Dynamic and participatory methods and media when working with visualization in product development

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2009

Contents

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Abstract

Visualization has been highlighted as a highly useful approach for product development that is characterized by both complexity and uncertainty, but research on the subject is limited and few delve into details on how to visualize. This paper investigates pedagogical processes when working with visual management in product development by focusing on challenges and solutions when handling interfaces between departments.

The traditional, mainstream techniques for project and product development (e.g. Gannt charts) produce visual images that have been criticized for their static nature and inability to function in projects with difficult interdependencies and changing prerequisites. By taking a reflective approach and codifying knowledge developed in the field, this paper investigates how visualization can be used to handle two challenges: physical barriers and personal as well as departmental differences. The paper proposes that an extended view of visualization is useful in this kind of product development. This means that visualization is handled as a dynamic and participatory process where multi-dimensional methods and media are used to stimulate multiple senses so that project participants can explore and exploit knowledge, and form a shared mental model of the project.

1. Introduction

Interdepartmental communication and coordination is crucial for both R&D performance in general (Håkansson and Nobel, 1993; Keller, 1986) and product development performance in specific (Clark and Fujimoto, 1991; Riggs, 2004). Stimulating communication is one of the most important productivity problems in R&D (De Meyer, 1991), and it is important for overcoming interdepartmental barriers in product development (Lakemond and Berggren, 2006). However, simply increasing the degree of communication increases complexity and could result in information overload (Allen, 1977) or even lack of information if it is not presented in the right format. For example, the introduction of modern information and communication technologies has in several instances resulted in information overload (Kiesler and Cummings, 2002). Although it is paramount to ensure effective communication (Brown and Eisenhardt, 1995; Krishnan and Ulrich, 2001), the combination of increasing complexity and uncertainty (Davies and Hobday, 2005), and limitations in human information processing (Miller, 1956) means that it is no trivial task. The difficulty is reinforced by the fact that departments exhibit differences in needs/wants, professional orientation, time orientation, bureaucratic orientation, which result in conflicting requirements (Griffin and Hauser, 1996; Lawrence and Lorsch, 1967; Vandevelde and Van Dierdonck, 2003).

Thus, it is challenging to establish effective communication and many firms fail to resolve the situation (Shenhar and Dvir, 2007), and it is particularly challenging in situations where both complexity and uncertainty is high (Lindkvist et al., 1998; Loch et al., 2008). One difficulty is to find a repertoire of media and methods that addresses problems related to interdepartmental interfaces (Lakemond et al., 2007), and that allows for effective communication in product development without creating information overload or lack of information (cf. Daft and Lengel, 1984, 1986; Schrader et al., 1993). In order to resolve the situation, both practitioners (Hilborn and Lugnfors, 2004; Wenell, 2001) and academics (Eppler and Platts, 2009; Forsberg et al., 2005) have stressed the need for visual communication.

The purpose of this paper is to investigate pedagogical processes when working with visual management in product development which is characterized by high degrees of complexity and uncertainty. The focus is on challenges and solutions when handling interfaces between departments.

2. Theoretical perspectives on visualization

Visualization has attracted attention in a wide range of areas (see Bresciani and Eppler, 2008 for a literature review), such as manufacturing (Greif, 1991), information systems (Zhang, 1998) and human-computer interaction (Preece, 1994). Although visual management has been highlighted as a key factor for explaining the success of many Japanese firms (Dennis, 2002; Ho, 1993), there are still relatively few management studies that focus on visualization (Bresciani and Eppler, 2008; Eppler and Platts, 2009) and, in particular, in the area of product development projects. A search in the Science Direct Database, including 106 journals in the category ‘business, management and accounting’, and a complementary search in 13 other management journals (e.g. Harvard Business Review and Project Management Journal), resulted in a total of 251 articles of which only 32 focused on management issues and as few as 10 discussed product development projects. The search was conducted at the end of March 2009 using truncations of visual* and visib* in combination with manage*, plan*, contr* and aid*, e.g. [“visual* manage*” or “visib* manage*”] and [All years]. Visualization can obviously be reported using various other phrases, but the result clearly indicates that visualization has not been at the centre of attention in studies of product development projects.

