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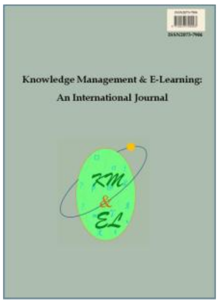

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Knowledge scaffolding visualizations: A guiding framework

Elitsa Alexander
Sabrina Bresciani
Martin J. Eppler
University of St. Gallen (HSG), Switzerland

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Knowledge scaffolding visualizations: A guiding framework

Elitsa Alexander*

Institute for Media and Communications Management
University of St. Gallen (HSG), Switzerland
E-mail: elitsa.alexander@unisg.ch

Sabrina Bresciani

Institute for Media and Communications Management
University of St. Gallen (HSG), Switzerland
E-mail: sabrina.bresciani@unisg.ch

Martin J. Eppler

Institute for Media and Communications Management
University of St. Gallen (HSG), Switzerland
E-mail: martin.eppler@unisg.ch

*Corresponding author

Abstract: In this paper we provide a guiding framework for understanding and selecting visual representations in the knowledge management (KM) practice. We build on an interdisciplinary analogy between two connotations of the notion of "scaffolding": physical scaffolding from an architectural-engineering perspective and scaffolding of the "everyday knowing in practice" from a KM perspective. We classify visual structures for knowledge communication in teams into four types of scaffolds: grounded (corresponding e.g., to perspectives diagrams or dynamic facilitation diagrams), suspended (e.g., negotiation sketches, argument maps), panel (e.g., roadmaps or timelines) and reinforcing (e.g., concept diagrams). The article concludes with a set of recommendations in the form of questions to ask whenever practitioners are choosing visualizations for specific KM needs. Our recommendations aim at providing a framework at a broad-brush level to aid choosing a suitable visualization template depending on the type of KM endeavour.

Keywords: Knowledge visualization; Knowledge modelling; Knowledge management; Knowledgeability

Biographical notes: Dr. Elitsa Alexander is a Post Doc researcher in knowledge visualization at the University of St. Gallen, Institute for Media and Communications Management (=mcm institute). She has been an Assistant Professor at the American University in Bulgaria and a course manager at the University of South Australia.

Dr. Sabrina Bresciani is an Assistant Professor at the University of St. Gallen (Switzerland). She has been a researcher at Harvard University (Boston), at the University of Cambridge (U.K.) and at the National University of Singapore. She is/has been a guest professor at various universities worldwide.

Dr. Martin J. Eppler is a full professor of media and communication management at the University of St. Gallen, where he is also the managing director of the Institute for Media and Communications Management (=mcm institute) and the head of the International Study MBA Program (ISP).

1. Introduction

In her research, Wanda Orlikowski (2006) has elaborated on the fact that knowledge is not an external, enduring, or essential substance – but a dynamic and ongoing social accomplishment. She has focused on the "scaffolding of knowledgeability" and suggested that consideration of the distinguishing characteristics of *physical scaffolds* can offer intriguing insights into how everyday knowing in practice is materially scaffolded. In this article, we develop Orlikowski's idea further in order to gain insights into how knowledge-in-practice is (or could optimally be) built and shared with the help of interactive visual representations (visual scaffolds) used by small groups of people.

A perennial knowledge management challenge is how to facilitate knowledge sharing among different professional disciplines for problem solving and decision making. There are numerous attempts for analysing the usability of scaffolds, especially in computer supported collaborative learning (CSCL), but most of these focus on the finest details of the interaction. Instead, our conceptual essay extracts the most relevant aspects of scaffolding from a building-industry perspective, at a broad-brush level, and highlights useful insights that KM practitioners can learn from.

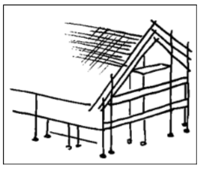
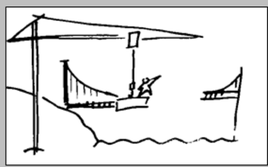
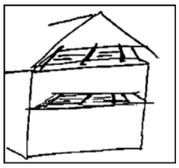
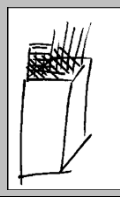
According to Orlikowski (2006), scaffolds "structure human activity by supporting and guiding it, while at the same time configuring and disciplining it". The research mandate proposed by Orlikowski invites investigation into the characteristics of physical scaffolds, thereby breaking down the orthodox distinctions between the social and the material, for understanding the material basis of knowledgeable action. Metaphorically, the juxtaposition of the building-industry versus the knowledge management approaches to scaffolding – i.e., the scaffold as a physical device versus the scaffold as a knowledge visualization device – can be useful for knowledge managers to aid their everyday knowledge communication endeavours.

Based on a review of building industry literature (UK National Access and Scaffolding Confederation, 2012; Anonymous, 1954; Peng, Pan, Rosowsky, Chen, & Yen, 1996; Hong Kong Buildings Department, 2006; Lotz, 2000), we have identified four generic functional types of physical scaffolds that can be used as fruitful analogies: *grounded* scaffold, *suspended* scaffold, *panel* scaffold, and *reinforcing* scaffold. The next section outlines some important functional features of the four physical scaffolding types and compares each of them to visualization templates for knowledge communication during team meetings.

2. Physical scaffolding techniques and knowledge scaffolding types

Table 1 provides brief descriptions of each physical scaffolding type in terms of its use, purpose, modus operandi, types of work supported, and lifespan.

