	Experiment, 96 participants	Visual facilitation raises performance and satisfaction from collaboration
[11]	Quantitative	PowerPoint presentation	Knowledge communication at university	Survey, 145 respondents	The CLEAR formula has been developed, along with a corresponding list of control questions
[12]	Quantitative	Interactive visualization	Work with knowledge in teams	Experiment, 131 managers	Interactive visualization exerts a statistically significant positive influence on knowledge exchange and involvement in work, but respondents are unaware of this
[14]	Qualitative	Group of methods	Company strategizing	Action research, 5 companies	Visualization is a process that simplifies strategizing. But it can also have negative consequences if it is not administered properly
[15]	Quantitative	Sketches, icons	Communication using IT	Experiment, 37 pairs of managers	The incompleteness of imagery stimulates social cooperation
[16]	Quantitative	Grid, matrix	Communication in small groups	Experiment, 96 professionals	The average level of visual restrictiveness stimulates experience exchange
[21]	Qualitative	Visualization of organizational competencies	Qualitative interviewing	Individual and group interviews	The integration of design procedures with facilitations using visualization improves mutual understanding and makes it possible to elicit more profound knowledge from the interviewed party
[22]	Qualitative	Knowledge boards	Knowledge exchange in extreme situations	Observations, focus groups, interviews	The combination of virtual and physical visualization is a useful strategy for corporate knowledge management.

Another important aspect is the organizational level the analysis is conducted on. The authors focus on teamwork, but also study personal, organizational and interorganizational cooperation levels through visualization. Additionally, the authors describe the process of development and use of visualization, conduct experiments with the goal of revealing the most effective approaches for specific situations, and devote attention to the degrees of visualization maturity.

The researchers conduct an unbiased analysis of all aspects of visual method use, paying attention to issues that arise during work with visualization. These issues are generally subdivided into three groups: cognitive, emotional and social.

The first group is the most extensive and is often the only one in the other authors' studies. This is why St. Gallen School researchers pay special attention and give a more detailed description of emotional and social issues in the development and perception of visualization. For example, during the development of a certain diagram, the opinions of certain group participants may carry greater weight owing to their status, while experts possessing critical knowledge do not have the opportunity to be heard. Therefore, visualization is considered, among other things, as a process driven by a facilitator. In this case, the level of social tension during group work and the objectivity of the result, as well as the effectiveness of the visual model, depend on the skill of the facilitator.

In general, the authors strive to describe a wide range of visualization methods and related features, however, its boundaries may be so indistinct that it is difficult to identify precise recommendations for work with a certain method or a group of methods. The issues described correlate with specific visualization methods in only one article [24]. In this way, the list of issues without an indication of "where they live" creates a false sensation of the failure of visualization as an effective tool for business. However, the causes

of errors and ways of eliminating them are generally not addressed in the articles.

It should be separately noted that a few works spark theoretical interest, focusing on the study of the combination of different visualization procedures.

1.2. Main research objectives

In earlier works, the authors primarily answer the question "what?": "what is visualization?", "what is associated with it?", "what can be visualized?". They examine a broad range of visualization methods and provide their detailed definitions with striking examples, which makes it possible to treat the St. Gallen School works as a kind of dictionary of visual methods. In this regard, the authors established a clear tradition of discussing visualization methods, specifically their direct combination with illustrations. This may be a stylized image of a specific diagram, or a real-life example from business practice. Such an approach makes it possible to avoid discrepancies in term comprehension and is more than appropriate for this area of research. At the same time, early approaches to classification did not involve a division between data and knowledge visualization.

St. Gallen School researchers extend the theoretical basis of knowledge visualization through close examination of the organizational abilities of family firms [20], new business model development [9], strategic planning [14], and interviewing [21]. They consider visualization to be a form of boundary object. Boundary objects are "plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" [26]. This ethnographic understanding of the term "boundary object" was reevaluated in the work [1] illustrating that all engineering schemas are boundary objects. The School authors continue work in this area and consider all visual knowledge models as boundary objects. For example,

an article [9] reveals that the use of a digital business model template significantly increases perceptions of collaboration, but reduces creativity (other examples are provided in *Table 2*). In this way, the authors expand the concept of boundary objects and elaborate it with examples, as well as formulating a number of new research objectives in this area.

