Developing managerial expertise: studies on managerial cognition and the implications for management education

Document status and date:
Published: 01/01/2007

DOI:
10.26481/dis.20070126ja

Document Version:
Publisher's PDF, also known as Version of record

DEVELOPING MANAGERIAL EXPERTISE:
STUDIES ON MANAGERIAL COGNITION AND THE IMPLICATIONS FOR MANAGEMENT EDUCATION

ISBN-13: 978 90 5278 597 4

Coverdesign: Mark de Jong
Druk: Datawyse / Universitaire Pers Maastricht

DEVELOPING MANAGERIAL EXPERTISE:
STUDIES ON MANAGERIAL COGNITION AND THE IMPLICATIONS FOR MANAGEMENT EDUCATION

PROEFSCHRIFT

Ter verkrijging van de graad van doctor
aan de Universiteit Maastricht
op gezag van de Rector Magnificus,
Prof. Mr. G. P. M. F. Mols
volgens het besluit van het College van Decanen,
in het openbaar te verdedigen

op vrijdag 26 januari 2007 om 14.00 uur

door

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UNIVERSITAIRE PERS MAASTRICHT

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TABLE OF CONTENTS

DANKWOORD

Op de eerste plaats ben ik Wim Gijselaers enorm dankbaar als grootste initiator en begeleider bij dit proefschrift. Wim, inhoudelijk ben je voor mij van grote waarde geweest, vooral op het strategische vlak (iets wat ook de UM zelf de afgelopen jaren heeft gemerkt). Je maakte je (op ieder moment) sterk voor vragen als ‘hoe en waar publiceren we een stuk’, en ‘welke insteek nemen we daarbij’. Wat je bijvoorbeeld ook zo typeert is dat je met heel veel zaken bezig bent en dus weinig tijd hebt maar dit naar mij toe nauwelijks liet merken; Je bent geen klager maar een bedenker èn doener.

Mien (Segers), jouw niveau van ‘emotionele of sociale intelligentie’ moet torenhoog zijn. Jij voelt perfect aan hoe je mensen motiveert. Je wist altijd respectvol en constructief om te gaan met de feedback op stukken en kritiek op de juiste wijze te ‘verpakken’. Zeker in de begintijd is er een groot niveauverschil tussen degene die een proefschrift begint en de promotor, maar jij hebt me altijd in mijn waarde gelaten.

Els (Boshuizen), ik noem slechts één van jouw vele toegevoegde waarden bij onze samenwerking, namelijk dat je ontzettend gedegen een proefschrift stuk kunt becommentariëren. Soms wenste ik wel eens dat je iets minder gedegen en diepgaand een stuk van mij bekeek. Dat was natuurlijk een korte termijn kijk, want op de langere termijn was het stuk altijd kwalitatief veel beter en was ik je erg dankbaar.

Een speciaal woord van dank richt ik graag aan mijn oud-collega’s van de vakgroep Onderwijsontwikkeling en Onderwijsresearch te Maastricht waarmee ik zo’n prettige band heb opgebouwd dat het bijna familiaal aanvoelde: Henny Dankers dank voor al het organisatorische en lay-outwerk, Paul Jacobs dank voor alle databestanden en de prettige (ook niet werk- gerelateerde) gesprekken, Jeannette Hommes (voor de altijd genomen tijd en interesse voor welke kwestie dan ook); Jan Nijhuis, Piet Van den Bossche, Emily Teunissen, Tamerius Cohen en Geke Blok: dank voor het inhoudelijk meedenken bij dit proefschrift en bij het werk dat ik uitgevoerd heb op de faculteit Economie aan de Tongersestraat te Maastricht.

Ik dank verder heel erg de collega’s aan de UM en aan de TUe en de vrienden en familieleden die belangstelling of interesse hebben getoond gedurende het ‘werkstuk’.

Ook mijn thuishaven ben ik tenslotte zeer veel dank verschuldigd.

Alexander en Lisanne: opvoeding is erg intensief voor jezelf en je relatie als je het (zoals tegenwoordig alles...) ‘goed’ wilt doen, maar daarvoor heb ik van jullie echter enorm veel voldoening, motivatie en inspiratie teruggekregen.

Last but not least, Corinne: toi tu m’as soutenu depuis le début et tu m’as donné la liberté et l’énergie pour commencer et finir cette thèse. Tous les deux on a tellement appris de la vie, et de la psychologie des hommes que nous pourrions en écrire une thèse. Bien sur, vivre ensemble est intensif qu’on en oublie parfois les bons moments, mais c’est bien avec toi que j’ai eu les meilleurs moments de ma vie. Dans notre ‘monde individualiste’ tu m’as montré le ‘vrai amour’. Merci. Je t’aime.

