An investigation into the knowledge creation process within product development teams

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Abstract

This paper reports on the findings from an empirical study of the knowledge creation process within product development teams. Previous writings on knowledge, information, creativity, etc have been dominated by definitional discussions, prescriptive models, and debates about the social basis of knowledge, etc. A large proportion of research has focused on technological means, in particular ICT, to provide the means for sharing information – in the hope to promote knowledge and knowledge creation (see for example AKT – www.aktors.org). The seminal work of Takeuchi & Nonaka (1995) introduced the notion of explicit and implicit knowledge, coupled with the SECI cycle, in which implicit knowledge embodied within an individual is made explicit and socialized into the organization. The investigation reported here develops and applies a new methodology for the investigation of the activities of new product development teams to develop an in-depth understanding of the knowledge creation process. A model of this process is presented and fully described with examples taken from an empirical study.

Keywords: Knowledge Creation Process; Knowledge Creation Model, Knowledge Creation Episodes, NPD Teams, Empirical Study.

Suggested track: Please indicate the suggested track for your paper:

A. Managing organizational knowledge and competence
B. Knowledge creation and innovation, e.g., in R & D
C. Knowledge sharing within and across organizations and cultures e.g., in off-shoring arrangements
D. Micro, meso and macro institutional factors affecting knowledge and learning
E. The relationship between knowledge and power
F. Communities of practice, knowledge networks and networking
G. Practice-based perspectives on knowledge and learning

Introduction

This paper reports on the findings from an empirical study of the knowledge creation process within product development teams. Previous writings on knowledge, information, creativity, etc have been dominated by definitional discussions, prescriptive models, and debates about the social basis of knowledge, etc. A large proportion of research has focused on technological means, in particular ICT, to provide the means for sharing information – in the hope to promote knowledge and knowledge creation (see for example AKT – www.aktors.org).

The seminal work of Takeuchi & Nonaka (1995) introduced the notion of explicit and implicit knowledge, coupled with the SECI cycle, in which implicit knowledge embodied within an individual is made explicit and socialized into the organization. A recent exposition of this approach is given by Zarraga and Garcia-Falcon (2003): “We can conceptualise Knowledge management as a process whose input is the individual knowledge of a person, which is created transferred and integrated in work teams within the company while its output is organisational knowledge a source of competitive advantage”. However, this approach does not fully explain how knowledge is created by people nor what could be done to support its creation. On the other hand studies of designer’s creativity, problem solving etc (Lindemann, 1999) have focused on individuals and have failed to address the social dimension of knowledge creation.

In this empirically based study a novel method combined with the development of a theoretically grounded analytical technique was deployed to understand the knowledge creation process within small product development teams. The study used a computer-based simulation of the product design process. This novel approach allowed extensive data to be collected (video, audio, text, questionnaire, and observational). The approach also holds out the hope of creating a ‘virtual laboratory’ whereby multiple experiments can be run, carefully controlling for various factors (eg. communication means, physical or virtual collocation, etc). Simulation games are great methods for experiential learning. They create awareness, understanding and new knowledge about complex systems that would be very costly, even impossible to gain in practice through trial and error (Smeds & Riis, 1997; Quanjel & Wenzler, 1995; Wolfe & Crookall, 1998; Riedel et.al. 2001). The simulation used in the study is a role-playing ‘game’ with five participants: project manager, design manager, marketing manager, purchasing manager and production manager. The simulation was originally designed and developed in the European research and technology development project, Cosiga (see www.cosiga.com). Simulation games can be often used as a social research tool to study and assess human behaviours (Greenbalt & Duke, 1981). As it has turned out, the Cosiga simulation has been of more value as a research tool than as an educational tool!

In Cosiga the participants interact in a product development scenario where they have to specify, design and produce a simple truck for a specific market. A truck was chosen as the product because everyone intuitively knows what the main components of a truck should be (cabin, chassis, wheels, axles, gearbox, seats…etc.). The design process would involve the players drawing up a market specification and a product specification, designing the truck, purchasing components, and allocating production processes. The product's manufacturability will be put to the test in the simulated factory to produce final trucks. It is an open-ended simulation in the sense that there is no right-way to play the simulation. Each participant has documents and information available to them, which are ordinarily not available to their fellow participants – thus information has to be shared between the participants. Further, information/ knowledge has to be combined to produce an understanding of the other participants' perspective, to produce a common understanding, and to create knowledge – come up with solutions to the design decisions which have to be made in order to successfully produce trucks.