2. The formative phases of the St. Gallen School

Based on an analysis of the works of Martin Eppler, three phases of the formation and development of the St. Gallen School can be

identified: preliminary, empirical data accumulation and theory construction phases.

2.1. Preliminary phase

This phase, which lasted from 2002 to 2008, is characterized by several key features. The first is the predominance of theoretical articles of a synthesizing nature. In a number of works, attempts are made at the classification of visualization methods. Complexity level and solvable issues are employed (*Figure 2*) as the basis for classification. The authors also theoretically developed and applied their own typology of complexity levels of work with visualization:

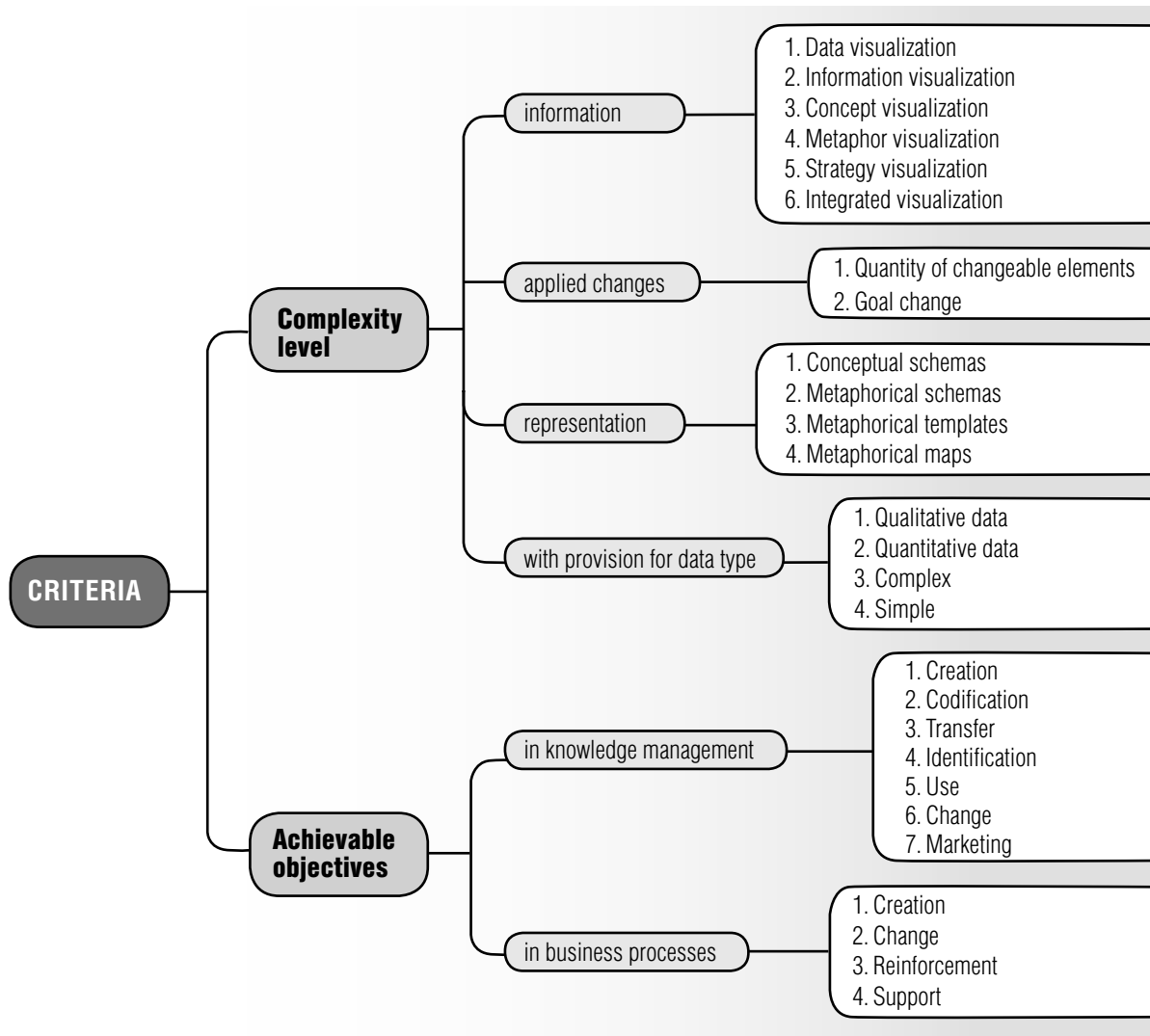


Fig. 2. Criteria for visual method classification

cognitive, emotional, and social. This classification is found in both the preliminary phase and in later works [14, 11, 19].

The second feature is the predominance of the number of conference proceedings over the number of publications in journals. In these proceedings, the researchers are fairly inconsistent in visual model structuring: a form of the periodic table is used [2], answers to the questions “what – why – how?” [5] and “who – what – where – why?” [26]. This inconsistency can be seen in later stages: various kinds of tables are used [16, 27], along with matrixes [28], which have a different structure and cannot be combined. By contrast, at this stage works appear which propose using visualization tools to complement one another. A striking example of this approach is an article [24], in which the author proposes applying, in an integrated manner, concept maps, mind maps, conceptual diagrams and visual metaphors, introducing them sequentially at different phases of the manager’s work.

2.2. Empirical data accumulation phase

From 2009 to 2013 the works of the St. Gallen School are characterized by a predominance of empirical works. The main research method at this phase is the experiment. The main research question that the authors raise is the influence of specific kinds of visualization on certain types of managerial activity (*Figure 3*). Specifically, the authors address how the implementation of visualization affects strategizing and business models, risk management and communication.