Table 1
Types of physical scaffolds

Grounded scaffold	Suspended scaffold	Panel scaffold	Reinforcing scaffold
			
Use:			
allows workers to walk along the outside of buildings	suspends workers and materials from above	suspends workers and materials on layered structures	serves as reinforcing backbone of constructions made of concrete
Purpose:			
erection of (ground floors of) buildings	supports problem-related work (e.g., construction of bridges, and skyscrapers, connections of buildings or parts of buildings and physical structures)	layered, incremental erection of forms and structures made of concrete	counteract tension stress, long-term resilience against seismic activity
Modus Operandi:			
fixed to the ground	suspended by cranes, tower cranes, (electrical) hoist or extension arms, consoles	fixed on each layer to hold up slabs until the poured concrete is cured	invisibly integrated inside a construction's formwork/ a backbone
Types of work supported:			
Various	various	limited (to temporary reinforcement)	limited (to permanent reinforcement)
Lifespan:			
temporary	temporary	temporary	permanent

2.1. Grounded scaffold

A *grounded scaffold* (Fig. 1) is one which resembles a ladder or a frame and has its parts fixed to the ground. Physical grounded scaffolds "allow people to walk along the outside of buildings" (Orlikowski, 2006) and observe their common object of creation (the building) from various perspectives. Comparably, certain types of visual knowledge scaffolding templates allow collaborators to contemplate their common object of knowledge creation from various perspectives. Fig. 2 provides examples of two templates which have the same purpose as the grounded scaffold, conceptually and structurally. A *perspectives diagram* (left) maps different perspectives of a main topic (placed centrally) on a one-point perspective grid. It thus allows the team to consider the main topic from four different angles: e.g., prior knowledge, open questions, and positive versus negative experiences. A *dynamic facilitation diagram* (right) is a matrix-like representation of problems and solutions pertaining to an information repository base (placed along the bottom). It allows teams to debate on the realm of information they have available concerning an issue from different viewpoints. The latter two diagrams both serve the purpose of providing a “common ground” (Clark & Brennan, 1991) framework of shared beliefs and assumptions at a certain common level of knowledgeability.

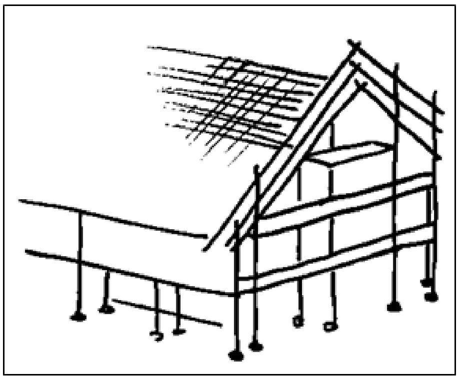


Fig. 1. Sketch of a grounded scaffold

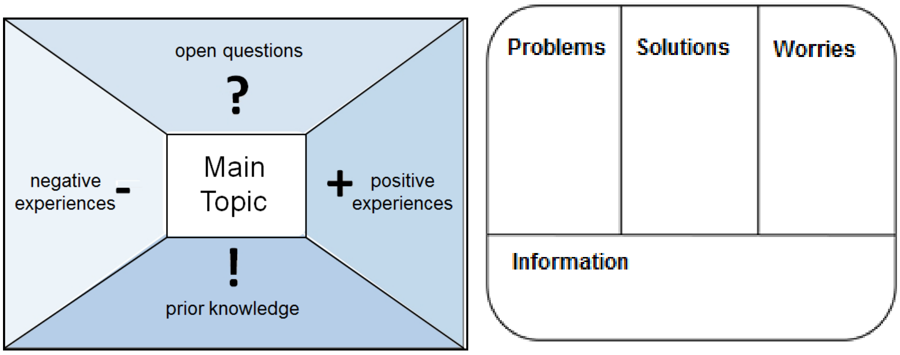


Fig. 2. Grounded scaffolds for knowledge visualization – the perspectives diagram by Martin Eppler (left) and the dynamic facilitation template by Jim Rough (right). Adapted from Eppler (2005) and Rough (1997)

Like a physical grounded scaffold is fixed to the ground and resembles a frame, so does a grounded knowledge scaffold (Fig. 2) resemble a framework for “grounding”. Grounding is a construct frequently invoked in the computer supported cooperative work (CSCW) literature as a “mechanism by which participants engaged in joint activity coordinate their respective understandings of matters at hand” (Koschmann & LeBaron, 2003). “Everyday knowing in practice” (Orlikowski, 2006) is grounded in the material forms, artefacts, and spaces through which humans act. Visualization templates for grounding (Fig. 2) can serve as representation aids for problem structuring as a group strives to create a shared problem perspective (Massey & Wallace, 1996). The latter is especially relevant for complex and ill-structured issues. The degree of “groundedness” (Roque & Traum, 2008) is the extent to which the matter at hand has achieved mutual belief and a common level of knowing while being discussed. For example, a dynamic facilitation diagram helps meeting participants self-manage the group and bring themselves to a “common level of capability” (Rough, 1997). The latter is often related to avoiding frustration and reducing cognitive load, especially for groups of people that are beginning a “collaborative episode” (when there are no or little experiences in collaboration and the collective sense making is at its beginning) (Reimann, 2005). Table

2 describes the main design features of grounded scaffolds, which include a frame-like design and embedded "unevenness" (Blackwell et al., 2001) to emphasize a central topic or a central information repository. Unevenness is a property of a visual representation to make things easy to see and do, so as to push the observers' ideas in a certain direction. Features of unevenness are important because of whatever part of the visualization is emphasized tends to become the focus of subsequent discussions mediated by the visualization.

Table 2
Design features of grounded scaffolds

Physical grounded scaffolds	**Grounded scaffolds for knowledge visualization,** e.g., perspectives diagram (**a**) and dynamic facilitation diagram (**b**)
Design features:	
• Resembles a ladder or a **frame**. *The frame allows workers to walk along the outside of a building and observe it from various perspectives.*	• Designed to represent a **frame of categories**. *The frame of categories allows collaborators to contemplate their common object of knowledge creation from different angles: e.g., prior knowledge, open questions, and positive/negative experiences (a); problems, solutions, and worries (b).*
• Has its parts **fixed to the ground**. *The ground level allows workers to walk along the outside of buildings together, at one level.*	• Designed with embedded unevenness to emphasize a central topic or a central information repository, with the purpose of achieving a coordinated understanding of matters at hand (**grounding**) and a common level of knowing (**groundedness**). *The visual unevenness allows collaborators to achieve a common level of groundedness around a main topic (a) or around common information (b).*