Jos Arts, november 2006

CHAPTER 1: INTRODUCTION

1.1 Management education: what's the problem?

1.1.1 Criticism on management education

Societal developments such as globalization and the growing role of information and communication technology have changed the managerial workplace. Management education is expected to respond adequately to the more complex and dynamic organizational environments. However, since years, business schools have been criticized for not preparing graduates who have the knowledge and skills to function effectively in the workplace. Already in 1988, Porter and McKibbin argued that business graduates were not considered by the business community to be well prepared for the daily realities of the business world. They recommended that the teaching of various skills be incorporated into the business school curriculum in order to assist students in their roles at the workplace. This situation occurred more than 15 years ago. What happened afterwards? A report from the Business-Higher Education Forum out of 1995 states some main critics on management education: This report summarizes that business graduates (a) are not well prepared for encountering the realities of the business world, (b) lack vision, (c) cannot sufficiently link knowledge to practical situations and (d) cannot relate and integrate knowledge disciplines. A survey of employers by ACNielsen (2000) showed that graduates are still deficient in various skills and have a lack of understanding of business practice. Such criticisms on management education not only come from researchers or employers, they also stem from students, the media and from deans of business schools (Bennis & O'Toole, 2005). According to Bennis and O'Toole (2005) business schools have 'lost their way' by failing to recognize that business is a profession derived from practice, not an academic discipline like physics and economics. As a result business schools have embraced the scientific model rather than the more appropriate professional model of medicine and law. Many tenured business professors have never been inside a real business, except as customers (Bennis & O'Toole, 2005).

We conclude therefore that the study of Porter and McKibbin (1988) was not just one exemplary critic on management education: In fact, from of the 1980s continuously critics appeared on business administration education. Management programs are still criticised for their failure to prepare graduates adequately for dealing with daily business work situations in ways for which employers are calling (e.g. Baets & Van der Linden, 2000; Bigelow, 2001; Crainer & Dearlove, 1998). Boyatzis, Cowen and Kolb (1995) add that the criticisms of graduates of other professional disciplines, or programs often appear similar.

Below we discuss some major critics, related to the use of management knowledge and problem solving skills, which are the main focus of this thesis.

1.1.2 Workplace problem contexts differ from educational contexts

Surveys of employers (e.g. ACNielsen, 2000) conclude that graduates have a lack of understanding of business practice. One of the criticisms is that a large amount of knowledge is imparted to the learner without enough interlinks with reality (Seufert & Seufert, 1998). Porter and McKibbin (1988) and Stinson and Milter (1996) conclude that traditional business education is oriented more toward the *acquisition* than the use of knowledge. In this respect, Leinhardt, McCarthy Young and Merriman (1995) have put forward that 'applying knowledge' in an *educational* context often differs from applying knowledge in *professional practice*. Applying knowledge in an educational context is focused on labelling, differentiating and justifying the existence of it. Practical contexts by contrast require executing, applying knowledge and prioritizing one method above another (Leinhardt et al., 1995). This difference of focus may be one reason why the applicability of the knowledge that managerial graduates have acquired is a consistent source of critiques (e.g. ACNielsen, 2000). Further, Mintzberg (2004) has argued that traditional business education often uses pre-defined case studies that do not or only slightly resemble the managerial problems that managers face today. Today's manager is challenged how to most appropriately frame and define problems that are complex and often ill-structured (Mintberg, 2004). Mintzberg therefore argues that management education should offer more real life situations.

1.1.3 Educational and workplace knowledge and skills differ

Due to the rapid change of knowledge and information in our society (e.g. Boshuizen, 2003), it is often argued that there is a gap ('time delay') between what is learned at schools and what is required at the workplace. But the critics on management education are beyond this issue. Even if students acquire knowledge that is actual and still used at the workplace, this 'educational knowledge' not always meets the needs of business practice. Already in the 1980s, authors like Porter and McKibbin (1988) have pointed out that business schools put too much emphasis on *technical* knowledge and often neglect what knowledge truly makes the essence of professional contexts. In a similar discussion, Schön (1983) distinguished two types of important managerial knowledge. The first is technical knowledge that should be useful for well-defined situations in defined, stable contexts. The second, *professional knowledge* is necessary for ill-defined, practical and multi-disciplinary situations.

Additionally, a recurring criticism of graduates in management concerns their *problem-solving abilities* (Boyatzis et al., 1995; Business-Higher Education Forum, 1999; EFMD, 1994). Today, problem-solving abilities are considered as core competencies in management curricula. Management education plays an indispensable role in contributing to the acquisition of these competencies. A weakness perceived by employers is that business schools focus more on problem analysis than on problem finding, creating novel approaches to problem solution and risk taking (Porter & McKibbin, 1988). Also, in professional practice the emphasis seems not only to be on just applying methods, but also on solving the problems by choosing *appropriate methods* (the 'when' question), which demands the ability of prioritizing between acquired methods. In line with this, Joyce & Weil (1986) argue that a weakness of education in general lies in the neglect of *process* oriented learning, which implies making the *learning* and *thought* process visible in order to develop learners' metacognition.