The general findings indicate the advantages of visualization: ease of communications and increased work performance of managers or teams of managers. However, the rigid frameworks that it can impose reduce creativity and have a number of negative consequences in social and emotional spheres.

The empirical research contains examples of questionnaires and descriptions of experiments that can be repeated in a different context or as a supplement to achieve other managerial objectives. The features of empirical research methods are characteristic for this scientific area as a whole. Among eight empirical articles in this phase, only one is based on a non-interventive research method. The extensive use of experimental research methods is a shortcoming of the St. Gallen School, as there is no theoretical basis for these experiments.

The article [11] is based on a survey of students and teachers on the particularities of using PowerPoint as a knowledge exchange tool. In this case, the use of closed questions was possible because PowerPoint is a popular tool that all respondents were familiar with.

2.3. Theory construction phase

In publications of 2013 and later the authors, having accumulated empirical material, return to the theoretical questions that were raised at the preliminary phase. However, if in this case the opportunities to combine different visualization methods, such as concept maps, mind maps, and argument maps [24] were investigated, now opportunities to combine different model construction procedures are studied.

In particular, the article [22] is dedicated to the combination of virtual and real visualization. The case description of visualization knowledge in police force crime fighting is notable, but is the only example of a descriptive qualitative research method to date. The authors showed how visual methods are applied to real life in situations when it is necessary to make responsible decisions within constrained timeframes, which is especially relevant for the modern business environment. Moreover, this article examines features of the visual model development procedure. The resulting model is further used for facilitating communications during qualitative research.

