Exploring the Dynamics of Knowledge Integration: Acting and Interacting in Project Teams
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Abstract This article investigates knowledge integration in product development projects. While much previous literature draws attention to the need for clearly specified goals, extensive knowledge sharing and close face-to-face interaction for activity and knowledge integration, alternative explanations are offered. The findings highlight the integrative capacity of individuals’ experience and tacit foreknowledge of the stacker artefact, as well as the complementary role of meetings and ad hoc problem solving. The article proposes an iterative model of the individual/collective dynamics involved and calls attention to its economizing potential. More generally, it provides an example of how the issue of knowledge integration may be reformulated into a dynamic perspective, recognizing the intergenerational learning benefits that accrue. The conclusions extend the argument of Zollo and Winter by showing how different task-related learning mechanisms may be combined and obtain their integrative capacity within an iterative process. Key Words: knowledge integration; learning; project; tacit knowledge; teamwork

In this article we take an empirical point of departure in an in-depth study of a project where the task was to develop a new stacker; that is, a kind of warehouse truck. The study lasted a year from the moment when the project entered the development phase until its completion. The project group comprised a project leader and 12 team members with different functional backgrounds. The project proved to be successful. The product that was developed exceeded the most optimistic sales expectations, and project members were very satisfied with the way in which project work had been carried out. In their view, it was the best project they had ever participated in.

Our observations of how such successful activity and knowledge integration was brought about, however, contrasted sharply with the images of project work integration—as a matter of clearly specified goals, knowledge sharing and close teamwork—which are often encountered in project management and product...
development literature. Based on our case study, we suggest a different interpretation, which emphasizes the importance of the individuals’ experience accumulation and tacit understandings as well as the complementary role of collective arenas for knowledge articulation.

We also present an iterative model, which displays the integrative and economizing features of this individual–collective dynamic. More generally, we suggest how the learning investment framework of Zollo and Winter (2002) may be used and extended into a dynamic knowledge integration perspective. While their framework shows how different task characteristics influence the choice of learning mechanism, our iterative model implies an extension in that it suggests how such task-related mechanisms may be combined and obtain their integrative capacity in a dynamic interplay.

First, we outline the basic features of the knowledge integration framework that we develop in this article. In the following section we describe our research methodology and empirical data collection. We then present the case study of the stacker project and submit our analysis of this case. Conclusions and implications for theories of knowledge integration and learning are proposed in the final section.

Knowledge Integration in Project Contexts

Firms operating within dynamic industries, characterized by fast changes in customer preferences and/or technology, appear to increasingly organize their developmental activities in projects. To stay competitive in such pace-rewarding competition, firms use project groups in the hope of bringing about fast and focused product development effort (Hobday, 2000; Lindkvist, 2004; Lindkvist et al., 1998). In the vast normative literature on project management, the message is that great care should be taken to clearly specify project goals, and that those involved should engage extensively in planning, and creating a well-specification schedule, a clear work breakdown structure, and the like (see e.g. Lock, 1996; Project Management Institute, 1996). While many have heavily criticized the overly rationalistic view presented in that planning-oriented literature, and argued that it tends to neglect the uncertainties and political processes that prevail (see e.g. Hodgson, 2002; Lindkvist and Söderlund, 2002; Lundin and Söderholm, 1995; Sahlin-Andersson, 1996), little effort has been devoted to developing alternative concepts of what processes go on in projects and what means and mechanisms may be used in bringing about knowledge integration in such contexts.

Similarly, in the product development literature successful performance is often associated with promoting direct and extensive communication between members from different functions. This is underlined in Allen (1977), who shows that co-location is a highly efficient way of promoting communication among engineers. The need for close interaction is also clearly spelled out in the vast literature on concurrent engineering (Eisenhardt and Tabrizi, 1995) and in the Nonaka and Takeuchi (1995: 242) ‘rugby approach’, in which ‘the product development process emerges from the constant interaction of a multidisciplinary team whose members work together from start to finish’. Moreover, as discussed at length by Nonaka and Takeuchi (1995: 11), such product development interaction is
important in converting individual (tacit) knowledge into explicit knowledge, ‘allowing it to be shared with others in the company’.

In the more general literature on teams it is often suggested that in order to have a ‘high-performing team’ (Katzenbach and Smith, 1993: 92), its members should cooperate closely. What distinguishes such a team is that members are not only ‘equally committed to a common purpose, goals and a working approach for which they hold themselves mutually accountable’, but also ‘deeply committed to one another’s personal growth and success’. The image of projects, product development, and team work promoted in this literature is thus one that emphasizes the idea that good performance results from clearly specified goals, knowledge sharing, and reliance on a tightly knit, more or less constantly interacting team.

The successful execution of a product development project is highly dependent on how individual knowledge bases are integrated (Dougherty, 1992; Eisenhardt and Tabrizi, 1995; Lindkvist et al., 1998). Knowledge integration in firms has received considerable attention in recent research (see Grandori, 2001; Grant, 1996; Hansen et al., 1999; Kogut and Zander, 1992; Zollo and Winter, 2002). From the perspective of the knowledge-based theory of the firm, the main problem lies in assuring the most effective integration of individuals’ specialized knowledge at the lowest attainable cost (Grandori, 2001; Grant, 1996). The mechanisms of knowledge integration that it is possible to use can be distinguished, taking into consideration their way of achieving integration and their costs.

Organizational routines emanating from experience accumulation cause predictable patterns of collective behaviour, and hence are appropriate integration mechanisms in stable environments (Gittell, 2002; Zollo and Winter, 2002). Routines also support complex, simultaneous and varied sequences of interactions among agents (Becker, 2004; Grant, 1996). Grandori (2001) suggests that the tacit and unobservable nature of judgement and action generates epistemic complexity. Such complexities can be captured in tacit organizational routines, and the automatic, but far from trivial, patterns of behaviour captured in organizational routines then allow for task partitioning and for specialization among organizational members (Nelson and Winter, 1982; Prencipe and Tell, 2001).