1.1.4 The integration of knowledge versus isolated knowledge

Real-life business problems mostly have an interdisciplinary and multi-disciplinary nature (Baets & Van der Linden, 2000). Therefore, integration of managerial knowledge from various functional areas seems to be important when addressing real-world business problems (Hansen, 2002; Porter & McKibbin, 1988). However, it is claimed (Hansen, 2002) that a large percentage of management programs is too much oriented on separate disciplines and functions (instead of integrated managing practices), characterized by Mintzberg (2004) as a 'silo-thinking' disciplinary mentality which characterizes the typical business curriculum. The usual structure of MBA's divides the management world into isolated silo's or discrete business functions such as marketing, finance and accounting (Mintzberg, 2004). Many business schools seem to follow an insufficient integration of the different functional areas in management, and the knowledge from separate functional areas differs from the practical and hence *integrated* nature of knowledge at the workplace. According to Mintzberg, curricula need more synthesis instead of separated discipline learning. In line with these critics, Hansen (2002) concludes that more attention should be paid to the graduate's ability to *combine* academic functional knowledge and acquired skills in creative ways that add value to their employers.

1.1.5 Conclusion

In sum, the educational and workplace *problem contexts* and also the *knowledge* that is involved, differ. It is hypothesized that management schools educate students by offering knowledge that is too de-contextualized for resolving problems encountered at the managerial workplace. Many critics on management education refer to the knowledge transfer problem, indicating a discrepancy in the knowledge and skills that management education offers and what is required at the workplace. We assume that the educational problem solving contexts do not evoke the same cognitive activities as required in practice. As a consequence, a problem of knowledge transfer can occur. In the past, not enough attention is paid to managerial knowledge and the knowledge underlying problems solving skills. Therefore it is likely that investigating and better understanding the nature of managerial knowledge, can help management education to produce graduates that can better use the knowledge at the workplace and finally become more effective managers.

1.2 The context of this thesis

Pellegrino, Chudowski and Glaser (2001) have proposed a ‘triangle-model’ on the relation between (a) the workplace, (b) learning environments and (c) the development of managerial cognition (knowledge and skills). The ‘triangle-model’ consists of three *corners* (see Figure 1):

A. *“Learning environments”* refers to instructional approaches that might enhance the development of managerial knowledge and skills.

B. The *workplace* refers to the (managerial) profession and the knowledge and skills necessary for (managerial) practice.

C. *“Cognition”* refers to theories about knowledge and skills to develop competence in a domain (‘expertise development’). We see cognition as the ‘knowledge products’ or results of research of the (managerial) sciences at universities.

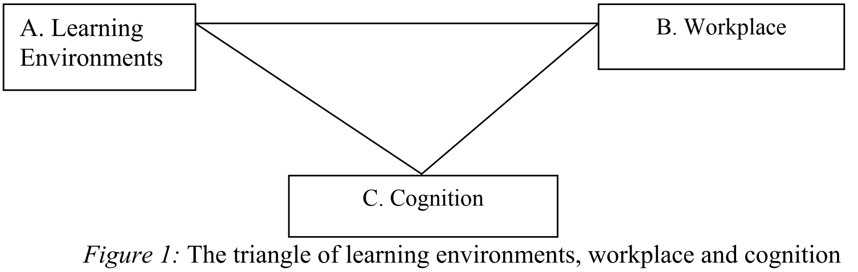

Figure 1: The triangle of learning environments, workplace and cognition

In the present thesis, all research studies are situated between learning environments (management education), the (managerial) workplace, and cognition. In Figure 2 we have applied the model of Pellegrino et al. (2001) on the managerial domain.