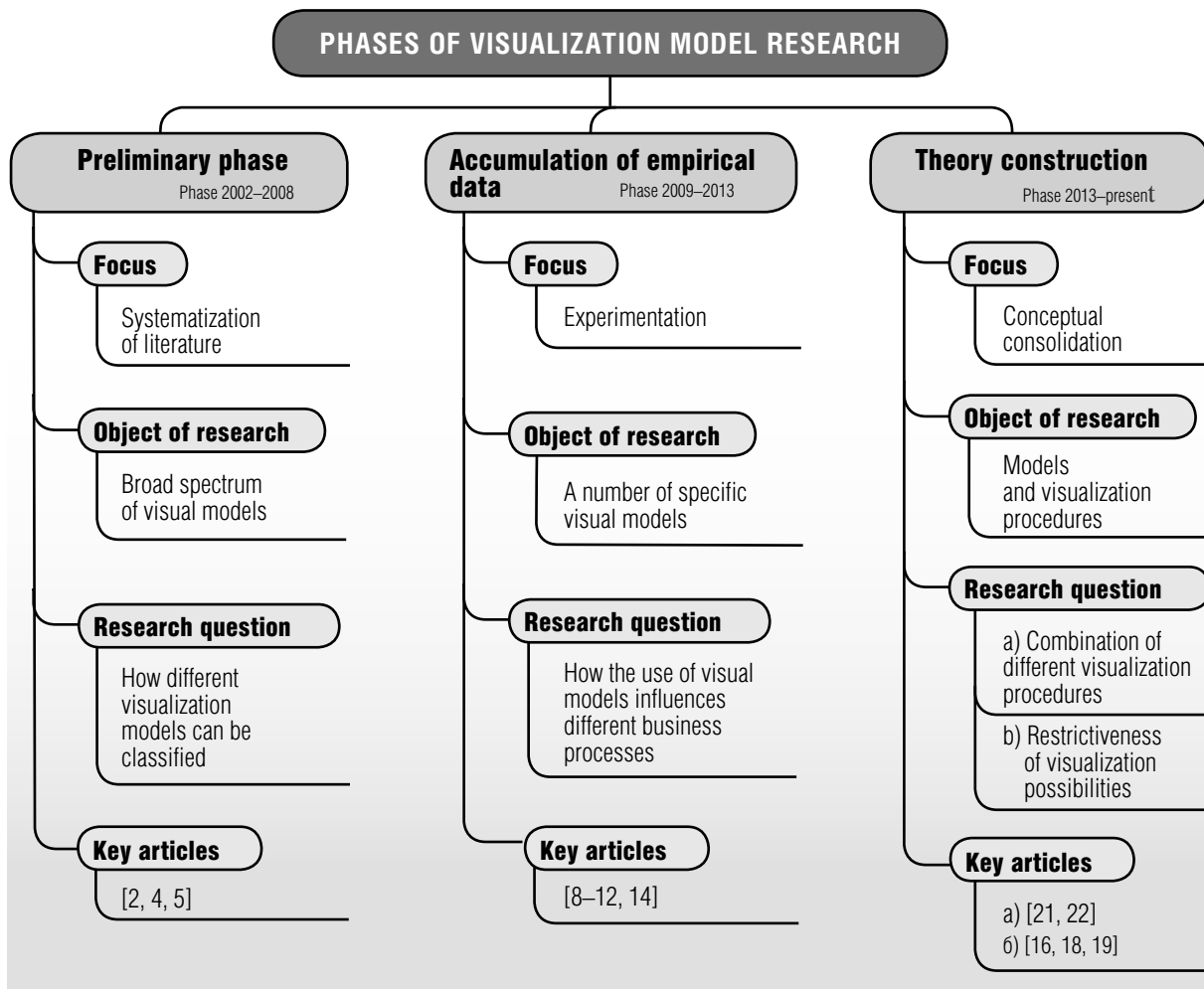


Fig. 3. Research phases of St. Gallen School visual models

3. The current state of knowledge visualization research

3.1. Issues and trends in the works of the St. Gallen School

In the works of Martin Eppler and his co-authors, the difference between knowledge and data visualization is identified as the visualization of qualitative and quantitative data. The conceptualization of the difference between data and knowledge visualization is valuable with regard to the development of a knowledge visualization theory. The data visualization theory is well developed, and the quantity of accumulated knowledge exceeds thousands of works related to dozens of areas. At the same time, knowledge

visualization theory is a new subject that necessitates a different approach to research.