Simulations, of course, suffer from the fact that they are simplified models of reality and they may therefore lack face validity for the participants. Cosiga has been extensively tested by its target participants – primarily engineering students, by both undergraduate and postgraduate students. Over 100 simulations have been run with over 100 participants. It has also been tested by industrial participants in several companies. In both cases students and industrialists have reacted favourably to the simulation – becoming engaged in the game and wanting to complete it by producing their first truck. Notwithstanding, this favourable response there remains the concern that being a simulated version of a real-life process how much like the real process is it and the results obtained from it? The answer to this is that as far as the participants are concerned they are engaged in a problem solving exercise (albeit a simulated version of a real process). Their interactions, behaviour, communications, etc are all directed to solving the design problem within the simulated NPD environment. There is thus an equivalence between these activities, interactions, etc, as problem solving activities between the real and simulated worlds – despite their being no equivalence between the design problem in the simulated Cosiga version (relatively simple design problem:

only 7 components to design/specify, duration about 4 hours) and real life design problems (typically very complex, typical duration 18 months). It is argued that the development and refinement of the methodology presented in the next section will allow comparative studies between simulated and real life design processes to be carried out. Such studies can then provide the ultimate validation of the results reported here.

Theory and Research Approach

The original Cosiga project had the aim of improving the learning of engineering students and hence one of the project's objectives was to evaluate the improvement in learning that resulted from playing the simulation. Three approaches to this evaluation were developed. Firstly, a cognitive analysis technique based on an assessment of conceptual change in the participants, before and after a Cosiga game, was developed (content evaluation). Secondly, a process analysis method to investigate the interactions between participants during Cosiga was developed. This latter was based on an analysis of participants' communication using a text chat communication tool. This produced a written log of all the typed messages sent by the participants. Even though the cognitive analysis (Thayyib, 2000) and the communication chat log analysis (ibid, Cole, 2001) are capable of assessing the improvements made after playing Cosiga they do not allow the study of the developmental processes involved in the overall game and for each player individually. Thirdly, the measurement of situation awareness at regular intervals during the game was also developed (Sakiroglu, et.al., 2002). This showed that in collocated games the participants' situation awareness improves during the game, over time, and conversely in virtual games (with no face to face contact) awareness degrades during the game. These three approaches provide diagnostic information about the general 'effectiveness' of a specific game session, however, they do not explain why certain games were more effective than others (eg. why collocated games are better than virtual ones).

Unfortunately, there are no standard, off-the-shelf methods which can be used to analyse conversational data (Plowman, 1996, 1998, 1999) – each researcher devises their own conceptual categories, carries out an analysis and produces conclusions. The existing approaches, where there is some standardisation of methods, in psychology either suffer from the limitation of being focused on individuals or pairs (Stanton et.al. 2002), or their objective is narrow (eg. studying turn-taking in team discussions (Kuk, 2000). In engineering design research "studies differ in their nature, data collection methods, environment where the study was conducted, number of subjects, and type of design. It is therefore very difficult to relate the findings." (Aurisicchio, 2003, p2). There is a need to develop a systematic, scientific, methodology for the study of design activity which allows comparison across studies and hence knowledge to accumulate. The research work reported here is a step towards the development of such a systematic and scientifically grounded methodology for the study of design (and other developmental processes).

In the search for an appropriate methodology to analyse the significant amount of qualitative data (chat log, video, game actions, observations, etc.) of Cosiga simulation sessions the authors came across Activity Theory (www.edu.helsinki.fi/activity/). In fact Activity Theory has been found to be very productive in allowing for rapid and rigorous analysis of the complex interactions within Cosiga, or indeed any complex interactive human activity (ibid). The Cultural – historical activity theory framework (Engeström 2000) takes a collective object orientated activity system as its primary unit of analysis. Activity theory conceptualises networks of activity systems attached within the context of analysed processes. An activity system integrates several elements: the subject, the object and the instruments into an incorporated whole. In principal activity is driven by a collective object and motive, but it is realised in goal orientated individual and group actions, and operations (Leont'ev 1978).

A model of the basic structure of a human activity system is presented in

Figure **1** (Engeström 1987). In the model, the subject refers to the individual or sub group whose agency is chosen as the point of view in the analysis. The object refers to the 'raw material' or 'problem space' at which the activity is directed and transformed into outcomes with the help of physical and symbolic, external and internal tools. The community comprises multiple individuals and groups who share the same general object. The division of labour refers to both horizontal divisions of tasks between the members of the community and the vertical division of power and status. Finally the rules refer to the explicit and implicit regulations, norms and conventions that constrain actions and interactions within the activity system (Engeström, et al, 1998).

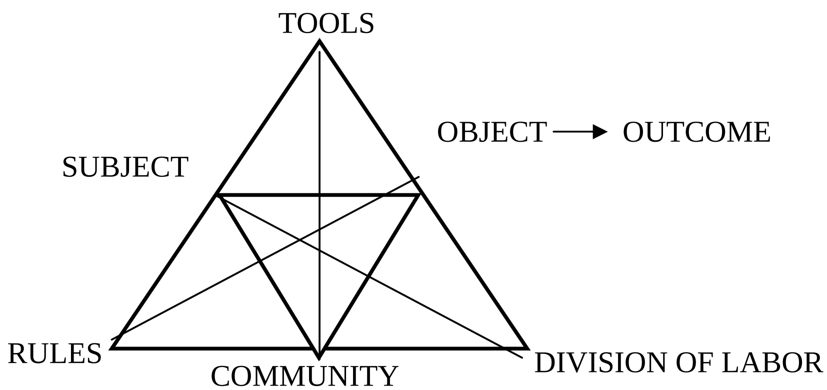

Figure 1. Human Model of an Activity System

In this paper the Activity Theory model has been applied to the analysis of the process of knowledge creation occurring during the Cosiga simulation. The subjects and communities of Cosiga consist of the players of the game with different roles and responsibilities (project manager, marketing manager, designer, purchasing manager and production manager). The division of labour determines the tasks and decision powers of each of these roles. The main object of their work is to design a new truck. This product development process involves many micro, meso and macro level activities and motives within the activity system, see Table 1.