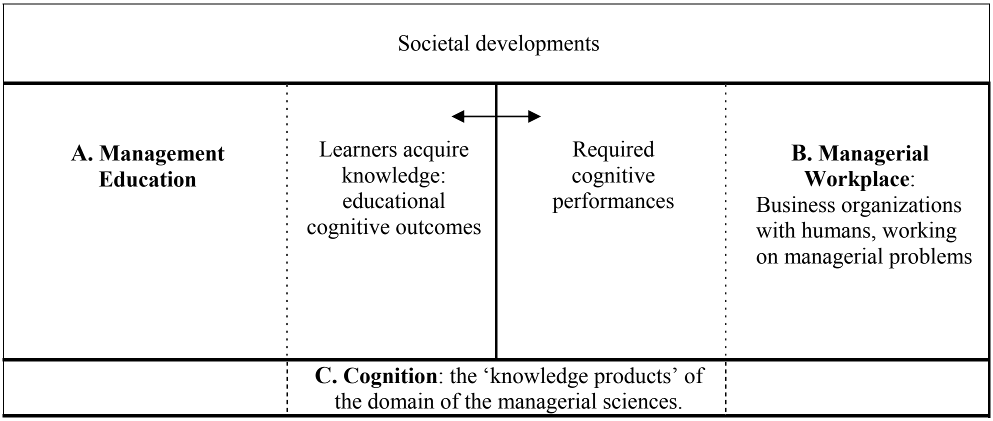

Figure 2: The context of the present thesis

The three elements in Figure 1 are represented as corners of a triangle because each is connected to and dependent on the other two. For instance, the flash in Figure 2 represents the idea that what educational institutes deliver ('knowledge products') is influenced by the requirements at the workplace. As the three elements are interrelated, a major tenet in this thesis is that for an educational program to be effective, the three elements must be aligned to each other. In this thesis we take into account all elements (education, workplace and cognition), but cognition and education are the objects of study. Given the interrelations of the three elements, below we will discuss all three elements of Figure 2 (A, B, C) in the perspective of managerial knowledge and managerial problem-solving, the main focus of this thesis.

1.2.1 Management education

Management education serves as the major context for the experimental studies as reported in the present thesis. According to Bennis and O'Toole (2005) the main goals of management education are to create managerial knowledge ('cognition') through research and to educate practitioners that perform well at the workplace. As argued, management education plays an indispensable role in contributing to the acquisition of knowledge and problem-solving skills. First, it can provide managerial workers with a background of knowledge modes for examining new problems. Second, education can be an accelerator of experiences in working with managerial problems.

During the 1990s, business schools made increasing efforts to adapt the curricular content. Examples are more emphasis on skills acquisition and designing multidisciplinary courses. However, according to Baets and Van der Linden (2000) the majority of criticisms on business education stems from wrong *educational approaches*, instead of wrong curricular content itself. *Educational approaches* serve as a vehicle for developing managerial knowledge and problem-solving. As a response to the critics on management education, in the past, different curricular structures and educational approaches have been employed supporting the acquisition of managerial knowledge and skills. Over the last decades, numerous efforts have been made to improve the structure and modes of (management) education. Approaches like case-based and action-based learning have tried to make a better fit with management education and the requirements of corporate world. In the 70s, in order to bridge the gap between theory and practice, the case-method became popular. In the 80s and 90s, business games and the theoretical framework of action learning were widely applied in management education. Action-learning ('learning by doing' in practice) involves structured projects in organizations rather than traditional classroom instruction (e.g. Revans, 1980). In the 90s also Problem-Based Learning curricula emerged in the management (e.g. Gijselaers, 1995). These new instructional formats have in common that learners play an active role during learning. Other (educational) trends that emerged in the 90s are (a) moving from individual towards collaborative learning, (b) the shift of 'detached' learning of 'isolated' knowledge and skills, toward learning in meaningful (workplace-oriented) contexts, and (c) providing students with more responsibility and control over the learning process (Jonassen, 2000).

In the present thesis, we conducted our research in a Problem-Based Learning (PBL) environment. We consider PBL as a case-based, constructivist method that requires students, working together in small groups, to analyse realistic problems to acquire the knowledge and skills needed for professional practice (Barrows & Tamblyn, 1980; Williams, 1992). Case-based methods such as PBL, aim at developing students' expertise related to solving problems. It has been argued (e.g. Wilkerson & Gijselaers, 1996) that PBL supports the development of students' expertise. However, Albanese (2000), Hmelo, Gotterer and Bransford (1997), and Norman and Schmidt (2000) have argued, that comparative studies of PBL and traditional approaches have failed to demonstrate conclusive evidence of substantial gains in expertise as a result of PBL. Most reviews concerning the effects of PBL have reported mixed results on the cognitive merits of PBL (Albanese & Mitchell, 1993; Dochy, Segers, Van den Bossche & Gijbels, 2003; Vernon & Blake, 1993). Also, although interesting research has been done in the domain of case-based reasoning and on knowledge transfer (Bransford & Schwarz, 1999; Kolodner, Gray & Fasse, 2003), only few PBL-environments have implemented the instructional design implications, deduced from these research studies. PBL environments offer an interesting context to investigate in depth if and under which condition instructional design implications can enhance the development of expertise.

Despite all the attempts at reform, many business schools still face the problem of bridging the gap between educational and professional practice. Overall, there is still little evidence that undergraduate programs have responded sufficiently to these criticisms (Bigelow, 2001). One important reason is that the university curriculum development process of teachers and administrators is often isolated and disconnected from employer concerns and market pressures (Bigelow, 2001; Miller, 1998). Approaches to optimising education often seem to be driven by *demands* from the workplace, instead on analyzing *real performance* itself at the workplace. The latter can be investigated through a sound, factual analysis of differences between new graduates and experts in performing relevant workplace tasks. To develop improved understanding of students' problem-solving behavior, *expert* problem-solving behavior should be investigated and compared with managerial *novices* (students, graduates). Such research (also used in this thesis) is referred to as the 'novice-expert' research paradigm.