Researchers at the St. Gallen Institute for Media and Communication Management strive to raise the overall level of visual literacy and therefore they are creating a web portal of the same name, www.visual-literacy.org, aimed at eliminating this gap. Additionally, the center’s staff regularly holds seminars and master classes for the business community. One of the main trends in the work of the St. Gallen School is its practical orientation. The authors give multiple detailed recommendations and examples for practitioners. Problems arising from perception of visual forms are closely examined in the work [19] and illustrated in a number of works [8, 11, 18].

3.2. The current state of research

As knowledge visualization is a new and rapidly developing area of research, at its initial phase there is not yet theoretical maturity or a precise classification of terms, and there is still no systematic approach to research.

A classification of visualization methods was the main focus of the works of the St. Gallen School in the preliminary phase. However, after the creation of an entire range of classifications, the authors set aside the subject for five years and returned to it in earnest only after accumulating extensive work experience with commercial companies and government organizations. *Figure 4* presents different approaches that the authors undertook in order to unite visualization methods into specific groups and identify links between these groups. An entire range of factors may be noted as the cause of the failures of the first classification attempts. First of all, at the time the articles were written, terms that designated different types of diagrams, graphs, matrices, and other graphics were largely undefined. For example, the term “knowledge map” in certain works is defined as a kind of analogue of a locality map, making it possible to determine where certain knowledge can be found while other authors use this term to designate the totality of diagrams displaying knowledge. Second, neither in the St. Gallen School works, nor in those of other authors studying visualization, can we witness the use of a powerful knowledge-structuring tool such as ontology. Ontology or specification conceptualization [29] is a hierarchical model of a subject field possessing a sound mathematical and programmatic foundation. Without ontology, it is fairly difficult to construct any kind of classification, particularly if the number of elements at the lower level of the hierarchy exceeds one hundred [2]. As regards the rules of ontology construction, it is apparent that division into 4-7 groups is insufficient; it is necessary to add one or two more hierarchical levels.

Returning to the issue of the division of research boundaries in data and knowledge visualization, we propose constructing separate ontologies for both the former and the latter. In this way, the number of elements will be reduced, while the classification criteria will become more lucid.

Research of visual methods in the current phase of development theory and practice are frequently focused on the features of a specific visual method. However, the number of visualization methods is not only great at present, but continues to rise. In keeping with the logic proposed, following the appearance of each new visualization method, researchers must explore the possibilities of using it in different business spheres, as well as the particularities of combining it with other methods. Such work appears to be excessively labor-intensive and to lead to the blurring of the subject of research instead of focusing on and forming a synthesized theory. It has evidently become imperative to redefine the structure of research in the area of study under discussion.

3.3. Features of knowledge visualization research

Currently, the majority of empirical research in the area of knowledge visualization is based on interventive methods, among which the experiment predominates. A similar strategy during visualization research is observed by many authors [30, 31]. It is likely that this is due to the fact that quantitative research entails the provision of a set of closed questions, which is only feasible if the respondent is well acquainted with the terminology of the subject area. As was previously mentioned, a uniform classification of visualization methods has not formed in scientific literature. Moreover, practitioners may work with visualization without realizing precisely which method they are employing and which business objectives this method can be applied to. Thus, the research methods used in this phase of the area of knowledge visualization make it impossible