Visualization is typically depicted in the form of two-dimensional images or objects. In other words, visualization is viewed as a noun, an end-product. For example, trade-off curves are sometimes described in the literature as an important tool for highlighting and clarifying the relation between two parameters. While traditional visualization such as trade-off curves have their merits, it seems that they do little to capture the often chaotic and emergent character in complex systems development, or identify the interrelation between multiple parameters (Berggren et al., 2008). Thus, this paper argues that it is important to investigate the importance of visualization as a verb (method) and tool (media) where project members participate in the production of the noun (end-result). For example, it could be beneficial to focus on the use of multiple dimensions (e.g. the height, width and depth of a room) in order to stimulate multiple senses, because this is directly linked to the episodic and procedural memory, and thereby also learning (Tulving, 1985). Thus, this paper takes an extended view on visualization by defining it as a dynamic and participatory process where multi-dimensional methods and media are used to stimulate multiple senses so that project participants can explore and exploit knowledge, and form a shared mental model of the project.

Although the mainstream product development literature describes many tools, such as Gantt charts, that produce useful images for management (Forsberg et al., 2005; Ulrich and Eppinger, 2003), they seldom discuss how to work with visualization in product development projects. In addition, Taxén and Lilliesköld (2008) argue that the problem is that many of these traditional tools produce visual images that are focused on optimizations and control rather than action and coordination. They also claim that the 'cognitive load' of deciphering these images can easily become too complex as they compress different modalities into a single image. The tools have also been criticized for lacking flexibility and adaptability (Davies and Hobday, 2005; Hobday, 1998). For example, Christensen and Kreiner (1997) state that many traditional approaches are useful for providing high operational performance in stable environments, but are less useful when the prerequisites change. Based on a case study of a complex, uncertain and time-critical product development project in the telecom industry, Lindkvist et al. (1998) argue that all issues cannot be solved at the outset of this kind of product development project so public arenas seem to be vital for communicating changes and establishing a commitment from project members. The authors conclude that it appears that traditional structures and mechanisms are somewhat useful in this kind of product development, but that other mechanisms are also needed. Jaafari (2003) proclaims that there is an acute need to develop approaches that allows for feed-back and reflection, and that can be used in projects that are both complex and uncertain. Our paper addresses this critique by proposing how visualization can used in product development where complexity and uncertainty must be dealt with simultaneously.

Research shows that visual objects are often crucial for mediating boundaries between practices such as R&D and manufacturing in product development (Carlile, 2002). Benchky (2003) argues that engineering drawings 'embed knowledge' and they therefore serve as boundary spanning objects. Ewenstein and Whyte's (2009) study provides some insight into the role of such objects, and the authors argue that visual objects are important for mediating between epistemic communities within organizations. Their case data indicate that visual representations have the power to bridge the concrete and the abstract, and they can be used to communicate design ideas, to work collaboratively in problem solving and to coordinate the inputs of different parties. While the authors provide a reasonably detailed discussion on different objects, they do not elaborate on different methods used when visualizing. It is plausible to assume that the method and media used will affect the usefulness of visual objects. For example, Morgan and Liker (2006) report that paper based visual management, in combination with sophisticated IT systems (e.g. CAD/CAM), is essential for effective communication and coordination in product development projects at Toyota. Project rooms are often utilized where engineers plaster the room's walls and mobile walls with information organized by vehicle parts. The information is then moved downstream to the plant as the project progresses to manufacturing. Engineers who are not collocated visit the room regularly (often daily) for collaborative work sessions (not traditional meetings). The authors emphasize that it is essential to harmoniously bring together all the individual inputs to achieve the desired objective. However, the authors provide relatively few details on how project managers can work with visualization to accomplish this difficult task. Sobek and Smally (2008) also draw on experiences from Toyota and they conclude that a strength of the technique called 'A3 reporting and thinking' is that it reconciles multiple viewpoints and encourages visualization of key synthesized information in order to communicate the message clearly and efficiently. The book, however, provides rather static, two-dimensional solutions for visualization that do not address the critique against traditional product development tools and images. Based on data from the telecom industry, Berggren et al. (2008) present solutions to the management of complex product development and all the solutions revolve around rapid, frequent and public communication using visual management. More specifically, the authors present three theoretical interpretations:

1. There is inherent overoptimism and underestimation of the consequences of complexity.
2. Visual structuring of interdependencies is critical to create shared mental maps.
3. Decision making needs to be enacted on stage and exercised daily as a core capability.