In contrast to these internalizing features of learning through experience accumulation and routines, processes of knowledge articulation signify collective endeavours aimed at externalizing implicit knowledge (see Nonaka and Takeuchi, 1995). Knowledge articulation may take place through expressions of opinions and beliefs in group problem-solving activities. Using such a communication-intensive device for the integration of knowledge is more expensive than relying on routines, but may be necessary when complexity increases (Grant, 1996) or may be needed in order to enable dialogue to overcome communication impasses caused by a high degree of knowledge differentiation (Grandori, 2001). While hierarchical arrangements easily fail when knowledge is complex and differentiated, the collective dialogue implied by knowledge articulation is generally supported by team-based or project-based organizations (Lindkvist, 2005; Prencipe and Tell, 2001).

Knowledge codification represents an even higher degree of cognitive investment than knowledge articulation and denotes ‘an effort to understand the causal links between the decisions to be made and the performance outcomes to be expected’ (Zollo and Winter, 2002: 342). In proceeding with a knowledge
codification effort, the cognizing agent(s) form(s) a mental model representing a selection of actions and associated outcomes. Codification thus enhances understanding among the members of the organization of the overall process, allowing for effective knowledge integration under conditions of uncertainty. Much of the research into knowledge codification, however, pays less attention to the learning process dimension of codification, and emphasizes the economics of diffusion and implementation associated with codified knowledge as an outcome (Prencipe and Tell, 2001). In Grant (1996), for example, codified rules and directives are portrayed as low-cost communication devices for knowledge integration. Similarly, for Grandori (2001), codified IT communication networks constitute a cheap alternative for coordination under conditions of low knowledge complexity and knowledge differentiation.

More generally, Hansen et al.’s (1999) analysis of knowledge management may serve as a paradigmatic example of the mainstream view of efficient knowledge integration. They suggest that successful consulting firms choose either a personalization strategy, which relies on extensive face-to-face coordination between experts, or a codification strategy, which utilizes information technology where knowledge integration takes place through people-to-document. It is suggested that the personalization approach to knowledge integration is particularly effective when highly customized solutions are offered. In contrast, the codification strategy supports ‘economics of reuse’; that is, repeatable solutions.

In contrast to this view, Zollo and Winter (2002) and Prencipe and Tell (2001) suggest an almost inverse relationship between personalization–codification strategies and knowledge integration efficiency. Zollo and Winter (2002) argue that, in comparison with experience accumulation in tacit routines, the time, effort and resources devoted to knowledge codification are substantially higher. In this approach knowledge articulation represents an intermediate learning investment between these two end points. According to Zollo and Winter (2002), economizing on knowledge integration rests on task features; that is, the problems to be solved. First, where the frequency with which the task is performed in the organization decreases, they hypothesize that codification and articulation will be more effective than experience accumulation. Second, with decreasing homogeneity of task experiences, they hypothesize that codification and articulation will be more effective than experience accumulation. Third, if there is high causal ambiguity or complexity of the task at hand, they hypothesize that codification and articulation will be more effective than experience accumulation.

In this article, we relate this discussion about the efficiency of different learning mechanisms with regard to task characteristics to the more general problem of knowledge integration in firms. While the approaches of Grant (1996) and Grandori (2001) focus on how different situational characteristics affect the suitability and comparative costs of various mechanisms for knowledge integration, our ambition is to use the learning investment framework of Zollo and Winter (2002) as a way of grounding a dynamic perspective on knowledge integration. Hence, adding to the contributions of Grant (1996) and Grandori (2001), the analysis presented here focuses on the multi-period feasibility of different learning mechanisms for knowledge integration in project settings where particular task characteristics prevail. The framework provided by Zollo and Winter (2002) offers
a range of combinations with regard to frequency, homogeneity and causal ambiguity of the task. In the light of the task characteristics identified in our case study, we assess the integration properties of different learning processes as well as combinations thereof, in terms of their cognitive feasibility and comparative cost.

Method

Case-based research aims at generating new and/or refined theory from the basis of an in-depth understanding of a particular context, hence the choice of empirical case is crucial. Guided by our general interest in knowledge integration processes in interdisciplinary project contexts, we were looking for a case where we could carry out a study of this problem over an extended period of time. Moreover, our focus on knowledge integration apparently highlights a social process of a dynamic and ongoing character, which it is preferable to study in a natural setting (Silverman, 1993). A study of the stacker project was also considered interesting by the research and development (R&D) managers of the company because a major organizational change, which was intended to promote an increased project and project management focus, had recently been introduced. Moreover, we were granted unrestricted access to interviewing those involved and to attending all meetings, equipped with a tape recorder. Therefore, we believe we had a good opportunity to gain the kind of in-depth understanding that is a qualitative mark of any single case study (Dyer and Wilkins, 1991).

The empirical work was conducted during the period March 2001 to October 2002—that is, from the time when the project entered into the development phase until its completion (Frohm, 2002). In order to grasp the general background of the project and its context, we started the collection of empirical material by conducting two unstructured interviews with the project manager and the director of the R&D department respectively. Thereafter, we decided to undertake the empirical study in three different phases, focusing interchangeably on observation and interviewing. We built our understanding of the ways in which knowledge integration was achieved in this context by means of successive induction (Alvesson and Sköldberg, 2000), focusing interchangeably on data collection and conceptual issues as a way of grounding our findings and conclusions.