Table 1. Activity Levels and Examples from Cosiga

LEVEL OF ACTIVITY	INVOLVED SUBJECTS	Examples from COSIGA
Macro Level	Always consists of a community	Truck length configuration Comfort level decision
Meso Level	Can be done at an individual level but requires involvement of a community, due to interdependent activities	Body Colour Cabin colour Engine Selection Gearbox Selection Seats and Windows Selection Cabin and Chassis material Selection Requesting time
Micro Level	Always at an individual level	Placing an order Requesting a pre-design Advancing the clock Assigning factory shops Info. Gathering

Macro level activities are the core decision-making processes of the game they require a community of subjects working in co-operation, and are usually dependent on the meso level activities. Meso level activities are the ones, which can be accomplished at an individual level, however, due to interdependency between activities they may require the involvement of a community. Micro level activities do not require community interaction and can be accomplished at an individual level. Examples of few of the many micro level activity systems within the game are: the marketing manager asking for information from marketing survey reports, rumours, or newspapers, and the purchasing manager researching component specifications or the delivery lead times.

Deciding on the chassis length, body colour and the product comfort level are three of the main decision activities that occur in the game's process of product development. The outcomes of these activities include decisions about purchased and factory produced components, regarding product specification and design decisions. The instruments include in built marketing survey reports, rumours, news articles, a suppliers list giving the specifications of every component that can be bought, and in built robots (that represent staff members) to retrieve information and carry out actions.

Finally, the rules will be the constraints on some production machinery, the pre-defined specifications for each purchased component (eg. engine sizes) and the fact that only five robots (staff members) can carry out actions simultaneously.

Activity theory is based on the object-related nature of human activity. It can be easy to distinguish the objects of basic material activities such as in manual labour, however, a closer look at the activity systems involved in the Cosiga simulation game's 'new product development process' reveals that the character of its objects can be versatile (Engeström & Escalante, 1996). For example, it is clear that the activities involved in Cosiga are orientated towards designing and producing a new truck, and this whole design process is larger and more durable than just the specific goals of particular actions and operations. The object of this activity system network is constantly in transition and under construction and it manifests itself in different forms for different players and at different stages of the activity within the game (Engeström 1987). For example, when we go back to the example of the chassis length decision activity at the beginning of the game we can identify the transition of the object of an activity system more clearly. In the beginning of this activity system the main problem space, or the object, is the length of the chassis. However, after trying to come up with an outcome players, 'subjects', realise that the actual problem space is the length of the body as well as the cabin length, thus causing the object of their activity to change from chassis length to cabin length and body length.

The Truck Length Configuration (TLC) activity system is one of the core macro level decision making activities within Cosiga. According to the hypothetical (or ideal) activity system that exists within the TLC the subjects, ‘players’, of the activity system tackle the problem of deciding on the length of the chassis as seen in Figure 2.