To sum up, literature on product development and project management has been criticized for adopting a too rational perspective and focusing too much on detailed planning and decomposition tools that are useful in stable environments (Davies and Hobday, 2005; Hodgson and Cicmil, 2006; Packendorff, 1995). Successful product development management in many modern firms requires specific efforts to elaborate and visualize system requirements and interdependencies in order to create a shared understanding and to be able to handle errors rapidly. Visualization provides a potentially important mean for effectively identifying and articulating the often chaotic and emergent character in complex systems development and it could increase the innovative potential of modern product development and project management (Berggren et al., 2008). This seems to require dynamic and participatory visualization so that information is revealed rather than hidden (cf. Whyte et al., 2008). Research has compared the benefits and disadvantages of visualization (Bresciani and Eppler, 2008; Eppler and Platts, 2009), see Table 1, and it seems that the results are dependent on both media and method used when working with visualization. Our article extends the view of visualization by studying the use of both media and method.

Table 1
Example of advantages and disadvantages in three categories*

Categories	Advantages	Disadvantages
Cognitive	Facilitating elicitation and synthesis of information, enabling new perspectives, allowing for more exhaustive comparisons and making it easier to recall and sequencing.	Ambiguity, confusion, cryptic encoding, technology/template driven, time consuming to produce and cognitive overload.
Social	Integrating different perspectives, assisting mutual understanding, and tracking and showing interdependencies.	Affordance conflict, inhibit conversation and different cross-cultural differences.
Emotional	Creating involvement and engagement, providing inspiration, and providing convincing communication.	Disturbing, wrong use of colour and visual stress.

* Source: based on Bresciani and Eppler (2008), and Eppler and Platts (2009)

3. Methodology

The data underpinning this paper draw on several sources. Most important are the practical experience of one of the authors (Thomas De Ming) who has worked for decades with visualization in R&D and various other forums. The experience include both temporary (e.g. kick-offs) and more permanent (e.g. visualization rooms) tasks. He has worked in close collaboration with a wide range of companies such as the truck manufacturer Scania and SAAB Technologies. The experience is complemented with in-depth studies from an on-going program for project managers in R&D called ‘Advanced Project Management’ (e.g. Johnson and Nyström, 2002; Nordenfelt et al., 2007) where the authors have coached project managers who have investigated and introduced visualization techniques. The data were also based on an *in situ*, case study of a world-leading developer and manufacturer of laser pattern generators that implemented numerous quasi-formalized visualization techniques (Gemzell and Wadman, 2008; Olausson and Berggren, 2009).

In other words, the paper engages in co-production of knowledge based on a strong interplay between the authors in order to codify the tacit knowledge of practitioners. It has been argued that this kind of knowledge, which is created in the context of application, is robust (Nowotny et al., 2003). While being a potentially fruitful approach, it seems to be relatively rare to engage in this kind of cooperation in both the wider research community (Nowotny et al., 2003) and in research on product development projects (Guo, 2008). As Berggren et al. (2008) argue, this kind of knowledge does not allow for statistical generalizations, but offers value by providing inspirations on innovative practices and contributing to the understanding of highly demanding areas.