The first phase of collecting empirical material (see Table 1) extended over a period of three months, during which one of us attended eight project meetings. The observations made at these project meetings revealed how project members focused on aligning their experiences and images of project work, rather than on planning, decision-making or problem-solving. After each meeting, informal discussions took place with a number of the participants in order to get more insight into the matters presented, and to have their views explained in more detail. During the first phase our focus was thus geared towards identifying the character of project work and project member interaction. During the second phase, we conducted semi-structured interviews with all 12 project members and the project manager. Questions centred on issues of cooperation and the coordination in project work, and each interview lasted on average 70 minutes.
These interviews, in turn, promoted much reflection about the significance of individual work and the role of goals and knowledge sharing in project work.

During the third phase we wrote the case story and compared our findings to extant theories. Along with this, we also conducted additional observations, which enabled us to further elaborate on the empirical patterns that had been identified and to refine our categories. In total, 16 meetings were attended. Thirteen of these were regular project meetings, one was a design control meeting and two were ad hoc meetings convened to deal with problematic situations that had arisen. As was the case during the first phase, informal discussions were held with a number of participants to follow up on issues presented or discussed at these meetings in more detail. A draft of the written case and analysis was sent to the project manager and the project members alike, inviting them to comment. We arranged one meeting where we discussed our findings with the project manager. At a later meeting, we presented our findings to the entire project team and top managers from the R&D department. The comments received during these meetings served to reassure us that we had succeeded in acquiring in-depth familiarity with the project and its context. In addition to interviews and access to project meetings, we had access to various documents about the stacker, the company’s project management manual, and other written material as we required.

The Stacker Case

ProLift is engaged in the manufacturing and development of warehouse trucks, and is one of the leading actors of the industry worldwide. ProLift’s sales are approximately US$1.2 billion a year and the company has about 8000 employees in more than 70 countries. Our case study was undertaken at ProLift’s R&D department, which is located at the company headquarters in Sweden. At ProLift, development activities are performed in module projects and product development projects. Module projects concern the development of new components, sub-systems and parts, based on leading edge technology, while product development projects are clearly a matter of incremental innovation. These latter type of projects typically involve a multitude of less radical technical improvements and the complexities of adaptation and integration of a large number of sub-technologies, marketing considerations, and so on. These product development projects are of a recurrent nature, with the average project lasting approximately a year.

Table 1  Data collection methods and conceptual issues of each phase

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**Project Organization**

The development of a new stacker, which was the aim of the project studied, was a venture involving a team comprising a project manager and 12 project members representing different competences. Project members, who were located at different functional departments throughout the organization during project work, were selected from different sub-groups within the R&D department as well as from the information technology (IT), manufacturing, marketing and quality & environment departments. The educational backgrounds of project members as well as their work experience varied significantly. While some project members had university degrees, others had no formal education at all and while some had many years experience of working at ProLift, others were newly employed or consultants hired specifically for this project (see Figure 1).

The project team was free to choose technical solutions, while a steering committee comprising top managers from different parts of the organization defined the constraints in terms of time and budget. The project was organized around frequently occurring project meetings. At these meetings, all project members were present, even those whose actual participation did not occur until later in the project.

**Project Goals**

When entering the development phase the project goals were stated in a project specification, which explained in rather detailed technical terms the expected outcome of the project. From this point on these goals could not be altered without the permission of the ProLift Product Council. The project leader gave his view of these goals as follows:

> The most important thing in order to reach a target is, first of all, that everybody agrees on it. (Martin)

This is the reason why Martin always started the development phase of every new project with an extended meeting lasting for a couple of days. He described this meeting as one of ‘brainstorming and Post-It notes’ and added that this time it had been ‘very successful’. There was every reason to believe that project members thought there was a truly shared goal.

Most project members underlined the importance of a clearly specified and shared goal and they all thought there was a consensus with regard to the target in this case. However, when asked to recollect the goal(s) they felt somewhat awkward and their accounts appeared vague, as exemplified by the statements of Richard, Albert and Tom:

> not very informed what the target is . . . but I suppose that the target is to get a better, more adaptable stacker and that we will be able to get a small pay-off from it. (Richard)

> I don’t think that has ever been said . . . that this is what we are supposed to do. Or maybe it has . . . but it is not very clear, it’s more that we have to develop a stacker but it seems to be negotiable sometimes, different functionalities and so on . . . but it is specified it is . . . I believe it is quite clear. (Albert)

> To make a stacker that satisfies the market so that our customers keep on buying, and we can produce and sell. (Tom)
**Figure 1** The project team

- **Sarah**
  - Responsible for technical requirements
  - Development department
  - MSc in engineering
  - Tenure: 2 years

- **Bill**
  - Design engineer consultant
  - Located at the development department
  - BSc in engineering

- **Harry**
  - Design engineer consultant
  - Located at the development department
  - Vocational training

- **Richard**
  - Manufacturing, walkie
  - (sub-group at the manufacturing department)
  - BSc in engineering
  - Tenure: 2 years

- **Martin**
  - Project manager
  - Located at the development department
  - Internal courses
  - Tenure: 2 years

- **John**
  - Electro-design
  - Located at the IT department
  - Vocational training
  - Tenure: 2 years

- **Steven**
  - Manufacturing, tripods and chassis
  - (sub-group at the manufacturing department)
  - Internal courses
  - Tenure: 2 years

- **Henry**
  - Marketing
  - No formal education
  - Tenure: 30 years

- **Paul**
  - Technical support and field testing
  - (sub-group at the development department)
  - Secondary school certificate
  - Tenure: 30 years

- **Anthony**
  - Quality and standards
  - (sub-group at the development department)
  - BSc in engineering
  - Tenure: 2 years

- **Tom**
  - Order and administration
  - Secondary school certificate
  - Tenure: 13 years

- **Albert**
  - Order structure builder
  - Manufacturing department
  - Tenure: 25 years

- **Charles**
  - Order structure builder
  - Manufacturing department
  - No formal education
  - Tenure: 17 years

- **Martin**
  - Project manager
  - Located at the development department
  - Internal courses
  - Tenure: 2 years
Thus there was some confusion with regard to the goals, and project members readily admitted their difficulties when asked to describe the goals in more detail. Despite this, nobody was worried about it and no one said there was a need for an increased clarity of goals. Judging from these quotes, what was shared in members’ perceptions of the project goals was that they should develop a ‘better stacker’.