1.2.2 The managerial workplace: managerial problems

Managerial practice is defined as fields and tasks conforming professional management functions. At the managerial workplace we consider the following 'objects' of study. First we have *organizations* (e.g. a firm). Within such organisations, employees study and solve *managerial problems*. Changes in the nature of organizations can affect managerial problem-solving. For instance, the transition into an information society and the upcoming use of media technologies requires new knowledge and skills of business professionals (Van Riel, 2003; Gijselaers & Arts, 2003). Below we go into more depth on an important object of our studies, managerial *problems*.

1.2.2.1 Characteristics of managerial problems and their consequences for problem-solving

In this thesis we will investigate cognitive (problem-solving) performance of managerial subjects. For this purpose we will build authentic business problems that function as a vehicle to *evoke* typical managerial cognitive processes as they occur in real-life settings. Hence, managerial problems are in this thesis used as instruments to investigate managerial knowledge in the context of problem-solving. Studying managerial expertise and the effect of learning environments on the development of managerial expertise requires understanding of the nature of managerial problems. Above we have put forward that a critic on management education is that educational problems differ from 'real' business problems. Realistic ('authentic') business problems have some *distinctive* features that are considered below. Managerial problems can be described as: ill-structured, multi-disciplinary and complex.

1.2.2.2 Ill-structuredness

Management represents a domain where most problems are ill-structured (Lash, 1988) which implies that there are no specific or pre-defined ways (algorithms) to solve them (Wickelgren, 1974). Ill-structured problems can have a number of causes and often have more than one possible solution. There is no such thing as *the* one and only cause or answer of a managerial problem (Baets & Van der Linden, 2000). In providing data and other evidence one can argue that one cause is the most likely reason for this business problem but, depending on one's the point of view, other causes can also be suggested. For instance, there can be various reasons why a company has lost turnover or has lost market share. In general, the range of all the outcome possibilities for ill-structured, practical problems (generally referred to as *problem space*) is wider than for well-structured problems. When the level of agreement about possible solution paths for a problem is low, the problem space is large and leads to a large number of *problem searches* (Simon, 1973; Wickelgren, 1974). Additionally, for many managerial problems the information for solving them is incomplete and ambiguous and may prove to be redundant. Moreover, related to the ill-structuredness of managerial problems, in practice the symptoms are not always clearly visible on the surface. In business practice it is up to the manager to *determine* whether or not a situation can be considered as problematic. The interpretation of indicators is dependent on the context. For example, a business result of 4 % might be very good in one context, for a supermarket, but a disaster in other fields, such as quality control. Therefore, a first step in managerial problem-solving is to identify problems and to decide on the basis of the available data whether or not a problem exists.

How is management education dealing with the ill-structuredness of managerial problems? Mintzberg (1973) has argued that a lot of management schools are more effective in training students to handle structured than unstructured problems. Mintzberg further contends that students are too often trained in the making of choices, rather than problem-solving, since often they receive a package of data, issues and problems, rather than having to derive or find these for themselves. 'Real' managerial problem-solving, however, is characterized by ambiguity, which means that very little information and analysis is given to the manager, and almost none of this is structured (Mintzberg, 1973). The ability to cope with fragmentation and unpredictability is a major requirement for managers (Mintzberg, 1980; Peters, 1988). Real world problems do not come in well-scripted, "canned", 10-page cases from Harvard. Instead, they are messy, with incomplete and sometimes inaccurate data (Revans, 1980).

1.2.2.3 Multi-disciplinarity

A second important feature of managerial problems is that many are of a multi-disciplinary nature (De Leeuw, 1996). An important reason is that the managerial sciences have originated from and still call upon a variety of disciplines, such as mathematics, economics, sociology and psychology (Bennis & O'Toole, 2005; Clegg & Ross-Smith, 2003). Thus, a business problem can be related to psychology (consumer behaviour), to organisational structures, or to quantitative economics. What may look like a straightforward financial decision – say to cut costs by relocating a service center – often has implications for marketing, sales, manufacturing (Bennis & O'Toole, 2005). As a result, an interdisciplinary approach to solving problems is required (De Leeuw, 1996), as applying only *one* discipline may only lead to a *partial* solution. Because of the multidisciplinary approach required for tackling many business problems, typically for business (and other multi-disciplinar) problems is to find out *which* particular area of expertise is required to arrive at acceptable solutions (O'Rourke, 1998).

1.2.2.4 Complexity

From the previous section it can be concluded that real managerial problems are complex because they are ill-defined, often based on incomplete information, require multiple viewpoints and have multiple solution paths. Mintzberg (1973) indeed has argued that managerial problems are often extremely complex. In this respect, it is often argued (Mintzberg, 2004) that today business problems are too complex and too large to be solved by individuals working alone. Since professional *team* settings offer the possibility of sharing multiple viewpoints and ideas, it can be argued that such teams likely have potential for effectively solving authentic business problems.