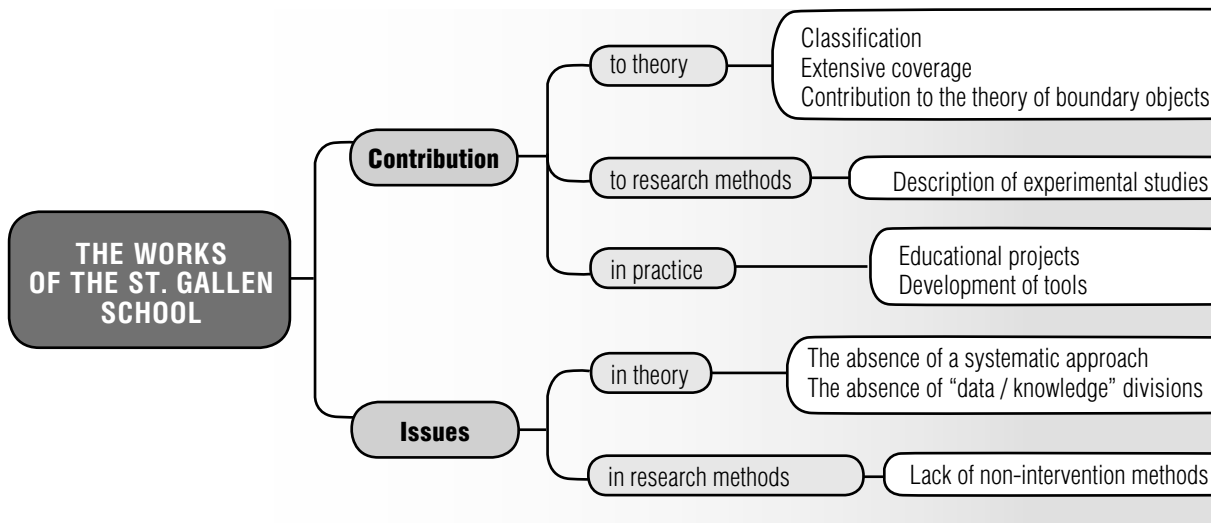


Fig. 4. Issues and trends in the study of visualization methods conducted by St. Gallen School

to reveal and observe the phenomenon in question in all of its manifestations.

In this case, the most appropriate method is the observation method (without interference), which was employed in only one study [32]. However, the study was conducted not in the business environment, but using the work of a police station as an example. As a result, the scientific community currently possesses an extremely restricted set of data on what is actually happening in visualization practice in business. This situation raises the issue of the importance and prospects of further study of this field using descriptive methods with the aim of identifying prevailing approaches to visualization in business [33–35].

Conclusion

The aim of this article was to analyze the leading European research in the area of knowledge visualization with the goal of identifying modern trends for their effective use in scientific and practical activity.

The article identifies the main phases of research formation of the so-called St. Gallen School: the preliminary, empirical data accumulation and theory construction phases.

Problematic areas are also identified, associ-

ated with applied research methods, the absence of a systematic structure and the inadequate differentiation of the concepts of “data visualization” and “knowledge visualization”.

As a whole, the works of the St. Gallen School made a significant contribution to the study of the matter of visualization and identified promising areas of research. Its contribution to theory includes classification of visualization methods, description of the use of visualization in business, development of a theory of boundary objects, as well as a detailed description of experimental research. Its contribution to business practice lies in its initiation of educational projects and development of new visual models.

Thus, there is a need to formulate a general theory of knowledge visualization in business, to create special tracks and seminars at international conferences of varying levels (for example, the Academy of Management, IFKAD, VISUAL, IEEE Pacific Visualization Symposium, et al.), as well as to formulate corresponding internet platforms. To effectively discuss the issues surrounding the creation of a general framework for methods, metrics and theoretical boundaries necessary for the development of the theoretical area, the development of a single ontology of visual methods seems particularly significant [36].

Among development trends in this area, the efforts of researchers to enlarge the scope of knowledge visualization in use by different business practices have been noted. In information processing (for example, when working with Big Data), the use of visualization as a clear, condensed description of data makes it possible to transition to more profound levels of interpretation. Currently, researchers note both the presence of diverse visualization software even for graphs with thousands of peaks and millions of connections [37] and the impossibility of depicting business processes using some uniform notation [38]. Thus, the crucial role in the processing of available data into knowledge, making it possible to take managerial decisions, is played by manager's expertise in synthesizing,

interpreting and systematizing information. The need to allocate knowledge visualization to a separate area of research is becoming apparent. It is worth taking into account that methods and approaches that were applied in the study of data visualization may be only partially applied to this situation. Because the field of study has not reached the necessary level of maturity, the use of quantitative methods or a deductive approach is currently underproductive. It is necessary, first and foremost, to develop an integral theoretical basis for further research, and then formulate empirically supported hypotheses.

This review makes it possible to identify new opportunities for research and focuses attention on the necessity of a systematization of existing knowledge. ■

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