4. Two key challenges when working with visual management

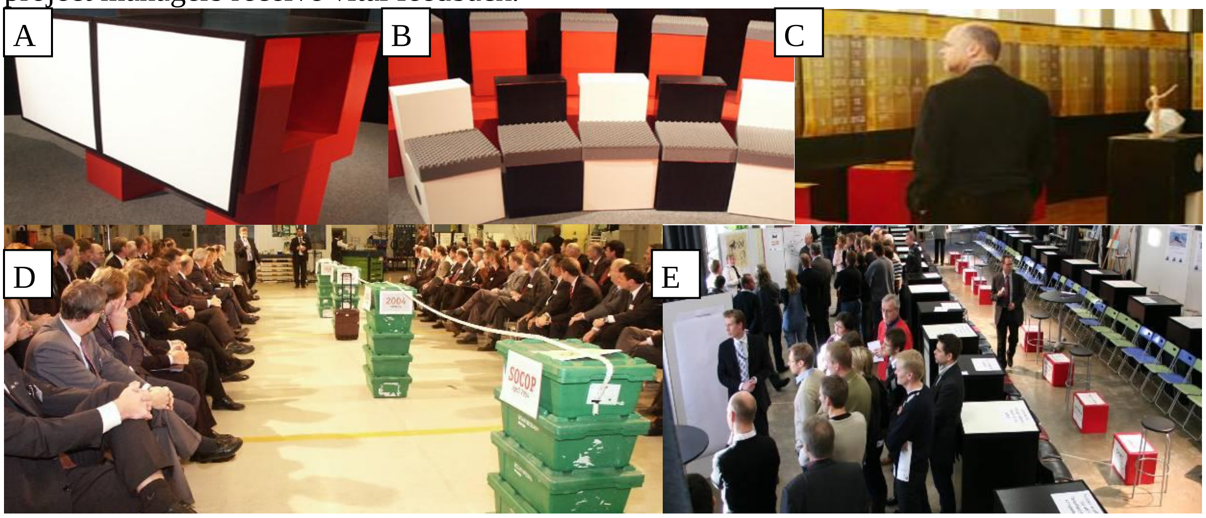
Our analysis concentrates on the pedagogical processes and it revolves around challenges and solutions when working with visual management to handle interfaces between departments. While there may be many challenges to overcome in product development, such as to establish trust, mutual goals and top management support, the analysis focuses on two challenges that were identified as particularly important: to overcome (i) physical barriers and (ii) individual and departmental differences. The challenges are discussed in the light of potential solutions based on reflected experience and practical examples.

Challenge 1 – To overcome physical barriers

People experience subtle, but clearly detectable, individual differences with regard to the senses they prefer to use in a learning situation (Dunn and Dunn, 1979; Dunn et al., 1995; Gardner, 1998; Levine, 2005). These differences affect people's perceptiveness and their ability to develop understanding and competencies. According to modern neurology science (see Gärdenfors, 2006 for an overview), the brain stores data in a way that it can be accessed when our senses are stimulated, which mean that it is easier to remember and recall events and facts that are associated with strong feelings and where multiple senses are stimulated (see also Tulving, 1985). However, the importance of stimulating multiple senses when working with visualization is seldom stressed in product development literature, which tends to emphasize issues such as communication in general (Brown and Eisenhardt, 1995) and clear messages in specific (Cooper and Kleinschmidt, 1995). While it is desirable to strive for delivering unambiguous messages, it does not solve all problems as people interpret messages depending on their own frame of references and experience before incorporating it into their thought world. In fact, Sandberg and Targarna's (1998; 2007) research demonstrates that it is very difficult to influence a human's frame of references by using rational arguments and facts only. In order for someone to reinterpret their view of reality, Sandberg and Targarna found that it is more effective if the individual is exposed to 'concrete, personal and emotional experiences' in order to reveal and create new perspectives and patterns.

At several of the firms we have encountered, there are physical barriers that prevent the stimulation of multiple senses and cross-functional visualization. The most obvious physical barrier is distance. Research demonstrates that interdepartmental communication, across all media, is inhibited when departments are dislocated (Sosa et al., 2002) even if the distance is as short as 20 meters (Allen, 1977). We have found that there are also physical barriers with respect to the properties of buildings (e.g. inflexible furniture). While the product development literature has demonstrated the need for cross-functional teams and collocation, relatively little attention has been directed towards the physical properties and their importance for communication in general and visualization in specific. A practical example is Micronic which has typical meeting rooms in the sense that they contain a table, shares, a whiteboard fixed to the wall and a projector fixed to the ceiling. As the firm started to introduce dynamic visualization tools based on the use of physical artefacts (e.g. Post-IT notes), they encountered physical barriers as the rooms were inflexible (e.g. tables were too large to be mobile), there were too few whiteboards and the whiteboards could not be moved. Micronic therefore introduced project rooms and large whiteboards on wheels. While this seems to have improved communication (Gemzell and Wadman, 2008), the quality manager at R&D argued that the whiteboards were still too inflexible as they consumed too much space and they were not easy to move around (e.g. the elevator turned into a bottleneck). In contrast, the theatre industry has for long acknowledged that scenography, props and different techniques should be flexible so that visualization can vary according to the characteristics of the task (Stuart, 2006). In addition, modern neuroscience shows that physical variation is important to the extent that it has the potential to contribute to activating a larger part of the neurological system, which is associated with improved learning (Gärdenfors, 2006). This paper suggests that variation of visualization props should not be confused with unsystematic procedures or randomness, since systematic approaches are generally associated with higher performance (Ulrich and Eppinger, 2003), at least if it is not equated to a linear logic in complex and uncertain product development (Christiansen and Varnes, 2008; Lindkvist et al., 1998).