2.2. Suspended scaffold

Another type of scaffold is a *suspended scaffold*. This is a scaffold which "suspends workers from above (Orlikowski, 2006)". A suspended scaffold needs to be built every time when a grounded scaffold is not possible to build. Scaffolds of this type are typically suspended by cranes, tower cranes, (electrical) hoist or extension arms, or other mounting or rolling consoles. Fig. 3 provides a sketch of one type of suspended scaffold. Suspended scaffolds are designed to support challenging (from an architectural perspective) work, i.e., the building of bridges and skyscrapers, as well as to support the connection of buildings or parts of buildings and physical structures. This type of work may be metaphorically compared to knowledge sharing in a business context whenever there is a need *solve a concrete problem*, often combined with a need to build mental bridges between: (a) different types of boundaries to allow people with different backgrounds to work together, i.e., to enable cross-disciplinary collaboration, (b) the points of agreement and disagreement during negotiation, (c) two extreme options, (d) a current state and a desired future state, (e) the synergies and conflicts between goals (adapted from Eppler & Pfister, 2012), etc. Software-embedded suspended scaffolds are visual templates which provide the highest level of granularity (level of detail), approximation (degree of interpretable closeness) and portability (affordance for useful interpretations in a variety of contexts and situations) (Ackerman, Dachtera, Pipek, & Wulf, 2013). Fig. 4 provides examples of visualization templates which resemble the suspended scaffold conceptually and structurally. A *Venn diagram* (left) shows all possible logical relations between two positions and a *bridge metaphor* (right) shows the possible realization anchors of a strategy (e.g., bridging the real world with the classroom world). Another example would be a problem-related *argument map*, e.g. a Toulmin maps describing an argument's backing, grounds, modalities and rebuttal.

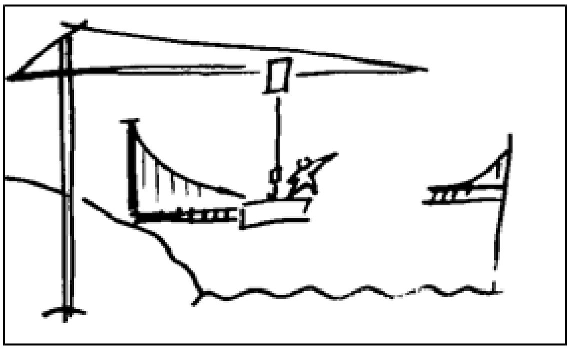


Fig. 3. Sketch of a suspended scaffold

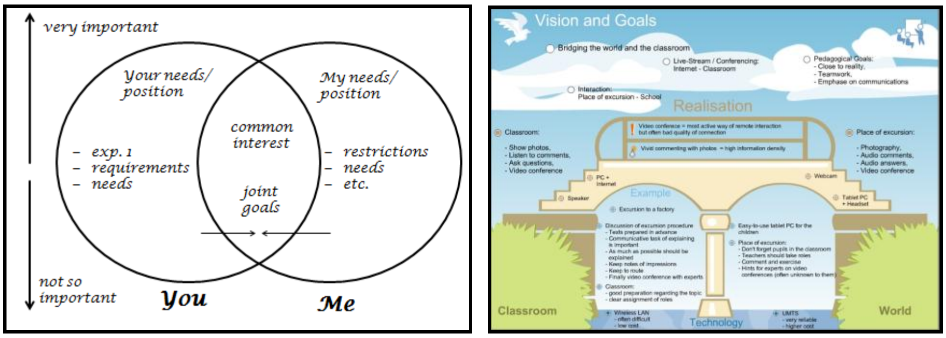


Fig. 4. Suspended scaffolds for knowledge visualization – Venn diagram (left) and bridge metaphor (right). Adapted from Eppler and Pfister (2012)

The mounting or rolling consoles, which are an essential part of suspended physical scaffolds, may be metaphorically compared to the boundary objects necessary to make visual templates work in certain collaborative settings. The notion of "boundary objects" (Carlile, 2004; Bechky, 2003; Carlile & Rebentisch, 2003; Levina, 2005; Star & Griesemer, 1989) highlights the capability of certain types of artefacts to act as translation devices across various thought worlds. Just like suspended scaffolds are designed to support the building of bridges, boundary objects are defined by their capacity to serve as mental bridges between intersecting knowledge worlds. An essential property of boundary objects is their loose structure to allow for interpretive flexibility (Star & Griesemer, 1989), not requiring "deep sharing" (Nicolini, Mengis, & Swan, 2012) and delimiting the need to learn across the boundary of practice. The boundary object thus allows each participant in the knowledge-sharing endeavour "to operate in condition of partial ignorance" (Nicolini, Mengis, & Swan, 2012) (see Table 3).

From a building-industry perspective, the condition of partial ignorance may be explained as follows. The suspended scaffold (unlike the panel and reinforcing scaffolds, see Table 1), supports various types of situated, *problem-related* work performed by different construction professionals. Whereas for the installers and technicians the building is an object of installation and removal of parts, for the painters and decorators it is subject to aesthetic improvement as well as protection from damage by rust and corrosion. Whereas estimators visit the site to record information about drainage and topography, equipment operators see the building as an object for holding machinery to move construction materials, etc. Each of these professionals works in condition of "partial ignorance" with regard to the work of others: neither of them is required to understand the full context of the construction process (technicians do not need to understand how paint protection exactly works, neither do estimators need to understand much about inspection and quality control).