Project Work

Formally, the project team included a certain number of members assigned to fulfil the project goals. The person responsible for technical requirements, together with the design engineer consultants, the manufacturer engineer, and the representative from the quality and standards department, constituted an important sub-group, comprising the technical core of the project. However, this does not mean that the project was run in a top-down fashion. Market and manufacturing considerations were important, and it was frequently emphasized that the project was likely to fail if any of the members did not do his or her job:

Probably you would get problems whoever you disregarded. (Richard)

The project leader, three members of the technical core (Sarah, Bill and Harry), and Albert, one of the order-structure builders, had their offices close to each other in the same building. All other project members were located at their functional departments during the project, except when they attended meetings or approached others to try to solve problems that had emerged. As co-location was thus not used intentionally to facilitate face-to-face communication, it would appear to contribute little to explaining the pattern of interaction that actually emerged.

Project members had different backgrounds and experience, but apparently the overlap in competences between the members of the technical core was greater than between the technical core and project members from the marketing department, order and administration and other non-technical departments. Differences in professional–educational–departmental background, however, say little about how task-relevant competences overlap. In particular, the project members outside the technical core had significant experience gained from working in different departments within the company, and to a fairly large extent those with long tenure and experience were autodidacts, who did not pay too much attention to formal devices such as documented routines or procedures. As a result, much knowledge was gained as experiential knowledge, and stayed quite ‘tacit’ and individual in character. Charles exemplified this:

I have been working in projects more or less the whole time. They have grown bigger, more people are involved and they have become a bit more organized than they were before. Everybody knows . . . you have that book to follow and you know better what to do . . . Well, even if I don’t know what’s in it. But I know by experience what has to be done. (Charles)

As the project did not require highly specialized technical knowledge and many of the project members had considerable experience of new stacker development, there were fairly good possibilities for interdepartmental communication and for
establishing a project-specific knowledge base that was shared to a considerable extent. However, it is one thing to be able to achieve this, but quite another actually to engage in such activities.

Each and every one knows what they are doing . . . So it is not important to know the same thing . . . you must know what you are doing and then, the other things, are more like information. (Harry)

Thus, knowledge was distributed, not because it was impossible to establish a strong basis of shared knowledge, but because other coordination mechanisms were preferred.

**Individual Routine Work**

While no one expressed any need to distance themselves from the project, their sense of being part of a team varied significantly. Some, like Albert and Paul, were highly appreciative, pointing at the possibilities of being able to get help in case of problems:

What I feel most is that it is a team that is working . . . I felt that you worked together for something. Nice atmosphere. Everybody supported each other and so on. That’s what I believe is the biggest difference, that you work in a team and it’s fun to work in a team. (Paul)

However, other members’ opinions were in sharp contrast to this, like those of Tom and Steven who felt little team spirit and emphasized that this was not a project characterized by close cooperation:

Team . . . I have the impression that everybody works at his place. You work a little with everybody but most of all you work by yourself . . . and then together with your little group [at the department] and then you just go down [to project meetings] and give a report of what you have . . . Everybody knows that they are members of the project but that’s it. You go on as usual because you know that this is only for a limited period of time and . . . then it’s gone. (Tom)

Well everybody . . . you’re expected to take care of the task you have been allocated and I think they all do that. Nothing much happens between meetings. They go their own way, the participants. (Steven)

Moreover, as noticed by Richard, not only did project members work alone most of the time, but most work was considered routine work. However, it was not a matter of following the organizational routines encoded in the Project Management Manual. Instead, routine work signified the ‘automatic’ way in which individuals carried out their everyday work guided by their skills and experience within a specific area. The prevailing pattern of individual routines was thus very much something that had evolved over time, without being promoted by conscious design:

I think that everyone has a well-defined task and it’s not by chance that it looks the way it does but an inhabituated pattern. (Richard)

Somewhat surprisingly, people did not seem to think a lot about coordination in their daily work. Even when they were engaged de facto in matters that involved interdependencies, work was still very much thought of as routine.
Interactive Problem Solving

Although project members put great emphasis on project work as individual work, there were also occasions where members met in face-to-face interaction and communication. When unexpected problems occurred, project members approached each other to discuss and sort out what could be done about them. People then talked to their fellow team members, most often those who were directly influenced by their work; that is, their ‘neighbours’. Often only two people engaged in such problem solving, as illustrated by Bill’s comment:

I had a problem with the hydraulics and electronics things and then I went down to him [John] and we discussed how we would be able to do it in order to get a simple drawing of the cables and assemble it. And then I made an outline for him and he drew the wires and I made it in the CAD and then we got it pretty well together. (Bill)

Sometimes several project members were involved. In such discussions it was common that participants went back to the older versions and drawings of warehouse trucks to find clues as to how to deal with new problems. In a discussion between Martin, Sarah, Harry, Richard and Henry regarding problems with the emergency stop button, Sarah’s explanation was based on this:

I had a look at the old machine, what it looked like today and the reason why. (Sarah)

But obviously, the recollection of previous stacker solutions could sometimes be more limiting than enlightening. Bill, who declared that he often used drawings of earlier stackers to get a picture of what was expected of him, noticed that this might not always work very well:

Because that’s difficult, I don’t always know . . . Because you use the old stacker very much and then you don’t always know what the new one looks like. That’s a problem. Because you don’t know everything about stackers, then you go and have a look at old drawings and you look at the structure of the drawing and then it turns out that it doesn’t fit with the one we have made and they come and ask you things: ‘Should it really look like this?’ (Bill)

Informative Meetings

Project meetings constituted the only arena where all the project members met face to face at the same time. Project meetings were often described as instruments of control, where the project manager, who was in the chair, compared results and outcomes to planned actions before he opened up the discussion and let everyone talk about their achievements and problems.