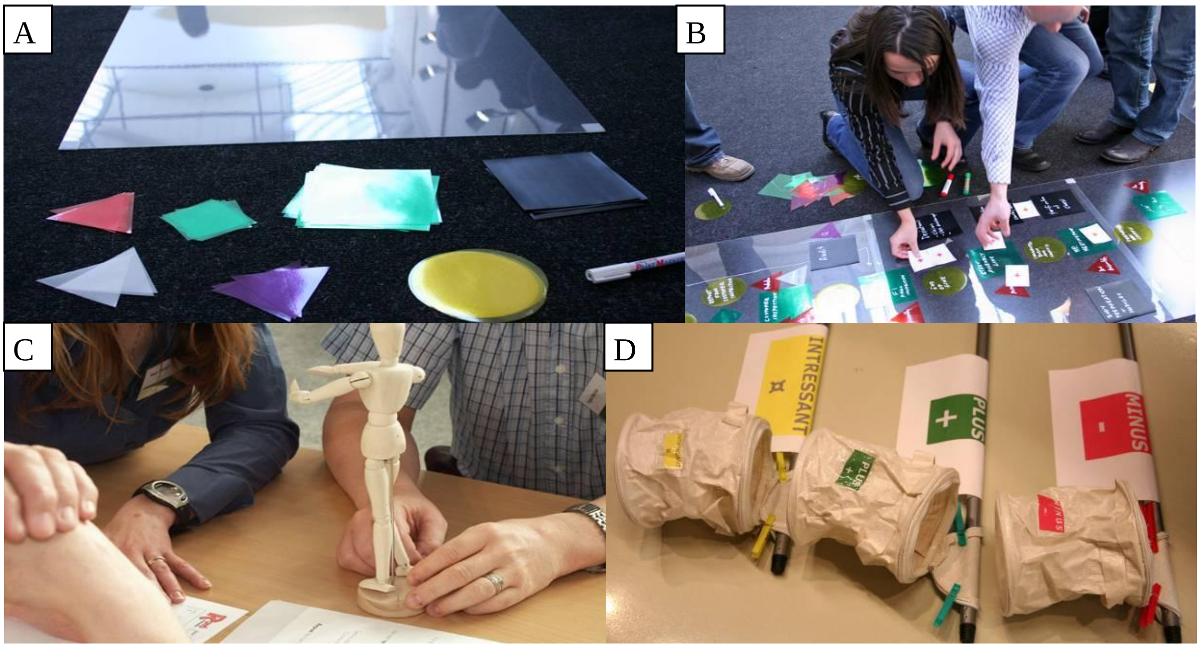
There are obviously many plausible solutions to stimulate multiple senses and introduce systematic variation, and Pictures 1a-c illustrate a few examples. The pictures show a few mobile building blocks that can be changed since they have multiple functions (e.g. table, board, chair). For example, the people in Picture 1d are listening to a presentation where the scenography has been arranged so that there is a close distance between people, which stimulates discussions and allows them to see facial expressions, which are also an important part of communication (source). The arrangement is similar in Picture 1e, which illustrates 'Day of Projects' where project managers at Scania present their projects. The audience first listens to a short introduction of the 10 projects in the middle of the room (each project is represented by a red block in the middle). Due to time limitations, the audience then chooses the four projects that they want to learn more about and they attend the parallel dialogues that take place on the left-hand side at different stations. All in all, the event can be viewed as a knowledge theatre where project information is spread throughout the organization and project managers receive vital feedback.



Picture 1a-e. Flexible and multifunctional scenography

Moreover, by using basic artefacts as a representation for both concrete and abstract activities and processes (see Picture 2a), and asking people to visualize the process on the floor (Picture 2b), we have found that participants are able to use multiple senses, such as see and do. According to experience from Toyota, the use of IT systems comes with the risk that engineers are more focused on setting up the system and trying to solve IT restrictions than on the content of visualization (Sobek and Smalley, 2008). In Picture 2c, the participants utilize a figure, which represents a specific actor in a specific situation, to discuss important question. Since participants are working with multiple senses, the approach is expected to have a positive impact on learning (Dunn and Dunn, 1979; Dunn et al., 1995). In addition, other studies show that physical objects can be useful for stimulating interface discussions, which can reduce interdepartmental differences (Carlile, 2002; Ewenstein and Whyte, 2009). Picture 2d shows three physical artefacts that were used to facilitate a group discussion followed by a cause-and-effect analysis. The artefacts represented different options (interesting, plus and minus) and they were used to help the participants to consciously choose between different mindsets and perspectives. To conclude, the findings presented in this sub-section illustrates that a key challenge is