Table 3
Design features of suspended scaffolds

Physical suspended scaffolds	**Suspended scaffolds for knowledge visualization,** e.g., Venn diagram (**a**) and bridge metaphor (**b**)
Design features:	
• Cranes, (electrical) hoist or extension arms, or other mounting or rolling consoles bring the workers to the exact **problem zone which needs special attention** (work or repair). *The rolling console allows workers to focus on a certain part of the construction.*	• Designed to **purposefully create a centre of interest or focus** around the points of agreement or common interests/common opinions in (interdisciplinary) **problem solving.** *Creates a focus on common interests and joint goals (a) and realisation (b).*
• **Neither** of the construction professionals **is required to understand the full context** of the construction process.	• Designed to allow collaborators work in **conditions of partial ignorance.** *Common knowledge is just the overlapping part of the two circles (a) and the central part of the bridge metaphor (b) – the rest is exclusive knowledge for some collaborators and purposeful ignorance for others.*

From a KM perspective, the condition of partial ignorance may be explained as follows: knowledge communication is characterized by exclusive and common knowledge, where the exclusive knowledge of one communication agent is the ignorance of the other communication agent in their shared context. In the Venn diagram depicted in Fig. 4, common knowledge is just the overlapping part of the two circles. "Everyday knowing in practice" (Orlikowski, 2006) is formed in a self-perpetuating process of mutuality (Knorr-Cetina, 1997) and solitary (exclusiveness) of expert subjects related to their object of shared activity. The organization of work depends, in part, on how mutuality and solitary (exclusiveness) are worked together. A healthy level of exclusiveness (i.e., the exclusive knowledge of one agent being equal to the ignorance of the other agents) delimits the need to learn across the boundary of practice. An excessive level of exclusiveness, however, may lead to a situation in which the scaffold retroacts on the community that generated it and "bites back" (Nicolini, Mengis, & Swan, 2012) as Engeström and Blackler (2005) colourfully put it.

For an analogy, imagine a relay race team being disqualified from a relay for losing or dropping the baton: in a similar vein, an excessive level of exclusiveness in knowledge sharing is like losing the baton of common achievement. Because suspended scaffolding is especially suitable for cross-disciplinary work, it may also be referred to as "reciprocal scaffolding" – a term applied in the field of CSCL (Carlile, 2004; Carlile, 2002; Holton & Clarke, 2006) to denote working with shared visuals that enable *reciprocal role switching*, and reciprocal entry of individual contributions. According to Holton and Clarke (2006) the lead in reciprocal scaffolding "passes from one person to another and is not totally the domain of any individual". One example of a GSS with embedded reciprocal scaffolds is the multi-mouse video conferencing system developed by Verma, Roman, Magrelli, Jermann, and Dillenbourg (2013). Each user takes an "expert" or "peer" role, stops the video stream on the shared screen at any time (with his/her own mouse cursor) and gives an individual contribution to the discussion by editing the visual on the screen (through note taking or sketching).

To go back to our construction industry metaphor, the quality of the knowledge-sharing endeavour is likely to depend on the quality of "full zooming", i.e., magnifying and compressing the entire representation to scale (Carpendale, 1999). By zooming, the visualization scaffold purposefully creates a centre of interest or focus around a knowledge unit (Larkin & Simon, 1987) (Table 3). The right timing of zooming is important in this context. Just like educators and instructors look for the "teachable moment" – that time and place where learners are ready to leap from one stage of cognitive mastery to another (Grady, 2006), so are the rolling consoles of suspended physical scaffolds installed, moved and disassembled according to the needs of the construction project. Like teachers use scaffolding to help learners span a cognitive gap or leap a learning hurdle (Grady, 2006), so do construction managers erect suspended scaffolds to support the construction of particular building elements. In their zooming capacity, suspended scaffolds may be interpreted as "epistemic objects" (Rheinberger, 1997): objects that take centre stage or shift into the background at different times (Nicolini, Mengis, & Swan, 2012). Epistemic objects embody what one does not yet know. They are open-ended and work as a source of interest and motivation by virtue of their "material transcendence" (Rheinberger, 2005). Like suspended physical scaffolds are designed to support the building of skyscrapers and bridges that are seemingly impossible to build, so are the visual structures for knowledge communication in cross-disciplinary teams designed to be driving forces in (seemingly impossible or challenging) knowledge development.

2.3. Panel scaffold

Panel scaffolds (Fig. 5) are designed to support the building of ceilings or the layered, incremental creation of forms and structures made of concrete. They "serve as structural columns to hold up slabs until the poured concrete is cured" (Orlikowski, 2006). Panel scaffolds are used sequentially, typically in a bottom-up fashion. In business, these types of work resemble knowledge sharing whenever there is a need to visualize: (a) a workflow, (b) a process by mapping its sequential steps, (c) a process by mapping key decision points and output documents, (d) a series of activities on a timeline, (e) a development through distinct stages of change, (f) a dynamic system through influencing factors, (g) the possible (prioritized) future states of a development (adapted from Eppler & Pfister, 2012).

Whenever there is a need to allocate, schedule, and synchronize activities, there is also some *commitment on the order of doing things* – e.g., sequential workflow steps or process steps. Teams in these collaboration conditions need to organize a meaningful way for working on every knowledge-building block. An effective knowledge communication scaffold in this context needs to have the ability to conceive things iteratively and deconstruct the knowledge domain into comprehensible pieces of temporally situated knowledge – created, re-created or revisited in the form of modular increments. Fig. 6 provides examples of visualization templates which resemble the panel scaffold conceptually and structurally. A *roadmap* (left) (Phaal, 2005) is a visual timeline which renders time, the ultimate abstraction (Adam, 2013) visible and concrete (Yakura, 2002) by deconstructing it into sequential steps as structural elements. A *workflow diagram* (right) is a representation of a work process, showing the process steps as boxes of various kinds, and their order by connecting them with arrows.