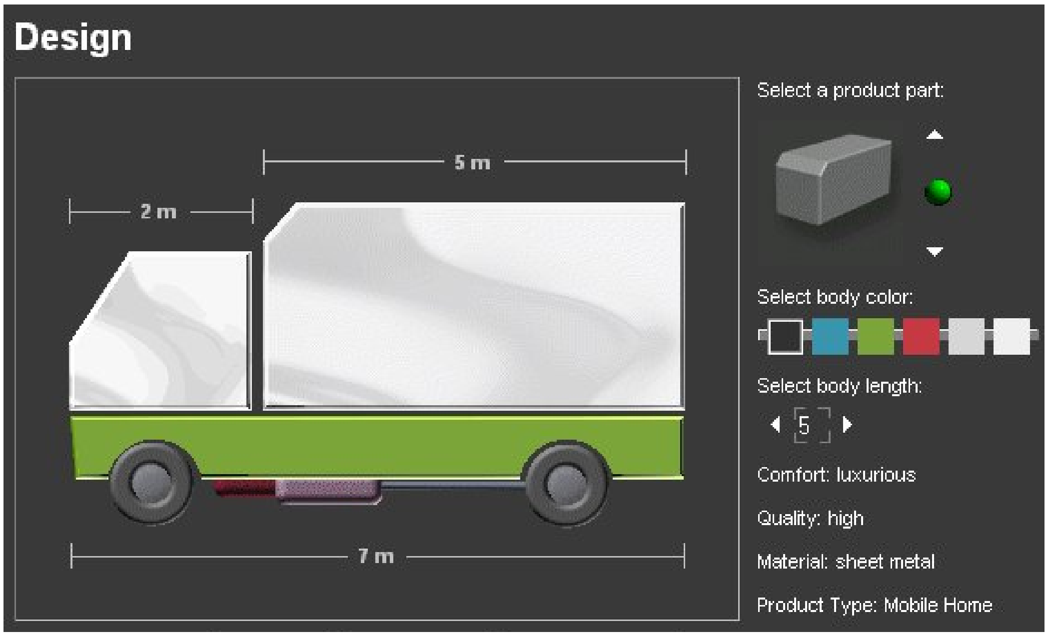

Figure 2. The Designer’s screenshot of the design document showing the Truck Length Configuration and body specifications

The chassis length decision appears as an easy task for the design manager to perform, however, as the activity progresses it is realised that the length of the cabin and the body length have an effect on the chassis length. As the cabin is produced in the factory’s press shop, the cabin length decision involves the production manager as well as the designer. The production manager must assign the cabin manufacture to one of the two available press shops, each of which has constraints regarding the feasible cabin length. This constraint information needs to be communicated to the designer so that the designer can proceed with the pre-designing of the cabin.

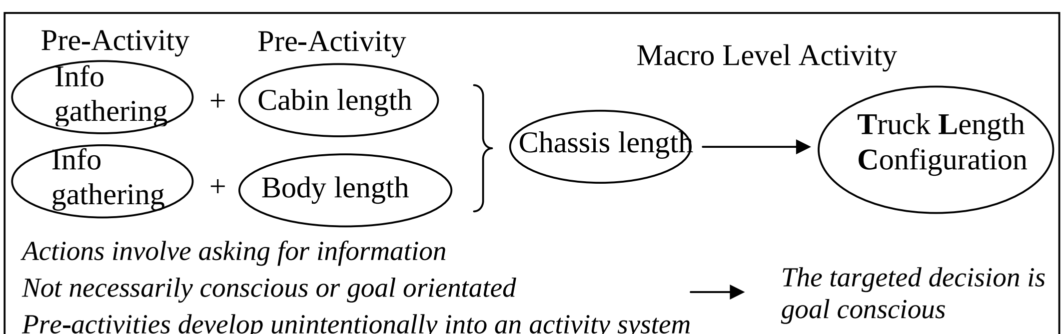

Figure 3. A model of the TLC network of activity systems in COSIGA

This interaction between activity systems is illustrated in Figure 3, where the formation of the complex activity system, TLC, within Cosiga is shown. Within the hypothetical activity system of TLC certain activities have to be carried out before other typically macro activities. These are called pre-activities see Figure 3. In fact these pre-activities form a network of activity systems; some activities of which are simultaneous (carried out in parallel), while others need to be carried out sequentially. In general these pre-activities have to be completed (ie. produce an outcome) before the next activity in the sequence can start. A crucial aspect of some of these pre-activities that applies to the initial pre-activities is that they do not have an explicit or conscious goal. For example, information-gathering activities don't have an explicit outcome in the mind of the participants (eg. the purchasing manager absorbing the information in the suppliers' list).

This overview of Activity Theory has presented the basic concepts of activity theory and described how the authors have applied it to the analysis of the activities undertaken by the participants in a Cosiga simulated NPD process. The next section presents the analysis and findings of the application of the activity theory derived methodology to the study of the knowledge creation process within Cosiga.

Results - The Knowledge Creation Process

After carrying out an analysis of the raw data (chat logs, video transcripts, and observation notes) a classification of the activities engaged in by the participants built upon Activity Theory concepts was developed. Knowledge creation is fundamentally a developmental process – ie. a change process. Change in this context refers to a change in the level of detail of a given issue in the product development (eg. product and process specifications), problematic situation, or of a concept. Activity theory masterfully enables the capture of these instances of change by focusing on the object of each activity. Analysis of continually developing episodes led the researchers to realise that when the episodes are evolving, the purpose (object) of them is also shifting from one to another. The shift indicates a direct link with the development stages of the product. Based on these deductions distinct patterns of characteristics were identified. Accordingly these characteristics were classified into five different conceptual categories: raising awareness, exploring complexities, developing understanding, creating alternatives, and finalizing an action. These five are referred to as knowledge creation episodes – they are part of the cycle of knowledge creation. The characteristics of these five episodes are detailed below.

1.1. Raising Awareness

Raising awareness is the first concept that is defined in the knowledge creation model. It represents an initial contribution to the creation of knowledge. Being aware implies knowledge gained through one's own perceptions or by means of information.