We conclude that typical characteristics of business problems (ill-structuredness, multi-disciplinarity and complexity) can influence the process of managerial decision-making (Seufert & Seufert, 1998).

1.2.3 Cognition: The 'managerial sciences'

Next to management education and the managerial workplace, the third and final element in Figure 2 is "the managerial sciences and its knowledge products". Managerial knowledge can be considered as a product ('outcome') of research in the managerial domain. In the studies in this thesis, cognition is the 'dependent variable'. What do we know about the nature of 'the managerial knowledge domain'? Management is an empirical science, in contrast to formal sciences such as mathematics. Mathematics knowledge is generated through a *deductive* method of using assumptions that are tested (Boone & Witteloostuijn, 2000). However, managerial knowledge is derived from *specific observations* in the world around us, similar as in physics, medicine or biology (De Leeuw, 1996). This business or management knowledge is created through an *inductive* process: sets of observations are captured into general knowledge products such as models. However, although the process of deriving knowledge is the same as the natural sciences, the type of object of study is different. Clegg and Ross-Smith (2003) draw a fundamental distinction between natural sciences studying *objects* (physics, biology, chemistry) and social sciences 'of practice' - such as the management sciences- that cope with *subjects*. The natural sciences consist of more objective, value-free knowledge, more fixed facts and more universal principles (Clegg & Ross-Smith, 2003). For instance, in biology or physics, examples of 'facts' are "Blood is red, and "Water freezes below 0 degrees". In the managerial domain however the question may be even raised whether many of such universal managerial 'facts' exist. As management is a '*science of practice*', researchers point out that managerial knowledge is uncertain, variable and bounded by its *context-dependent* nature (Reuber, 1997). Rules are applied in *local* situations and its use depends on certain conditions and circumstances. Also, most managerial work seems to be *context*- or *situation* dependent (Reuber, 1997). This implies that a procedure that has been found to work successfully for a certain task, does *not* provide a guarantee to be applicable for a similar task in another context. In sum, management is a social science and much managerial knowledge is derived through induction from observations in practice. Management knowledge is considered to be rather context-specific, whereas much knowledge of natural sciences holds a highly universal degree.

1.2.4 Conclusion

Above we have discussed the nature of the elements (a) education, (b) workplace and (c) cognition. Following Pellegrino et al. (2001), we have illustrated that these three elements are interrelated; for instance, changes at the workplace can influence or define the knowledge and skills that education offers.

An implication is that managerial education should be based on the *understanding* of the cognitive processes that are involved in information processing and decision-making in a management setting. Better understanding of these processes can improve the role of managerial education in providing the right knowledge and skills for students.

1.3 Research questions and outline of this thesis

In this thesis, we will study the nature and the development of managerial knowledge and managerial problem-solving. Both components can be referred to as 'managerial expertise'. For the remainder of this thesis we will use the term *expertise* for the "appropriate use of managerial knowledge and demonstration of appropriate problem-solving skills". Expertise research is not new. During the 1970s - within the tradition of the so-called 'first generation expertise research' - researchers aimed at finding algorithms and pre-fixed procedures for performing all kinds of tasks for typical workplace situations (Schraagen, 1993). Content or domain-specific knowledge was assumed to be as less important. But after several years, cognitive researchers realized that for ill-structured problems (as found in the managerial domain) hardly any of such general procedures could be fixed. As a result, cognitive researchers began focusing on the nature and role of domain specific knowledge, and the organization of human knowledge bases, the so-called second generation expertise studies (Schraagen, 1993). A conclusion of research on expertise is that domain-specific knowledge is the main determinant for problem-solving performance. Domain-specific knowledge is a concept, containing of a large spectrum of knowledge types such as facts, concepts, if-then procedures, etcetera (Sternberg, 1999).

The shift in research toward domain-specific knowledge has also generated questions like: What is the value of generic, domain-independent problem-solving methods for cognitive performance? A recent stream of cognitive research argues for a 'third generation' expertise research (Holyoak, 1991; Jonassen, 2000). Such research uses a comprehensive view on knowledge by considering the role of both domain-independent and domain-specific knowledge for explaining expertise. In the present thesis we will investigate domain-specific knowledge, and we will discuss both domain-specific and domain-independent knowledge.

Although expertise research started in the 70's, studies on expertise in this domain are limited as the domain of management is a rather young academic field (Arts, Gijselaers, & Boshuizen, 2000; O'Rourke, 1998). Studies on development of expertise typically have been conducted in traditional and more established domains such as medicine (Patel & Groen, 1991; Schmidt, Norman & Boshuizen, 1990) and physics (Chi, Glaser, & Farr, 1988). In particular, there is a shortage of studies involving a large number of research subjects. Additionally, in the past many studies have been performed using a *dichotomous* approach (with novices and experts only). In using such a dichotomous approach, many previous expertise studies have had difficulty extrapolating practical implications from their results, as these studies did not include *intermediate* participant levels - such as students and graduates (Alexander, 2003). Our expertise research includes intermediate levels of expertise and therefore is able to investigate characteristics of the *trajectory* (path) from novice *to* expert, such as the transition *from school-to-work*. Finally, in contrast to most former expertise studies, we will consider *several* dimensions of expertise (i.e. information processing, knowledge use and problem-solving skills.