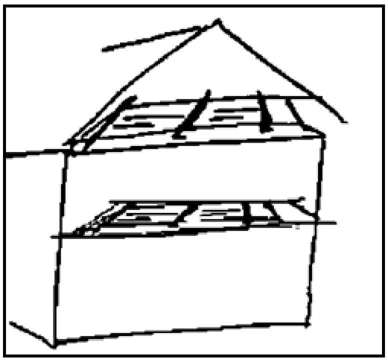


Fig. 5. Sketch of a panel scaffold

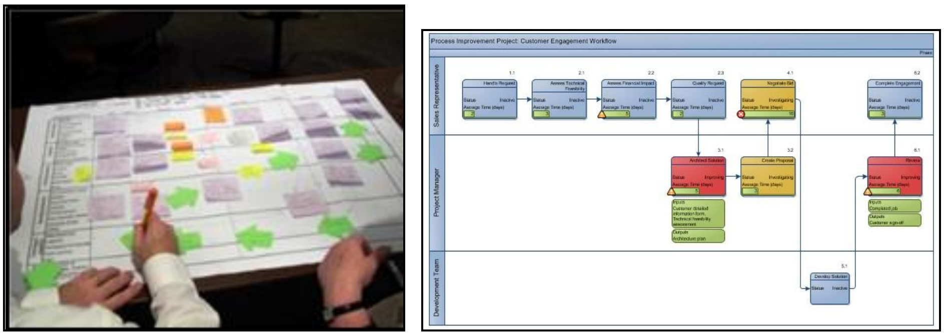


Fig. 6. Panel scaffolds for knowledge visualization: a roadmap (left) and workflow diagram (right). Adapted from *left* – Phaal (2005); *right* – screenshot used with permission from Microsoft

Roadmaps, timelines and workflows are capable of acting as visuomotor systems (Milner & Goodale, 2006) and allowing for progressive creation, sharing and evaluation (Green & Petre, 1996) of knowledge while stimulating the exchange of typical and predictable functional pieces of knowledge (Anderson & Rosenberg, 2008). Timelines embody the key elements of a narrative: a beginning, a middle, and an ending (van Dijk, 1997). Of these elements, the ending is the most important part: timelines allow participants to envision the ending of an otherwise open-ended story (Yakura, 2002). Comparably, the suspending structural columns of a physical scaffold are fixed on each layer (e.g., on the ceiling) and are removed after the concrete is cured. The ending of each incremental building procedure, i.e., the curing of the concrete in each panel, is the most important part and the principal goal of existence of each panel scaffold. Roadmaps, timelines and workflows embody objectivist assumptions about time (Yakura, 2002) and thus function as "inscription devices" (Henderson, 1991) – that is, entities that can pass across contexts, while they stay relatively unchanged (immutable). They are pivotal in producing stability (Simonsen, Bærenholdt, Büscher, & Scheuer, 2010) because they create an impression of concreteness that belies the inherent uncertainty of representing time (Yakura, 2002). These visual representations shape the structure of the collaborative work in predictable products (milestones). Table 4 summarises the design features of panel scaffolds, with a focus on their meaningful sequential structure for working on every knowledge-building block.

Table 4
Design features of panel scaffolds

Physical panel scaffolds	**Panel scaffolds for knowledge visualization,** e.g., roadmap (**a**) and workflow diagram (**b**)
Design features:	
• The overall scaffolding structure is decomposed into **modular increments – panels**.	• Designed to contain **structural elements.** *The roadmap (a) and workflow diagram (b) contain sequential steps as structural elements. This allows deconstructing the knowledge domain into temporally situated pieces.*
• Supports the incremental creation of panels – **sequentially and progressively**. *A new panel is built only after the preceding panel has been removed (after the concrete is cured).*	• Designed to provide **a meaningful sequential structure for working on every knowledge-building block**. *The pre-defined structure provides a predictable and logical commitment on the order of doing things.*

2.4. Reinforcing scaffold

Reinforcing scaffolds (Fig. 7) "serve as reinforcing formwork that becomes integrated into the final element being built" (Orlikowski, 2006). Many layers of stabs or arches form a skeleton for the concrete to be poured onto. This skeleton is invisible from the outside, permanent, and serves as a backbone to counteract tension stress and to guarantee the long-term resilience of a building against, e.g., seismic activity. In business, this type of purpose is served whenever teams are collaborating, inter alia, on: (a) finding ways to retain organisational and team-level knowledge for long periods of time (Novak & Cañas, 2008), (b) analysing possible long-term scenarios (adapted from Eppler & Pfister, 2012), (c) (ideally) gathering and combining a team's insights about a collaborative process and deducing lessons learned for future activities (Eppler & Sukowski, 2000), and (d) building team common terminology space(s). Fig. 8 provides examples of visualization templates which resemble the reinforcing scaffold conceptually and structurally. A *visual domain glossary* (left) is a common repository of shared norms, rules and terminology (i.e., shared meanings). In this way, the collective "knowing in practice" of the team can be consulted whenever needed. A *concept diagram* (right) visually depicts a concept with its definition (including type, area and modality), elements, examples, implications and related concepts.

Reinforcing scaffolds are powerful knowledge scaffolds that "not only permit utilization of the knowledge in new contexts, but also the retention of the knowledge for long periods of time" (Novak & Cañas, 2008). Eppler and Sukowski (2000) outlined two basic layers of shared spaces that "underpin successful knowledge work in teams" – the first layer being the communication infrastructure provided for the team and the second layer being the repertory of shared norms, rules and conventions within a team. The second layer is conceptually related to reinforcing scaffolds and to Nonaka and Konno's (1998) idea of the "shared mental space". The latter is characterized by "*internalization*", which, in its turn, is part of the SECI (socialization, externalization, combination, and internalization) model [Ibid.] illustrating the transfer of tacit and explicit knowledge within an organization. Internalization occurs whenever knowledge structures become deeply entangled in the practices of collaboration (Nicolini, Mengis, & Swan, 2012) and gradually become work-oriented situated infrastructures (Hanseth & Lundberg, 2001). Just like physical reinforcing scaffolds are invisible, so are work-oriented situated infrastructures "black-boxed" (Nicolini, Mengis, & Swan, 2012) and sunk into, inside of, universal infrastructures, "rather like Russian dolls" (Star & Ruhleder, 1996). According to the type of "knowledge regime" (Howard-Grenville & Carlile, 2006), reinforcing scaffolds, and the *work-oriented situated infrastructures* made possible by reinforcing scaffolds, are nested in wider rules and conventions (Table 5).