Project meetings can be of different types but most often it’s just a kind of report-giving, status. It’s an instrument of control of the project. To see if it follows the plans and if there are some decisions which cannot be taken if the project manager is not present. (Martin)

Many project members complained that project meetings were both boring and too time-consuming. Moreover, they said decisions were seldom made but the same issues were brought up over and over again. Yet many of them acknowledged
their importance to project work. Information about progress and other project members’ undertakings was shared, providing a picture of the current situation.

They [the meetings] are of great importance. Otherwise we would never meet . . . would not have a clue what is going on. (Sarah)

Otherwise [if I don’t attend project meetings] I may do something that is supposed to be done but maybe it should not have been done that way. Then I have to remake part of it. (Charles)

Project members used the information provided in project meetings to reflect on their own roles and undertakings and how it related to what their fellow team members were doing. At project meetings, project members got a kind of shared experience of the situation at hand and the problems encountered. However, as illustrated in the quotes that follow, this had nothing to do with establishing a shared knowledge base; rather participants were only seeking clues that were relevant to their own work:

There is often somebody who has thought a bit and then you sit down to discuss in the team. Somebody says something and someone else says something else and you think AHA! That has to be done! (Harry)

You talk and maybe you get an idea from somebody . . . what to look for. (Albert)

These meetings were, however, less of an arena for problem solving. As already illustrated, problems were typically solved individually, in dyads or in small group interaction. Meetings provided project members with news and ideas, or simply information about who to ask if a certain type of problem should appear:

more to know about the problem. And if you do some part that is related to that . . . then you start thinking. (Bill)

I know who to ask if I have a problem. (Albert)

Analysis

Shared Goal, Shared Knowledge?

Despite the fact that there was a rather clearly stated goal set a priori, and despite the project leader’s view of the importance of having a shared goal, most project members could not give a clear account of the project’s goal and some noticed that there seemed to be room for ‘negotiations’ as to what functionalities were targeted. While they all said it was important to have a shared goal, no one wanted to see efforts made to clarify goals, or to set up a hierarchy or sequence of sub-goals. Some of them believed that other members had a more clear view of the goals, but for themselves they were quite content with the knowledge that they were going to build ‘a better stacker’.

So, in a sense they did have a shared goal, to build a better stacker, but this is hardly the kind of well-specified goal that is advocated in the project management literature as a means to achieve activity integration. Indeed, considering the
absurdity of the opposite formulation of this goal—to build an inferior stacker—the ‘better-stacker’ goal would appear to be nonsensical. Yet, it apparently did contribute to a general feeling that there was a common goal and that they were engaged in teamwork. In the terminology of Brunsson (1982) it functioned more like an ideology that was important in bringing about strong motivations and commitments, necessary for getting things done. Moreover, such an open-ended goal allowed project participants to hold individualized interpretations of what improvements were most needed. As a result, while the project goal as interpreted by the participants was not very helpful as a rational means of activity and knowledge integration, it was highly beneficial as a means of bringing about action orientation (Brunsson, 1982).

Moreover, it was not easy to identify any efforts to promote knowledge conversion and knowledge sharing (Nonaka and Takeuchi, 1995) that would facilitate concerted action. Certainly, the instances of ad hoc problem solving did result in some ‘interface learning’ among specialists, but those interviewed did not point to this as a very significant way of generating a common project-specific knowledge base. Meetings may constitute important arenas for generating consensus and aligning views among various specialists. In this case, however, meetings were more a matter of reporting on project progress, delays, problems encountered, and so on, amounting to an exposition of experiences rather than serving as a means of reaching communal understandings. Due to the relatively general level of technical knowledge, much more communality could have been achieved, but this would have come at a cost.

Meetings can also be important as arenas where individuals learn ‘who knows what’, resulting in a ‘network memory’ (Lindkvist, 2004), enabling well-connected individuals to coordinate their activities in a transactive memory fashion (Wegner et al., 1991). Instead of constituting a well-developed group in the classical sense, operating on the basis of a strong cognitive and emotional unity, such a group mirrors the ‘undeveloped group–developed mind’ option as discussed by Weick and Roberts (1993). However, in this case it seems as if too many of the participants had been around too short a time to allow such a transactive memory to be powerful. For example, when we look at the individuals who constitute the technical core, we notice that Sarah, who was assigned overall technical responsibility, had only been employed for two years, the two design engineers were in-sourced consultants, and Richard, the manufacturing engineer, had recently finished his university studies.

In conclusion, it would appear that neither the recipes for establishing well-specified goals and knowledge sharing, nor the network memory option, were very significant in bringing about activity and knowledge integration. This is not to say that these means were in vain, but rather to point out that additional ones appear to be involved.