1.2. Exploring Complexities

Exploring Complexities is the second episode, commonly it follows the raising awareness process, and it triggers the beginning of a systematic investigation. Once individuals gain awareness of issues and concepts, they want to further their knowledge of the details. The interdependencies between and within the issues are often hidden and they emerge as the process evolves. In order to reveal theses interdependencies individuals are required to inquire into and explore them. Exploring complexities episodes are usually centered on problems and they enable knowledge creation once interdependencies are known to the members of the team. In this phase the knowledge creation is more advanced and specific.

1.3. Developing Understanding

Developing Understanding is the third concept defined in the knowledge creation model. This episode aims to develop very detailed understanding of the many intertwined issues of the new product development process. Prior to this stage, individuals begin with raising their awareness of the issues, then they explore into complexities and problems, and once these are revealed, they begin to understand issues. Only after those two episodes are executed, individuals can start sharing more structured and detailed discipline (eg. mechanical or electrical) based information amongst each other. The information shared is usually fact based; it is certain and enables the team to proceed to conclusions. During this episode individuals begin to logically reason situations. Firstly because they have very good individual understanding of the issues and different situations and secondly and more importantly they have very good shared understanding. Shared understanding is important in multidisciplinary NPD teams to avoid problems or pitfalls of the design in the earlier design stages instead of encountering them in the later stages (when their harmful impact is far greater).

1.4. Creating Alternatives

Creating Alternatives is the fourth episode, possibilities are illuminated and understandings of the issues are heightened and choices are generated. The second important aspect of this episode is the negotiation process that takes place for the many generated solutions. In order to minimize the late design changes team members often study and discuss on the feasibility of each solution very carefully.

1.5. Finalizing an Action

Finalizing an Action is the fifth and the final episode; it is about operationalising a decision to arrive at a concrete product or a development. Rather than a thought process, it is more of an action oriented phase. It involves execution by putting the knowledge created into use. It is a very important phase of the knowledge creation process, because if the execution fails the superior value of the knowledge created during the process will not be beneficial neither to the development process nor to the businesses of the company. Therefore to be able finalize an action has a great importance for the completion of the knowledge creation cycle.

In the context of new product development process, reoccurrences of finalizing action episodes result in the development of the full – complete product. For example, in this experiment, in order to develop the full truck, managers had to finalize actions regarding the cabin, engine, chassis, body, wheels, seats…etc. Each part had its own product and process specifications that needed to be finalized. These actions were taken during the development process at different times according to the pace and structure of the development. By no means are these actions finalized at once at any point in time. Therefore finalizing an action episode is an iterative episode, hence the more an action is finalized the more the knowledge creation cycle is completed.

1.6. Characteristics of the Knowledge Creation Episodes

The characteristics of the five knowledge creation episodes are shown in the table below (**Table 2**):

Table 2. Characteristics of the five knowledge creation episodes.

Knowledge Creation Episodes	Characteristics
Raising Awareness	▪ Intuition and perception based ▪ Abstract information ▪ Enables generic reasoning ▪ Enables differentiated consciousness
Exploring Complexities	▪ Inquiry and question based ▪ Problem centred ▪ Enables specific reasoning ▪ Reveals Interdependencies
Developing Understanding	▪ Facts based ▪ Structured and detailed information ▪ Enables logical reasoning ▪ Proceeds to a conclusion

Creating Alternatives	▪ Solutions generated ▪ Solutions negotiated ▪ Enables elimination of alternatives ▪ Proceeds to action
Finalizing an Action	▪ Operationalising a decision ▪ Taking actions ▪ Execution with excellence ▪ Completes knowledge creation cycle

Table 2 summarises the characteristics of each of the knowledge creation episodes – which should allow other authors to replicate the findings of these researchers.

Derivation of the Knowledge Creation Model

An analysis of the flow of episodes for different component parts of the truck was carried out. To show this the knowledge creation process for the Cabin will be presented. After having identified all the activities related to the cabin and having identified the knowledge creation episodes a flowchart was drawn, Figure 4:

Figure 4. The Cabin knowledge Creation Process

From this flowchart the flow between the different episodes can be shown in the following diagram (Figure 5):