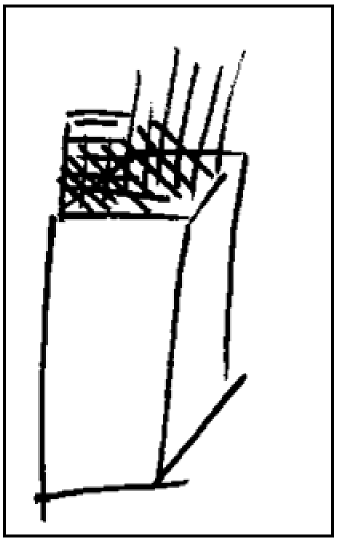


Fig. 7. Sketch of a reinforcing scaffold

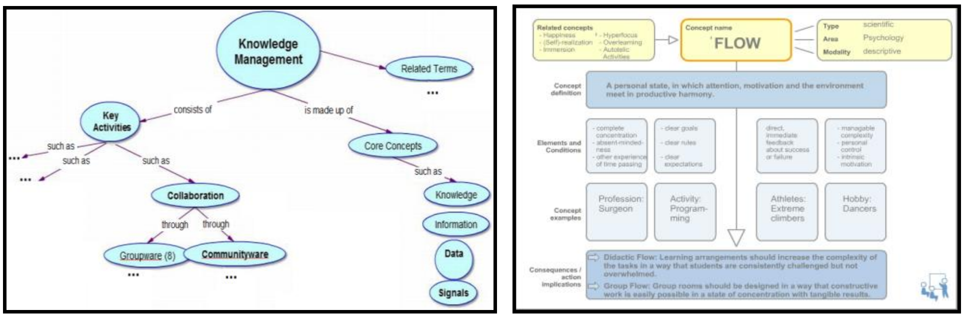


Fig. 8. Reinforcing scaffolds for knowledge visualization: visual domain glossary (left) and concept diagram (right). Adapted from Eppler (2005)

The more "sunk in" or "nested" an infrastructure is, the more we tend to consider it stable (Nicolini, Mengis, & Swan, 2012). In fact, reinforcing work-oriented infrastructures need to be both plastic and robust. They need to be robust because they do not grow *de novo* but are based on a high level of *institutional relevance* (Salisbury, Parent, & Chin, 2007); the latter is referred to by other authors as *closeness of mapping* (Green & Petre, 1996) of representation to domain. In this light, reinforcing scaffolds (e.g., visual domain glossaries) need to warrant some level of institutional relevance and closeness of mapping. At the same time, reinforcing scaffolds need to be plastic and flexible to enable their survival in conditions of change over longer periods of time. Without enough flexibility, reinforcing scaffolds would be "frozen visual templates… which pre-validate any new [conceptual, Ed.] category initiation" (McGrath, 2014) – i.e., even if they are otherwise affording, there would be no controversy (Seeber, Maier, Ceravolo, & Frati, 2014) in satisfying their affordances (McGrath, 2014).

Comparably, physical reinforcing scaffolds are designed to allow for a certain level of *flexibility* in the form of pre-calculated acceptable motion (e.g., in case of seismic activity). Metaphorically speaking, hence, reinforcing visualizations in general need to have some *permissiveness* (Blackwell et al., 2001), that is, a certain level of modifiability, to accommodate to fluctuating in situ (Suchman, 1987) knowledge communication practices. In this light, optimal reinforcing scaffolds should serve as *plastic-robust* foundations, comparable to *fluid-frozen materials* (Whyte, Ewenstein, Hales, & Tidd, 2007) used in building practices – i.e., constellations of inter-subjectivity and inter-objectivity (Latour, 2005) that are both frozen, hence making team's interaction endure beyond the present, and fluid, open and dynamic.

Table 5
Design features of reinforcing scaffolds

Physical reinforcing scaffolds	**Reinforcing scaffolds for knowledge visualization,** e.g., visual domain glossary (**a**) and concept map (**b**)
Design features:	
• Serves as reinforcing formwork that becomes **integrated into the final** element being built.	• Designed to permit the **retention of the knowledge for long periods of time**.
• **Many layers of stabs or arches** form a skeleton for the concrete to be poured onto.	• **Many layers of concepts** form a skeleton for the common terminology in the shared mental space.
• Are **invisible** from the outside.	• Designed to be part of universal knowledge infrastructures, **smoothly integrated into organization-wide established KM rules and conventions**.
• Designed to allow for a certain level of **flexibility** in the form of pre-calculated motion in case of seismic activity.	• Designed to **permit some modifiability** (e.g., modifiable concept categories/branches).

According to Orlikowski (2006), scaffolds are *dangerous*, i.e., they are vulnerable to breakdown and failure. In the building industry, dangerous situations frequently arise, consequently, building managers regard safety as an issue of crucial importance. Compared to safety on a building site, "situated safety" (Gherardi & Nicolini, 2002) as an organizational competence arises from a constellation of interconnected practices – it is socially constructed, innovated and transmitted to new members of the system of knowledge communication practices, and it is institutionalized in team values and norms. Just like physical reinforcing scaffolds are sunk inside the building's structure and only become visible when the building breaks down, the consequences of faulty working infrastructures [e.g., faulty visual domain glossaries, Ed.] become *visible upon breakdown* (Star, 2010).

3. Theoretical background

The underlying theoretical background of this conceptual paper is Orlikowski's piece "Material knowing: the scaffolding of human knowledgeability". In addition, we have mobilized multiple theoretical "lenses" through which to analyse the four different physical types of scaffolds we derive from the building industry and metaphorically compare to corresponding knowledge management situations. We have interpreted the *grounded scaffolding* technique mainly in the light of Clark and Brennan's (1991) common ground theory. We have further extended our interpretation to draw on the "grounding" construct from the field of CSCW (Koschmann & LeBaron, 2003) and the "groundedness" construct from the literature on discourse and dialogue (Roque & Traum, 2008). Our considerations related to the second type of scaffolding – the *suspended scaffolding* – have been fuelled by two theoretical concepts: "boundary objects" (Carlile, 2004; Bechky, 2003; Carlile & Rebentisch, 2003; Levina, 2005; Star & Griesemer, 1989) and "epistemic objects" (Rheinberger, 1997). From another interpretative angle, we have drawn on the notion of "reciprocal scaffolding" from the field of CSCL (Carlile, 2002; Holton & Clarke, 2006) and have viewed "everyday knowing in practice" (Orlikowski, 2006) as forming in a self-perpetuating process of knowledge solitary and mutuality. The central tenet of our discussion on *panel scaffolding* is Henderson's (1991) "inscription devices" concept, extended by a view on roadmaps, timelines and workflows acting as visuomotor systems embodying monotemporal assumptions about time (Yakura, 2002; Milner & Goodale, 2006). For analysing *reinforcing scaffolding* we have utilized Eppler & Sukowski's (2000) theoretical perspective of shared team norms, which, in its turn, is related to Nonaka and Konno's (1998) idea of knowledge "internalization" and the "shared mental space". We have conceived reinforcing scaffolds as work-oriented situated infrastructures (Hanseth & Lundberg, 2001) and have accentuated the role of "situated safety" (Gherardi & Nicolini, 2002) in this context.