> ***Challenge 1:*** *to overcome physical barriers that hinder the facilitation of effective visualization.*



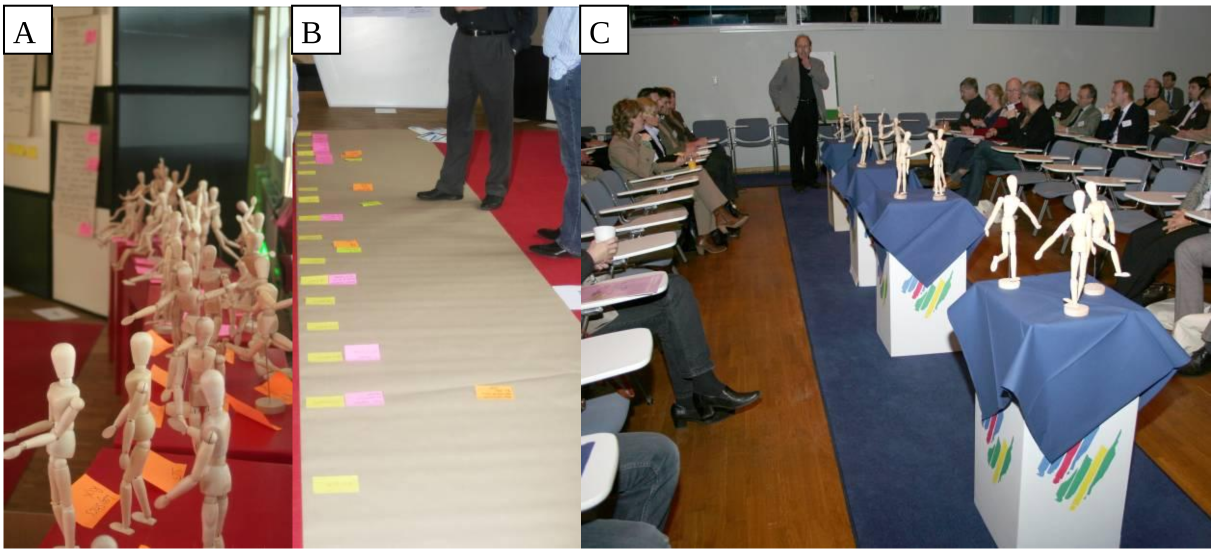
Pictures 2a-d. Visualization that stimulates multiple senses

Challenge 2 – To overcome individual and departmental differences

A standard presentation using visual representations consisting of 200 Power-Point slides can certainly be an experience that people will never forget. However, it is doubtful if it stimulates participation or learning, at least not for all participants. Thus, while the project manager is overall responsible for visualization in the product development project, including scenography, the data in this paper suggest that visualization is most effective when the participants create it. The reason is that it may help to overcome some of the identified risks with visualization, such as affordance confusion (Nicolini, 2007), see Table 1. The co-creation of visualization could also be important for identifying personal and interdepartmental differences among project participants, in particular as other studies demonstrate that such differences can have a significant impact on product development performance (e.g. Dougherty, 1992; Xie et al., 2003). On several occasions, we have witnessed that visualization fails to make an impact due to a lack of participation, which results in that visual representations are not utilized. For example, a Toyota visualization technique for project coordination called Visible Planning was introduced at Scania with little emphasis on participation from project members or cultural adaptations. The results were far from satisfying and there was what could be described as passive resistance, e.g. people neither opposed the initiative, nor supported or embraced it (Dimitriou and Eklöf, 2004). In April 2008, a process manager explained that they now focused on these issues to a greater extent during the reimplementation. Moreover, it was time consuming to implement the technique, which has also been reported from firms in the electronics industry (Gemzell and Wadman, 2008) and the construction industry (Dalman, 2005).