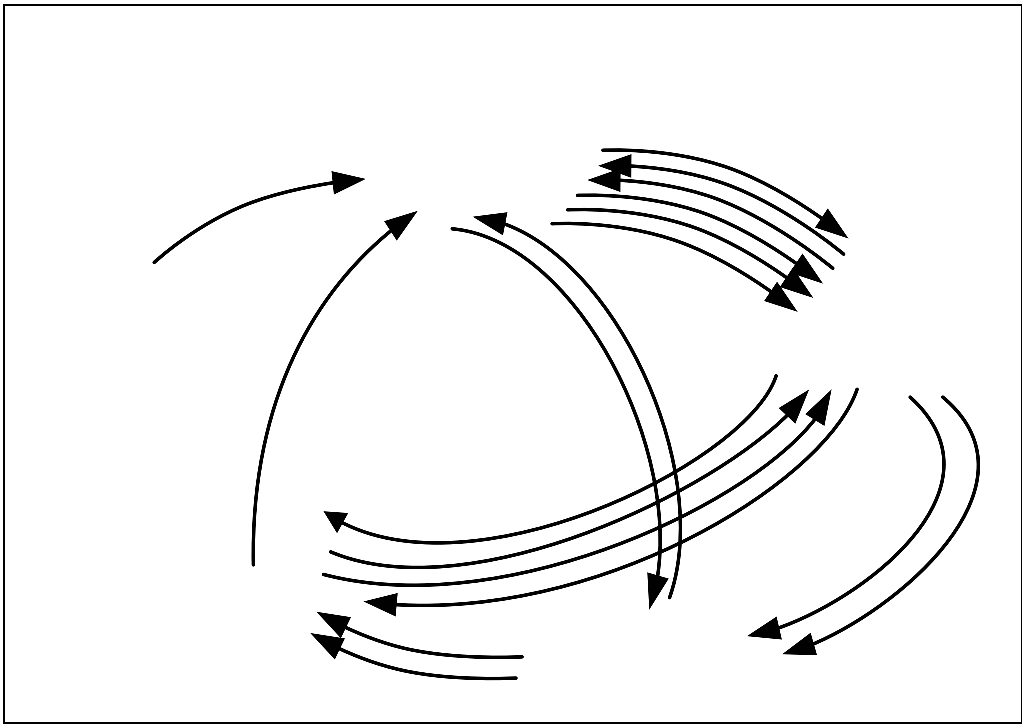

Figure 5. The Cabin knowledge creation model

This model of the knowledge creation process of the cabin is fairly complex – but it was realised that the cabin consisted of more than one knowledge cycle. In particular, in the specific simulation studied, the participants have to correct a number of mistakes during the ‘production’ of the cabin – this adds to the number of knowledge cycles. Stripping the cabin’s knowledge cycles down to exactly those needed to define the cabin, resulted in a ‘pure’ model. This model is shown in Figure 6. It is proposed that this model of the knowledge creation process is generic and can be applied to any domain (eg. different development processes – such as in decision making), and in any context (eg. virtual collocation). The reason for this assertion is that the development process engaged in by the participants of Cosiga, although, simulated is a real one for them – they have to develop an understanding of the market needs, interpret them, develop specifications for the truck, compile their ‘design’ (configuration) of the truck, purchase components, produce components and carry out the assembly operations to produce complete trucks. Although, of course, the knowledge creation model needs to be validated in real-life situations as well as in different domains and contexts, before it can truly be described as generic.

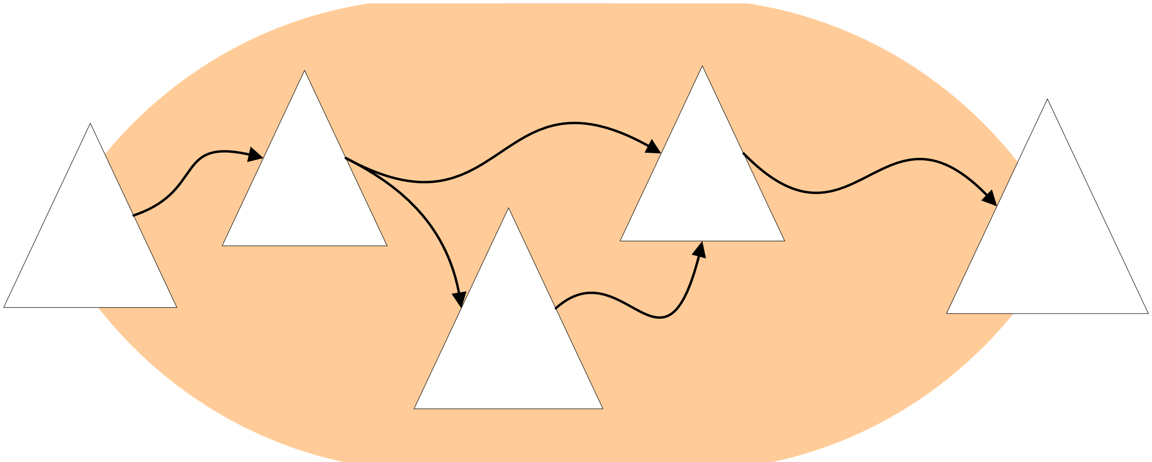

Figure 6. The Generic Knowledge Creation Model

1.7. Sequential Cyclic Model

The model shown below (Figure 7) is the sequential cyclic representation of the knowledge creation process taking place within the cabin activity system. It is different from the model presented in Figure 5, because this model not only show the links between the episodes but also sequentially illustrates how and when knowledge creation episodes take place throughout the entire cabin development process.