4. Similarity and differences among scaffolding types

We have analysed the concept of "scaffolding" as the support given during the knowledge communication process which is tailored to the needs of the collaborators and is performed with the help of visual templates, i.e., "cognitive tools as concept maps, semantic networks, causal maps, argument maps, and system models, etc., … applied to foster high-order thinking" (Wang, Peng, Cheng, Zhou, & Liu, 2011). The major similarity between the four scaffolding types is their role in building common knowledge among team members during knowledge sharing. This similarity is represented as the overlapping part of the Venn diagram depicted in Fig. 9. However, the four scaffolding types are also very different with respect to each other – i.e., they are as orthogonal as possible, in accordance with Blackwell et al's (2001) guidelines for creating new descriptive dimensions. The main differences are related to the typical design features (Tables 2-5) and are summarized in Fig. 9 as follows: (1) grounded scaffolds are built as a frame of categories around a central topic, enabling perspective taking; (2) suspended scaffolds are built with directed focus on a concrete problem; (3) panel scaffolds are built sequentially, in the form of temporally situated increments; and (4) reinforcing scaffolds are built in the form of skeletons of concepts.

If two (or more) scaffolding types are used in combination with one another, this can enable representational transfer (Novick & Hurley, 2001) and knowledge portability (Ackerman, Dachtera, Pipek, & Wulf, 2013) between different KM situations – e.g., problem solving and knowledge construction. A perennial CSCL challenge is how to facilitate knowledge transfer between "learning by problem-solving" (which may be easily forgotten or "inert", and hardly generalizable to conceptual knowledge) and general knowledge construction (with well-established, theory-anchored methods). To solve this problem, Wang, Wu, Kinshuk, Chen, and Spector (2013) proposed a visualization-based environment for problem-based learning (V-PBL). Problem-solving and knowledge-construction were integrated in the V-PBL through "dual mapping" – learners were encouraged to connect the nodes of an *argument map* to the relevant nodes in a *concept map* (and vice versa) to indicate the knowledge that supported the problem-solving process. The argument map, as a *suspended scaffold*, explicated the problem-solving experience with directed focus on the concrete problem, while the concept map, as a *reinforcing scaffold*, was built in the form of a skeleton of concepts that provided "anchored points for solving problems based on relevant knowledge and for integrating new understanding with prior knowledge" (Wang et al., 2013). Additionally, a *flowchart* was provided with recommended steps to go through while performing the learning task (as a *panel scaffold*).

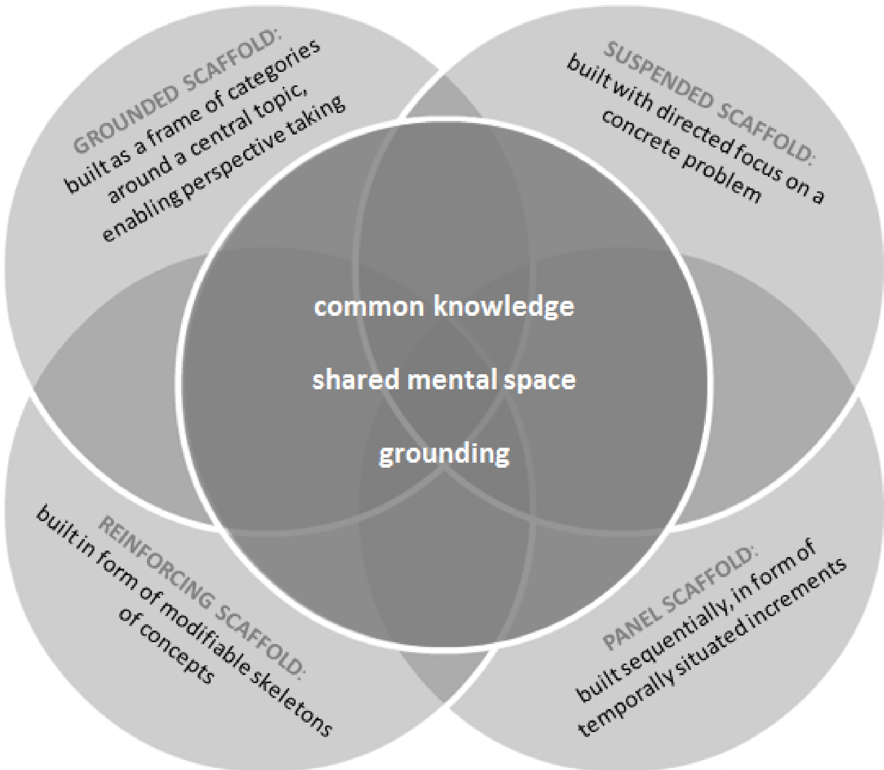


Fig. 9. Differences among scaffolding types

5. Similarity and differences among scaffolding types

The visual structures for knowledge communication in teams discussed above foreground a number of important and, at times, critical ways in which scaffolds may enable, sustain, or disable collaborative knowledge work. Our juxtaposition of building-industry and knowledge communication views on scaffolding has revealed a number of common assumptions and yielded arguments which support the validity of Orlikowski's scaffolding metaphor. Building-industry practices map well to certain KM situations and, hence, can be used as analogies for a guiding framework for choosing the best visualization format. The latter framework can be used in the design of various visualization functionalities of KM suites.