If the project members are not co-creating the visualization, the visual representation risks being a mere communication tool, which may be good enough, rather than a dynamic method for knowledge exploration and exploitation. A practical example can be found at Micronic. The firm developed a new platform and the manager for the sub-project 'industrialization' was responsible for linking R&D and manufacturing. The planning was conducted through a series of conversations and then the manager presented the plan using an IT tool (i.e. MS Project). The project experience review revealed several problems with this approach, such as misalignment of work at the operative level, a lack of understanding for the project among participants and an inability to access and update the plan since few had access to and knowledge about the software. This is in contrast to the next platform project at Micronic where almost 100 engineers were involved in the planning process using simple physical artefacts and where several co-joint sessions took place to synchronize plans between departments such as R&D and manufacturing. The project experience review in this project revealed that project members had a greater insight into the characteristics of the project, had been more active in the planning process, and were in a better position to handle changes, as these were visible in the public communication arenas where numerous informal and formal discussions took place.

Product development research shows that there are significant differences between people working in different departments (e.g. Griffin and Hauser, 1996; Lawrence and Lorsch, 1967). Dougherty (1992) even concludes that people in different departments have different thought worlds. This paper suggests that one approach to bridge these differences is simulation. Simulation in this paper does not refer to advanced computer simulations in product development that could take months (e.g. Nightingale, 2000), but rather relatively short meetings between people who tries to foresee different aspects by taking different roles and using visual aids. This kind of basic simulation can be compared to role-plays or experimentations, and it is likely to be particularly useful in the early stages of complex and uncertain projects for generating knowledge and detecting both problems and opportunities (Pisano, 1996). Simulation may also be used to test the visualization, e.g. the project manager can envisage how people will react during the visualization to anticipate how people will react and if the scenografy is flexible enough. Picture 3a illustrates an example where figures have been used by the participants in order to identify the key actors in a specific project. Each actor is represented by a figure and a description has been written down on a sticky note. The project goals, risks, and methods/tools have also been visualized as an important reminder (see background of picture). Picture 3b demonstrates how a group is visualizing different project activities and the order of execution. By literally constructing a visual room with clear patterns, the group is able to both highlight and handle large amounts of information. Once the necessary information is available, the participants simulate the actual project with the aim to identify critical factors that the project team needs to monitor during the execution. Picture 3c was taken during a simulation of how questions are processed and dealt with in different project decision forums (each forum is represented by figures and a pillar). Participants are placed on different sides of the process (i.e. the aisle), because they analyze the process from different perspectives to be able to detect what happens in different decision forums.



Pictures 3a-c. Visualization and simulation

The fact that project members take part in the creation of visual representations does not prevent the project manager from ensuring that certain key information is visualized. Our experience suggests that it is beneficial to visualize three kinds of information: goals, processes and key methods. This is in line with reports that claim that Toyota visualizes three kinds of data: dynamic (e.g. project status), structural (e.g. the project model) and performance (e.g. time, quality and costs) (Morgan and Liker, 2006). Picture 4a illustrates an example where key information has been visualized on physical objects to make it easier to synthesize and perceive patterns. It could be useful if the project manager helps the participants to arrive at some sort of overall conclusion or pattern as this may help to reduce the memory workload (cf. Tulving, 1985). It is potentially distressing for participants if they leave a session with only fragmented information. Picture 4b provides an alternative approach to the same theme. The people have been asked to place notes on the right place on the actual product (a truck), which was followed by a group discussion on product features and improvements. The aim with this approach was to improve the group's ability to understand the product and its context. Picture 4c offers a third alternative where zoning principles (cf. Bilalis et al., 2002) have been used to direct the participants' perceptiveness with regard to awareness and interpretation. In short, the room has been divided into different zones, which corresponds to different work tasks.

Pictures 4a-c. Three approaches used when visualizing key information

Visualization can also be used to ensure that differences between people are made visible by using visualization processes where participants take a stand and thereby make their opinion visible. Other studies show that visible commitment is important in complex product development (Berggren et al., 2008; Lindkvist et al., 1998). A practical example is illustrated in Picture 5a where the participants represent different project steering groups for sub-projects in a large project and they are asked to take side in different issues by clearly showing their point of view by standing on different positions in the room. Picture 5b demonstrates a situation where information has been visualized on different walls and people are asked to sit/stand next to the one that corresponds to their opinion. To conclude, based on the reasoning in this sub-chapter, a second key challenge is

> ***Challenge 2:*** *to overcome individual and departmental differences that hinder the facilitation of effective visualization.*

Picture 5a-b. People take a stand

Summing up

Research into the difficult task of managing product development projects have often resulted in rational planning techniques that decompose the project into independent work packages. The result is generally presented and communicated through the visual representation of two-dimensional images. However, the research has been criticized for being too rational and producing images that are static (Taxén and Lilliesköld, 2008). The analysis argues that an extended view on visualization, including not only visual images but also the process of visualizing, is one useful way for overcoming physical barriers and individual as well as departmental differences (cf. Dougherty, 1992).