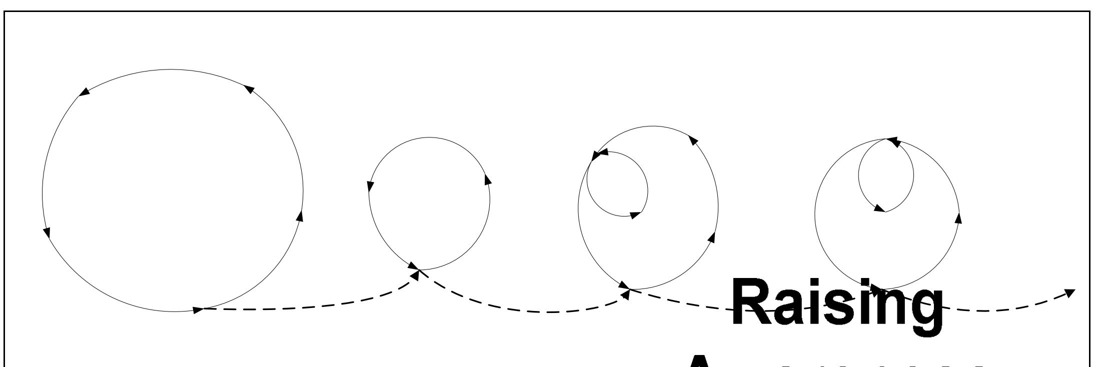

Figure 7. Cabin Sequential Cyclic Knowledge Creation Model

The model is made up of four complete knowledge cycles. The cabin development process entails four distinct stages. The first stage includes the design and product specification decision making processes until the production (pressing) of the first cabin is reached. The second stage includes the processes up until the mass (volume) production (pressing) of all cabins. The third stage includes the processes up until the painting operation of all the cabins. The fourth, and final, stage includes all the processes up until the assembly of the cabin. These stages are dependent to one another. The cabin assembly process requires all the cabins to be produced (pressed) and painted prior to any assembly operation. Likewise, painting and production (pressing) also require predecessor activities such as; quality control, tooling design and production, product and process specification decisions, and the freezing of the design document, to be completed prior to their execution. See Table 3, below, for the illustrated sequential cyclic knowledge creation model detailing the list of activities for each KC stage.

Table 3. Breakdown of Activity Objectives of Cabin Development Process

Cabin Development Stage	Activities Involved at Each Stage of the Cabin Development Process	
First Cabin Production (pressing)	Cabin Size - Seat Order Market Specifications Cabin Size – Cabin Size – Seat Order Cabin Colour Production of Cabin & Chassis in parallel Production of Cabin & Chassis in parallel Cabin and Chassis Machinery – shop floor functions Purchases and Produced Part Decision Purchased and Produced Part Decision – (cabin & chassis) vs. (purchased parts) Production Quality Level Cabin Paint Shop1 Constraints Cabin Press Shop1 Constraints Cabin Press Shop2 Constraints Cabin Size	Cabin Pre-designing and tooling order Cabin Pre-designing and tooling order Cabin Produced Part Confirmation Cabin Production Costs Cabin Production Costs Product Total Cost Product Constraints Cabin Painting Costs Cabin Colour Cabin Colour Cabin Colour Market Research Cabin Colour Change Cabin Tooling Completion First Cabin Production First Cabin Production First Cabin Production Completion
Mass Cabin Production	Cabin Raw Material Purchase First Cabin Production Completion Confirmation Rest of the Cabin Production	
Cabin Painting	Rest of the Cabin Production Cabin Size Iteration Discussion Cabin Quality Control Cabin Technical Problem Cabin Production Finished	First Cabin Production Completion Confirmation Cabin Painting Cabin Painting Cabin Painting
Cabin Assembly	Cabin Painting and Quality Control Cabin Assembly Cabin Assembly Components Check	Cabin Assembly First Cabin Assembly Completion Cabin Assembly Quality Control

The data in Table 3 has shown that the majority of the activities are within the first cabin production stage. This stage consists of all the foundational decision making processes of product and process specifications such as the market research of cabin specifications, actual design of the cabin (decisions on size, material, and colour), production of the tooling and the actual production (pressing) of the cabin itself. The first stage also includes other supportive decision making processes such as identifying the production costs, identifying the production constraints, deciding on the amount of concurrent engineering and the assignment of the machinery. Briefly, the first stage of the development process contains the main thrust of the development process in comparison to the other three stages. Conversely the other three stages (mass cabin production, cabin painting, and cabin assembly) are less thought process oriented. They are more automatic operations where, execution of one operation is dependent on the completion of another operation. For example, the cabin cannot be assembled before it is painted and quality controlled.

Going back to the knowledge creation process, similar differences to those explained above are reflected in the Knowledge Creation (KC) cycle of each development stage. The knowledge creation cycle of the first cabin production stage is a full cycle of all the knowledge creation episodes. The sequence of KC episodes follows a certain order (RA, EC, DU, CA, FA). However, the sequence and the occurrences of KC episodes happen in an ad hoc manner in the other stages. Especially during the cabin painting and cabin assembly processes, the knowledge creation cycles are quite complicated with embedded inner loops. The inner loops of KC cycles are caused due to the problems and difficulties encountered during those stages of the cabin development process. Based on that observation, the first stage of the cabin development process which entails all the activities leading up to the first pressing production did not encounter any significant problems or difficulties. The team members got all the decisions right first time. Nonetheless, it should be also realized that the cabin development process, with respect to the other development processes, took place concurrently within the larger whole of the truck development process. However, the cabin is a relatively less complicated component with simple decision making processes. There are fewer variables involved in the cabin development (only colour, and length), in comparison to some of the other complicated development processes such as the chassis development, or the body development. Nevertheless, to get it right first time is an achievement and possibly an indication of the experience of the industrial participants in this particular simulation.