Table 6
Knowledge scaffolding structures – A guiding framework for practitioners

Physical scaffolding type to think of:	Knowledge visualization type:	Questions to ask*:
Grounded	**COMMON GROUND TEMPLATES e.g., Perspectives Diagram, Dynamic Facilitation Diagram**	**a, b**
When to apply – to begin a collaborative episode, to discuss complex and ill-structured issues, etc.		
Suspended	**DELIBERATION & NEGOTIATION TEMPLATES e.g., Venn Diagram (Negotiation Sketch), Argument Map**	**c, d**
When to apply – to solve concrete problems by building mental bridges between: various types of boundaries to allow people with different backgrounds to work together, the points of agreement and disagreement during negotiation, two extreme options, a current state and a desired future state, the synergies and conflicts between goals, etc.		
Panel	**CO-CONSTRUCTION TEMPLATES e.g., Roadmap, Timeline, Workflow Diagram, Flowchart**	**e, f, g**
When to apply – to visualize: a workflow, a process by mapping its sequential steps, a process by sequentially mapping its key decision points and output documents, a series of activities on a timeline, a development through distinct stages of change, a dynamic system through influencing factors, the possible [prioritized] future states of a development, etc.		
Reinforcing	**ELICITATION TEMPLATES e.g., Visual Domain Glossary, Concept Map**	**h, i, j**
When to apply – to retain organizational and team-level knowledge for long periods of time, to gather and combine a team's insights about a collaborative process and deduce lessons learned for future activities, to build a common terminology space for a team, etc.		

*The questions are outlined in the section following Table 6

How do practitioners choose the best visualization format when teams need to work together for assessments, planning, or decision making? Which types of physical scaffolds can be thought of to guide the process of making this choice? Our recommendations presented in Table 6 are meant to provide a framework for thinking at a broad-brush level to aid choosing a suitable visualization template. We distinguish among four basic types of knowledge visualization templates – common ground, deliberation & negotiation, co-construction and elicitation templates – corresponding to the four scaffolding types.

Which questions could be asked to guide the process of choosing the best knowledge visualization template? Here are some example questions which are meant to serve as suggestive signposts (instead of formal criteria) for the suitability of the visualization templates. If the answer to a question is a definite "yes", then the templates proposed in Table 6 are most likely to be suitable:

(a) Is there a need to contemplate the common object of knowledge creation from different angles?

(b) Is a mechanism needed by which the team members could coordinate their respective understandings of the matter at hand?

(c) Is there a need to build mental bridges between intersecting (cross-disciplinary) knowledge worlds?

(d) Is there a need for zooming purposefully to create a centre of interest or focus around knowledge unit/units?

(e) Is a commitment on the order of doing things needed?

(f) Is there a need to allocate, schedule, and synchronize activities?

(g) Is there a need for the visualization scaffold to embody the key elements of a narrative: a beginning and an ending, by emphasizing on the ending?

(h) Is it possible to gather and combine a team's insights about a collaborative process and deduct lessons learned for future activities?

(i) Is there a way to build a common repository of shared norms, rules and terminology for the team?

(j) Is the project at risk from a KM point of view – is there a high probability of some knowledge-sharing failures becoming visible upon project breakdown?

6. Limitations of the scaffolding metaphor and future research

In her commentary on Wanda Orlikowski's "Material knowing: The scaffolding of human knowledgeability", Jacky Swan (2006) outlined some *limitations* of the scaffolding metaphor. Swan's first rational worry was that not all physical scaffolds are "temporary and flexible" (as per Orlikowski, 2006). Some physical scaffolds, like the scaffolding for the Sagrada Familia cathedral in Barcelona, are permanent and fixed. Swan's comment is consistent with our finding that there is a generic type of physical scaffolds which are permanent – i.e., *reinforcing scaffolds* (see Table 1). Most scaffolds are transcendental, being gradually dismantled (or "faded") and leaving behind them the "spirit" that made the building of physical or knowledge constructs possible. Unlike all other scaffolds, however, reinforcing scaffolds are permanent and fixed, and live as long as the building lives – comparably, work-oriented situated infrastructures make team's interaction endure beyond the present. Swan also notes that scaffolds can be "degenerative" (Swan, 2006), and not only "generative" (as per Orlikowski, 2006). We agree with Swan's observation that scaffolds may frustrate knowing in practice and, in doing so, may support dissent and disruption as well as assent and unity of purpose. To state the obvious, scaffolds seem to limit the pace of knowledge construction work that may be possible without them. Depending on their type, scaffolds provide some affordances for action and suspend others. In our analysis, we have given due regard to the fact that scaffolds are dangerous and vulnerable to failure – e.g., by emphasizing the importance of "situated safety" as an organizational competence. Again in her commentary on Orlikowski, Swan appreciated the power of the scaffolding metaphor by admitting that she was struck by the degree to which the metaphor made her reflect on "knowledge in technology" (Weick, 1990). In our analysis, we pay due regard to the "socio-materiality" (Orlikowski, 2006) of knowledge creation, knowledge sharing and knowledge utilization. Our contribution lies in the novel insights that we have derived from the comparison of building-industry and knowledge management approaches.

We view our guiding framework of visual structures for knowledge communication as outlining some "pre-inventive structures" (Finke, Ward, & Smith, 1992), serving as discursive devices and holding promise of being created and re-created throughout the course of knowledge communication. Because of the enduring applicability of the outlined scaffolding principles for knowledge creation and communication in general, their applicability in the knowledge management practice becomes intuitively and practically recommendable. In our future work we intend to conduct structured interviews with managers to investigate their use (or lack of use, or misuse) of knowledge scaffolding visualizations in their everyday practice. We also intend to perform a series of experiments on the applicability of the four identified types of scaffolds for their hypothesized optimally-suitable purposes. The insights we expect to gain will, inter alia, contribute towards revisiting Swan-Orlikowski's debate on the use of scaffolding in management and towards sharpening the KM community's sensitivity about the importance of the topic.

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