1.3.1 Research method

The research of the present thesis is framed in the tradition of cognitive research on the development of (professional) expertise. As much of a manager's problem-solving knowledge is tacit, it is nearly impossible to elicit this knowledge through direct observations or through questionnaires (Sternberg & Wagner, 1994). Instead of using direct observations, in this thesis we will use cognitive methods to capture human thoughts, where participants express their own thoughts. With these research methods, we intend to analyze performance differences between managerial novices and graduates (at educational contexts) and managerial experts (at the workplace context).

With the previous paragraphs as a contextual background, below we will summarize the research questions for this thesis:

The research questions that we will address in Chapter 2 are:

- *How do managers process and represent information?*
- *What managerial knowledge is important during problem-solving?*

The objective of Chapter 2 is to investigate how managerial information is selected, interpreted and finally represented. In Chapter 2 we further explore what cognitive units (knowledge and information types) are generally important during reasoning on managerial tasks.

The research in Chapter 3 explores differences in diagnostic and problem-solving abilities of managerial subjects. Therefore, in Chapter 3 we address the following main questions:

- *What are differences in problem-solving abilities between managerial novices and experts? How is managerial knowledge related to these problem-solving abilities?*
- *Which cognitive stages can be depicted in the development toward managerial experts?*

From explorative research on the development of managerial expertise (Chapters 2 and 3), we move on to acquisition of managerial knowledge through management education. Chapter 4 and 5 examine this issue through the following main questions:

- *Which educational design guidelines can be derived (from both cognitive research and from recent learning theories) to adapt education and to stimulate learning and problem solving?*
- *Can the modified instructional PBL-environment enhance the acquisition of managerial expertise?*

Chapter 4 aims to generate instructional guidelines by using a) the outcomes of chapters 2 and 3, b) the findings of expertise research in general and c) literature on effective instructional environments. With the instructional guidelines, a Problem-Based instructional design will be rebuilt. Both chapters 4 and 5 examine the cognitive merits of a redesigned PBL-environment (a marketing management course). The cognitive merits are assessed in terms of knowledge applicability (Chapter 4) and changes in expertise acquisition (Chapter 5). The final chapter 6 of this thesis provides a review of the major research outcomes of our studies. It contains further general implications for instructional design in management education and ideas for future research.

Figure 3 summarizes the content of this thesis. In chapter 2 and 3 we will investigate the nature of managerial expertise, while Chapter 4 and 5 measure the cognitive effects of an instructional design, based on expertise research.

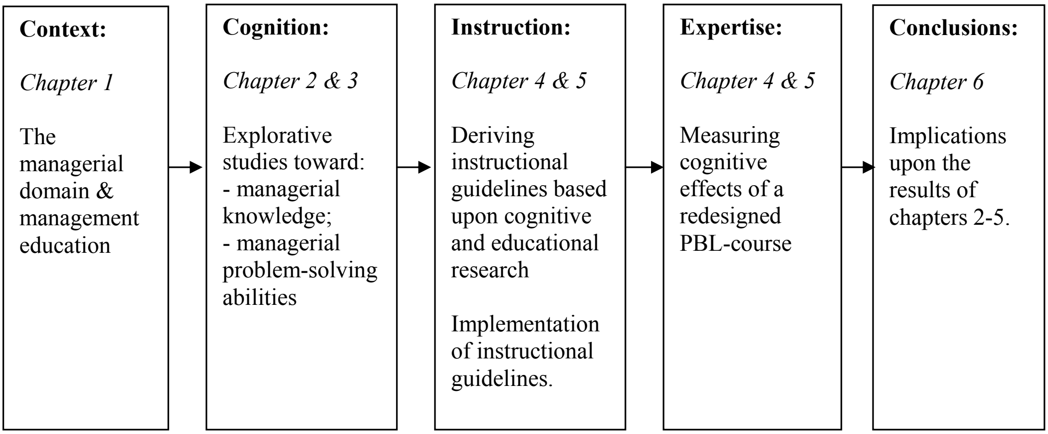

Figure 3: Overview of the present thesis: from cognition to instruction to expertise

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CHAPTER 2: A COGNITIVE SCIENCE APPROACH TO INVESTIGATE THE ROLE OF MANAGERIAL KNOWLEDGE IN INFORMATION PROCESSING AND PROBLEM SOLVING[1]

2.1 Introduction

In an increasingly knowledge-based economy, the ability to use knowledge for handling daily information is a critical skill (Pfeffer & Fong. 2000). For instance, processing and exchanging information are very important managerial tasks (Mintzberg, 1973; 2004) which account for about 50 % of an average CEO workday (Carlson, 1951; Tengblad, 2000). Managers are thus 'information-processors' spending their time absorbing, processing and disseminating information (McCall & Kaplan, 1985). Accordingly, managers are knowledge workers who are faced with a complex business environment, full of events and ambiguous information that challenges their ability to make sound strategic decisions (Walsh, 1995). For interpreting all data that managers encounter in their daily 'information worlds', they use their knowledge structures as mental 'templates' to filter and select information. Information is interpreted and transformed into meaningful interpretations or 'representations' (Walsh, 1995). This important 'sense-making' role of knowledge structures is reflected in Figure 1.