In conclusion it was deduced from the cabin development data, that the first stage of the cabin development process was more critical, more representative, and more comprehensive of all the four stages of the cabin development process. The two most important grounds for this inference were: firstly that the first stage included all the major decision making activities that defined the specifications and enabled the design of the cabin, and secondly this stage was completed with a minimal number of problems and difficulties – ‘right first time’, which leads to the conclusion that it represents an ideal development process. Consequently, the researchers adopted the knowledge creation cycle of the first production stage of cabin development as the ideal model of Knowledge Creation. Hence, Figures 8 and 9 below, show the ideal model of cabin knowledge creation both in sequential linear and sequential cyclic forms.

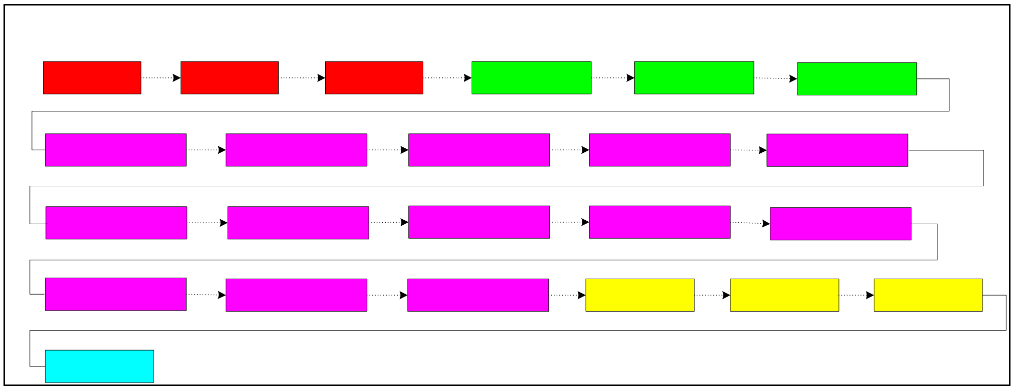

Figure 8. Cabin knowledge creation flowchart

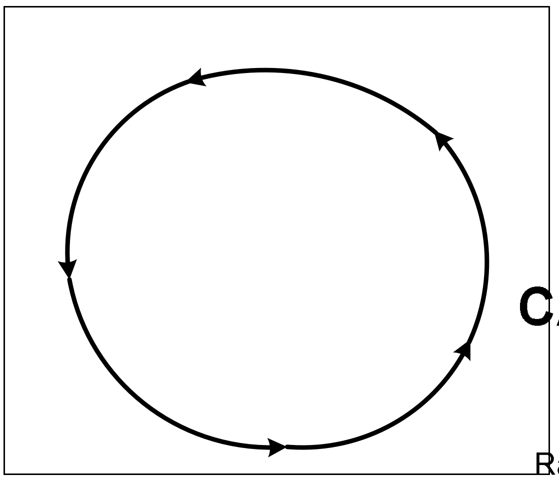

Figure 9. Ideal Knowledge Creation Model

Conclusions

This paper has given an outline of the novel and innovative use of simulation to study the knowledge creation process within new product development teams. A rigorous and scientifically grounded analysis method, Activity Theory, was applied by the researchers to yield new and important insights into the dynamic, interactive, social nature of the creation of knowledge. Using traditional techniques, such as participant observation or design protocol studies, the richness and interactive dimension would be less visible. The results of this application were encouraging. Activity Theory was very productive in allowing for rapid analysis of the interactions within the Cosiga NPD simulation. It is, therefore, a much more productive analysis method than audio and video recording – providing appropriate communication means can be used (text chat tool). Having, proved the suitability of activity theory for analysing the interactions between participants of a Cosiga, the researchers look forward to a fruitful period ahead. The researchers hope to develop their research so as to explain the many ways in which knowledge is created in small teams and to validate their generic model of knowledge creation model in other contexts, and with different communication mediums. The work also contributes to those researchers who are studying real design teams and knowledge creation/ sharing across organizational boundaries (Carlile, 2002). It provides a systematic and scientifically rigorous theoretically grounded methodology, with theoretically grounded concepts, for the analysis of the complex, interactive and interactive design and development process.

1.8. Acknowledgements

The authors would like to express their gratitude to the European Commission and the Cosiga project partners for funding the development of Cosiga. We are deeply grateful to BAE Systems for their collaboration in the research reported in the paper, and in particular to the engineer and scientist participants they provided for the simulations reported here.

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