The Role of Stacker Foreknowledge

A striking feature of the Stacker project is the almost unanimous view that most work is carried out by individuals working alone. Moreover, many of the participants use the term ‘routine’ when talking about their work. But what do they mean by that? Quite obviously it does not refer to explicitly stated or formalized
organizational routines, and it does not convey a view of their work as being a matter of tacitly operating organizational routines, in the sense of Nelson and Winter (1982). Instead, we suggest that their usage of this term amounts to saying that their work is guided by their individual tacit routines. Such individual-level routines should rather be conceived of as ‘skills’ as suggested by Nelson and Winter (1982) or ‘automatic knowledge’ (i.e. individual and tacit) as suggested by Spender (1996). But, how is it possible to achieve integration where such highly individualized tacit skills are significant?

In our view, the Stacker itself played an important role. Members repeatedly maintained that they knew what a stacker was and they often went back to drawings of older versions of stackers when problems appeared. Such knowledge of a stacker guided them in identifying interdependencies among parts and subsystems, what actors and departments needed to be involved. The fact that this kind of quite explicit and codified knowledge could constitute vital input for generating a guiding mental representation of the stacker within each individual is, of course, hardly surprising.

In addition, our conjecture is that many project members will have ‘access’ to a significant amount of relevant ‘tacit knowledge’ of previous stackers and the one about to be developed. We should recognize that the focus of the entire firm is on developing, manufacturing and selling warehouse trucks. Everybody knows that profits, careers, wages, and so on, hinge on the firm’s ability to offer better stackers. This makes it only natural for its individual members to consider more or less consciously how various aspects of stackers might possibly be improved. If so, we may think of them as a kind of ‘practitioner scientists’, always engaged in trying to solve a number of problems, improving existing solutions or finding new ones. If people did not have such intuitive personal visions, there would be no commitment and nothing much would happen:

This tentative vision must turn into a personal obsession; for a problem that does not worry us is no problem: there is no drive in it, it does not exist. This obsession, which spurs and guides us, is about something that no one can tell: its content is undefinable, indeterminate, strictly personal. (Polanyi, 1966: 75–6)

To experience a problem is thus to have some kind of vision or ‘foreknowledge’ of its hidden implications and ‘feel confident that they will prove right’ (Polanyi, 1966: 23). Certainly, it is not possible for the individual to have all the notions of possible improvements in mind. Most of what has been experienced, learnt, or just vaguely imagined, will have sunk into the subconscious levels of memory. Moreover, the complexity, ambiguity and sheer volume of such ‘knowledge’ would seem to preclude in abstracto articulation and codification. We may conjecture, however, that it will be possible to access and retrieve some of it in situ, triggered by specific problems, speech acts or events that appear as the development process unfolds (Lindkvist et al., 1998).

As suggested by Kreiner (2002), such tacit knowledge would appear to play a vital role in coordinating product development processes. Tacit foreknowledge (Polanyi, 1966) of the product to be developed, Kreiner contends, has coordinative power, making it possible to rely on the self-organizing abilities of those involved, rather than using central, pre-established plans to take care of interdependencies. By ‘enacting the same tacit foreknowledge’ (Kreiner, 2002: 116)
they may spontaneously seek to contribute to the realization of the tacitly existing product or technical system. The ‘presence’ of the not-yet-existing product or artefact (Latour, 1996) is thus seen as a means to unify perspectives and ways of relating to it.

In our case, the mere presence of the stacker no doubt contributed to erecting such a foreknowledge structure with a non-negligible degree of ‘sameness’, triggering subsequent spontaneous interaction in bringing the artefact into material existence. However, as discussed earlier, the number of ad hoc interaction events was sparse and in addition individuals in the stacker project had quite specialized tasks and responsibilities. While the specialization of technical knowledge was limited and did not in principle preclude the possibility of establishing a more communal knowledge base, either tacit or explicit, there was little effort to promote such communality or ‘sameness’. Hence, although tacit foreknowledge was indeed important, it is reasonable to assume that the foreknowledge accumulated by project members working alone for much of the time, was both individualized and idiosyncratic to a considerable extent.

As a result, the mere existence of the stacker contributed to a tacit foreknowledge structure that was highly significant, but due to the fact that the degree of sameness of representations that it implied was not known to anybody and could well be limited, we contend that, alone, it could not explain how coordination was brought about in the Stacker case. Rather, we contend that meetings and instances of ad hoc problem-solving interaction provided a necessary complement.

The Role of Meetings and Ad Hoc Problem Solving

Meetings were important; first, as arenas where project goals were introduced. As discussed previously, while it is true that the low degree of specificity implied in the ‘better stacker’ goal provided little guidance as to what should be done, it did provide project members with a general sense of having a communal goal and of being a project team. As a result, it strengthened commitment and willingness to integrate their specialized knowledge bases.

Second, the meetings focused far more on reporting experiences than on lengthy discussions aiming at problem solving or attaining shared understanding. Yet this reporting of experiences from the project leader and project members constituted a subtle way of aligning expectations about the actions of others, which facilitated concerted action. As expressed by Weick (1995: 42) ‘shared meaning is not what is crucial for collective action, but rather it is the experience of the collective action that is shared’. Such feedback reporting at regular intervals provided instances where everybody could check whether the creativity of their individual endeavours was reasonably in line with that of others, in terms of content and timing. Moreover, listening to the stories told by their colleagues would help their own imagination of new ideas, new intriguing questions and hints about solutions.

These regular meetings were not a timely or appropriate arena for dealing with unexpected events and problems. Time-limited meetings are not conducive to more in-depth problem-solving activity involving complex knowledge exchange (Hansen, 1999). Instead, such knowledge exchange calls for ad hoc interaction,
relying on extended, expensive face-to-face interaction. Apparently, the meetings and the instances of ad hoc problem solving predominantly contributed to knowledge integration using the mechanism of articulation, and occasionally some codification. At the same time, however, the significance of what was said and exchanged in these arenas calibrated the tacit knowledge accumulation of the individuals involved.