While this paper focuses on how to work with visualization, it is important to bear in mind that working with visualization entails both benefits and risks (Bresciani and Eppler, 2008; Eppler and Platts, 2009). For example, failing to include project members in the actual visualization or adapt the visualization used to the corporate culture could result in resistance. Working with visualization may be time consuming, as in the Micronic case where 100 people were involved, and seems to require a leadership style focused on decentralization and visions rather than detailed rules and regulation (cf. Sandberg and Targama, 2007). Thus, in contrast to what many advocates state, visualization can potentially result in lower productivity if it is a mere add-on. It may be necessary to replace the old working procedures by visualization to improve productivity. For example, the workload could double if a company retains the procedure of writing protocols, but also demands that the project group visualizes the same aspects on walls in project rooms. In addition, this imposes a risk of mismatches between the information stored in computers and on the walls. In order to take full advantage of visualization, it may be necessary to replace current procedures by visual group memories that can be incorporated in the physical visualization environment.

5. Conclusions and discussion

This paper engages in co-production of knowledge based on close interaction and codification of tacit knowledge of practitioners, and the approach was deemed as appropriate due to the limited number of studies of visualization. The examples provided in the paper derive from a wide range of companies and the results have often exceeded the project participants' expectations. For example, one project manager at Scania claimed that the project lead-time was reduced by six months after only a few hours of work with this kind of dynamic and participatory visualization. Although it took time to introduce new visualization approaches, two project managers at the world leading equipment manufacturer Micronic argued that it improved communication within the project and with the line organization, revealed mismatches between the sub-projects' plans and facilitated a shared understanding of the ambiguous requirements and solutions (Gemzell and Wadman, 2008). In addition, we have conducted evaluations in relation to visualization activities, such as the knowledge theatre, and the average scores have consistently been above four on a five point scale with regard to 'overall satisfaction' and 'usefulness for practice'. While this kind of research can provide robust knowledge (Nowotny et al., 2003), it is necessary to generalize the findings with caution and it is necessary to conduct further investigations based on more systematic data collection and rigorous research design.

Nevertheless, the findings could be of value as they provide inspiration on innovative practices in an area of new product development that few have focused on, i.e. how to work with visualization in complex and uncertain product development. More specifically, this paper contributes to New Product Development-literature by focusing on how visualization can be used to handle two challenges, namely (i) physical barriers, and (ii) personal and departmental barriers. Previous research shows that these barriers are particularly relevant in product development that is characterized by complexity and uncertainty, because departments are generally highly specialized and differentiated (Lawrence and Lorsch, 1967), interdependencies are numerous and ambiguous (Prencipe et al., 2003), and prerequisites change during the execution of projects (Wheelwright and Clark, 1992). In this kind of product development, research demonstrates that interdepartmental coordination becomes even more important and that an elaborative mix of approaches are needed, such as flexible adaptation and experiential planning (Eisenhardt and Tabrizi, 1995), basic simulation and feedback processes (Pisano, 1996), co-location during critical periods (Lakemond and Berggren, 2006), communication arenas (Söderlund, 2002) and frequent update of information in public (Berggren et al., 2008).

In relation to this, our paper provides practical examples and solutions which illustrate the importance of utilizing quasi-formalized visualization to achieve controlled variation, flexibility and responsiveness. This is in contrast to mainstream product development and project management which has largely turned into an administrative, bureaucratic and planning oriented discipline (for a critical review see Hodgson, 2002; Hodgson and Cicmil, 2006). While the project manager has an important pedagogical role in facilitating quasi-formalized visualization (cf. Söderlund, 2002), this paper argues that the actual visualizing is a quest of co-production between project members from R&D and other departments, and, sometimes, people from the line organization. It seems that the characteristics of complex and uncertain product development result in a need for interactive, flexible and adaptive methods and media when working with visualization.

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