The individuals’ idiosyncratic representations of the stacker artefact, the meetings and the instances of ad hoc problem solving were thus all significant in explaining how interrelating and integration were achieved in the Stacker case. By relying on these as complementary mechanisms, it was not necessary to specify goals in great detail a priori. Moreover it allowed work to be carried out in isolation without a lot of effort devoted to knowledge sharing. As will be discussed, this involved a cost-economizing strategy of iteration, where people could work alone most of the time, only being interrupted by a limited number of occasions involving face-to-face interaction.

**Acting and Interacting: An Iterative Model**

To summarize the discussion so far, we suggest a model that distinguishes between instances of interacting, where individuals meet face-to-face, and instances of acting, where the individual works alone (see Figure 2). As discussed, project meetings were used for communicating project goals and other parametric input, and for feedback reporting. These meetings may be thought of as a rather routine way of keeping each other informed about project progress and problems encountered. We denote such instances of predominantly unidirectional communication to be ‘experience’ sharing (Weick, 1995) to underline the absence of discussion, problem-solving, and knowledge sharing efforts. Yet the meetings, as arenas for experience sharing, were no doubt important for participants to gain insight into whether their own individual efforts were (still) broadly in line with those of others. In addition, there was sometimes a need for face-to-face-based knowledge exchange and problem solving that would allow for dealing with unexpected and extraordinary events. Recognizing their non-routine character

![Figure 2](https://example.com/figure2.png)
(Zollo and Winter, 2002), we here use the term ‘ad hoc’ problem solving. The left side of the model thus predominantly relies on quite expensive ‘articulation’ mechanisms.

However, this is only half the picture. Inspired by Weick and Roberts (1993) we let the model’s right-hand side picture how project participants may contribute individually to task achievement, based on their representations of the role and repertoire of other participants and their understanding of and subordination to the collective task. In conjunction, the two columns in the model depict a process wherein instances of interaction provide material for grounding within the individuals a proper sense of subordination to the collective task or ‘system’, and a representation of how their work is interrelated with that of others. However, these individual actions also constitute an emergent activity pattern, contributing to shaping the system. In the terminology of Weick and Roberts (1993: 374), this processual dialectic means that such a ‘pattern shaped the actions that produced it’.

Returning to our case, this implies that the individuals may act individually and yet perform a social act, as team members contributing to project progress. Apparently, cutting down on face-to-face meetings is a way of economizing on costs. Therefore, to rely heavily on individual work and individual knowledge bases would appear to be a way of adhering to norms of rationality in our case setting. Moreover, as discussed, the limited integrative power provided by the project goals and knowledge-sharing activities could be compensated for by the individual’s knowledge of what a stacker is and his or her tacit stacker foreknowledge.

To summarize, the model pictures project work in our case as a matter of iteration between instances of interaction and action, with the Stacker artefact serving as a kind of peculiar ‘boundary object’ (Carlile, 2002; Star, 1993), enabling ‘communication’ and dynamic interplay between individualized knowledge and explicitly articulated social knowledge.

Project Task Characteristics

The iterative model pictures knowledge integration as a matter of both tacit and explicit knowledge. While it highlights the importance of individualized tacit skills and foreknowledge, it also points out the need for processes involving articulation and face-to-face encounters. These features, however, should be seen as a contingent outcome, mirroring the preconditions for knowledge integration specific to our case study. In accordance with the Zollo and Winter (2002) framework presented earlier, we focus next on task characteristics as a way of identifying the peculiarities of our project setting.

In the Stacker case, task frequency was certainly high. Many similar projects had been conducted previously and it was expected that new ones would be started at relatively regular intervals. Such a high-frequency context makes it possible for individuals to retain and remember lessons learned from one project to the next. Therefore, as observed in the stacker case, there is less need for expensive ‘face-to-face contact to coordinate the completion or upgrading of a manual’ or to engage in other activities that ‘divert attention away from day-to-day operations’ (Zollo and Winter, 2002: 347).

Similarly, task homogeneity as discussed by Zollo and Winter (2002) was high, as individuals were often able to apply previous experience in carrying out their
tasks. For example, interviewees indicated that previous technical solutions were often used as templates, both in individualized problem solving and in ad hoc interactive settings. Although new projects presented new challenges, lessons previously learnt could often be recontextualized and provide important impetus to managing the new task at hand. More generally, in the prevailing context of incremental innovation, earlier experience was valuable and there was little risk of generating ‘inappropriate generalizations’ (Zollo and Winter, 2002: 348).

It could be noticed that Grandori (2001) has quite a different concept of homogeneity–heterogeneity, which focuses on whether or not there is a ‘cognitive distance’ between those involved. In our case, project members had differing educational backgrounds and organizational home bases, but we would not say that the degree of knowledge heterogeneity, as conceived by Grandori, was very high. Although their backgrounds varied, the project task did not require specialized technical expertise and communication problems were hardly mentioned.

For Zollo and Winter (2002), causal ambiguity refers to the degree of clarity in the relationships between actions/decisions taken and their outcomes. We contend that this task dimension is close to the knowledge complexity dimension in Grandori (2001) and we use her distinction between computational complexity (which refers to the number of elements and their connections) and epistemic complexity (which refers to the difficulty of establishing knowledge that is valid and reliable in terms of e.g. observing phenomena and diagnosing causal links).

In the Stacker case, computational complexity was quite high. Although project members operated primarily individually, there were numerous important technical interdependencies. While some of this computational complexity could be dealt with by resorting to a hierarchical decomposition of tasks, there was also a need for both meetings and ad hoc problem-solving instances, as shown in the case presentation. Tacit knowledge may constitute a major component of epistemic complexity (Grandori, 2001). As discussed, the individuals in the Stacker project responsible for their task, developed a tacit understanding and foreknowledge of that particular sub-package of the project. The reliance on such ‘hidden’ competences in the Stacker project thus hampered transparency; even if strong causal relationships and interdependencies among components and activities existed, they were obscured.

In sum, the Stacker case would appear to score ‘high’ on all three preconditions that are assumed to predict the kind of knowledge processes that were involved in this product development project.

**Knowledge Integration in Project Work**

What preconditions for knowledge integration emerge from these project task characteristics? Building on Zollo and Winter (2002), we expect that when tasks feature high frequency and high homogeneity, the effectiveness of tacit accumulation of past experiences as a knowledge integration mechanism will be higher than that gained by using articulation and codification of knowledge. On the other hand, when tasks exhibit a high degree of causal ambiguity and complexity, the inverse relation is hypothesized. Hence, while the framework suggested by Zollo and Winter (2002) is useful as an analytical tool for each task dimension, it does not suggest effective knowledge integration mechanisms in situations where not all
task characteristics are uniform in terms of their implications (Table 2). In attempting to resolve this matter in the specific case described, we suggest that the iterative model of interaction and acting (Figure 2) aids in understanding how 'mixes' of task characteristics can be handled in terms of knowledge integration.

While there are a multitude of mechanisms that can be used for integrating knowledge, our model contrasts in particular the relative advantages and costs of using experience accumulation and routines vis-à-vis more articulate mechanisms. Of particular significance in our case are routines that are memorized individually and constitute the idiosyncratic property of the individual (see Reber, 1993; Sparrow, 1998).

In face-to-face meetings, project members articulate knowledge in discussions about difficult tasks to be solved. This represents a higher cognitive effort on behalf of project members as it indicates quite extensive reflection on action (Lindkvist, 2005; Scarbrough et al., 2004; Schön, 1983). The meetings represent a multi-agent situation that has a higher likelihood of reaching more abstract solutions than does a single-agent situation, since collaborative articulation and reflection lead to rich solution variation and subsequent integration of variations (Shirouzu et al., 2002). While the use of tacit routines acquired through experiential learning primarily supports benefits accruing to specialization, articulation of knowledge furthers task coordination through abstraction and shared representation (Foray and Steinmueller, 2001; Prencipe and Tell, 2001).

The iterative model (see Figure 2) suggests that the oscillation between interacting and acting has significant economizing effects. Acting primarily economizes on knowledge integration costs by relying on individual routines (the least expensive option), and only where such mechanisms are no longer feasible or sufficient is there a need to resort to interacting that allows for integration through articulation and codification processes (the more expensive options).

Based on our empirical research we cannot extend our iterative model to contexts where other task characteristics prevail (there are another three combinations of task characteristics logically possible). However, we submit that the combination of task characteristics observed is quite common in product development projects. As Pavitt (1999: 8–9) argued: ‘Empirical analysis suggests that […] most technology is specific, complex, often tacit, and cumulative in its development.’

The cumulative nature of technology implies that product development most often occurs in increments rather than in radical steps (see Dosi, 1988; Freeman, 1994). Cumulativeness also suggests that even in so-called project-based firms, repeatable solutions play an important role (Davies and Brady, 2000). The high specificity and tacit nature of technology point to the importance of specific artefacts that entail

<table>
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<tr>
<th>Frequency</th>
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<tr>
<td>Homogeneity</td>
<td>High</td>
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<td>Causal ambiguity</td>
<td>Low</td>
<td>High</td>
<td>High</td>
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<td>Knowledge integration mechanisms</td>
<td>Experience accumulation</td>
<td>Articulation/codification</td>
<td>Iterative model</td>
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Table 2 Task characteristics and mechanisms for knowledge integration
members’ foreknowledge of product development projects. Our research also draws attention to the fact that projects aiming at what could be denoted ‘incremental’ innovation (see Garcia and Calantone, 2002), still can involve substantial complexities that require a dynamic approach to knowledge integration.

**Conclusions**

Attaining effective knowledge integration is an important challenge facing both general management and project managers. Our analysis of the Stacker case has shown how knowledge integration can be handled in project contexts where existing theory does not provide a clear-cut answer. The iterative model suggested served as a viable solution to the knowledge integration problematic in the observed case, due to its dynamic and complementary characteristics. Next we highlight a few general implications of our analysis.

First, where task characteristics are similar to those encountered in the Stacker case, it is essential for project managers to recognize that while they should sometimes facilitate interaction through meetings and artefacts, it is often more efficient to rely on tacit routines and individual work. In contexts where frequency and homogeneity are high, project work may be successfully undertaken without much communication or interaction between project members, even though substantial computational and epistemic complexity prevails. These findings also suggest that conceptualizations of successful project work as relying on frequent face-to-face interaction may be misleading. Much project work may be undertaken individually, and yet still be a matter of teamwork.

Second, most literature on knowledge integration (e.g. Grandori, 2001; Grant, 1996) has viewed knowledge integration primarily as a ‘snapshot’ problem, where stocks of knowledge are combined in order to achieve efficiency. By contrast, our discussion stresses that an important project management function in assuring knowledge integration is to appreciate the learning dynamics of their specific project context. Knowledge integration in a dynamic capability perspective (Teece and Pisano, 1994; Zollo and Winter, 2002) recasts the research agenda to some extent, making it necessary to consider learning processes and flows of knowledge over time. While our general discussion and our iterative model have the project as a unit of analysis, it reflects the tendency for firm-level (i.e. sequences of projects) learning processes to exhibit path-dependent characteristics. Future research should further explore how project-level modes of knowledge integration may mirror the learning benefits that accrue in an inter-generational project and firm-level perspective.

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