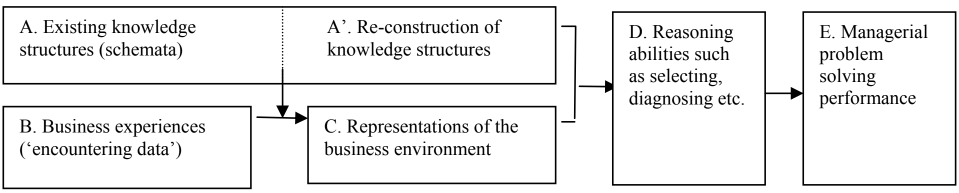

Figure 1: A Model for Managerial Knowledge Use, Reasoning and Cognitive Performance

The model in Figure 1 is based on cognitive theories proffered by Walsh (1995), Sternberg (1999) and Browne and Ramesh (2002). It illustrates the idea that the representations of problems in a business environment (C) are the result of applying existing ('prior') knowledge (A) on data that is encountered in a (business) environment (B). This representation ('interpretation') leads to accumulation of new knowledge which leads to adaptations of the knowledge base. Finally, the representations of specific business situations, together with the existing knowledge structure, determine managerial problem-solving (D, E). This implies that problem-solving abilities such as 'analyzing' and 'diagnosing' (D) are influenced or steered by knowledge structures. Thus, Figure 1 illustrates the importance of knowledge (structures) as lying at the basis of cognitive managerial performance.

Nevertheless, much is still unknown about the nature of (managerial) knowledge. The importance of investigating managerial knowledge is stressed by numerous papers which demonstrate that while management education delivers graduates that seem to possess a large amount of knowledge, graduates are not yet able to use the appropriate knowledge in a business context (e.g. Crainer & Dearlove, 1998; Porter & Mckibbin, 1988). Obviously there is a failure of knowledge transfer, which may be improved by studying the underlying managerial knowledge that is utilized by managers operating in a business environment.

Studies on expertise currently agree that the expert is distinguished by the possession of a well-organized, domain-specific knowledge network (Schmidt & Boshuizen, 1993). As

[1] Submitted for *Academy of Management: Education & Learning*.

knowledge plays such an important role, nowadays a major interest lies in the identification of 'knowledge structures' that enable managers to understand and process complex information (Walsh, 1995). As a consequence, an important question for management education is: what important knowledge components are used during reasoning in practical situations and which kind of knowledge is pivotal in these situations? The research in this paper addresses these questions and is therefore related to both managerial expertise and information processing.

2.2 Theoretical background and hypotheses

Knowledge structures are considered as representations of manager's organized knowledge built on previous experiences and representations. Isenberg (1986) was one of the first - in the management field - who aimed to identify (managerial) knowledge structures underlying problem solving by using research techniques adapted from cognitive psychology. In investigating managerial cognitive performance, Isenberg (1986), Lash (1988), and Van Fossen and Miller (1994) have found substantial differences between experienced managers and management students concerning their knowledge structures. Although these studies illustrate the potential for research in this area, some major shortcomings need to be mentioned. First, many previous expertise studies had a dichotomous focus (either novices or experts) while the current focus of expertise research is more on the trajectory from novice to expert, and changes within stages of cognitive development (Alexander, 2003). As these studies did not include intermediate participant levels, such as school graduates, these expertise studies had problems translating their results into practical implications (Alexander, 2003). Secondly, as numerous studies have been based on small sample sizes, generalization of the findings may not be warranted.

During the 1980's, cognitive scientists put forward theories about the organization of knowledge in memory to explain information processing and the decision-making abilities of managers (Eraut, 1994; Walsh, 1995). This cognitive research has shown that the capability to solve (managerial) problems does not solely depend on the acquisition of generic, pre-defined heuristics (e.g., Chi, Glaser & Farr, 1988; Ericsson & Smith, 1991) as had previously been assumed. In contrast, expertise research has demonstrated that managerial reasoning is "schema-driven" rather than algorithmic. An important reason for this is that many managerial problems are complex and ill-structured (information is incomplete, ambiguous, or changing) and such problems cannot be tackled by pre-defined algorithms (e.g. Arts, Gijselaers & Segers, 2004). The importance of knowledge structures as determinants of excellent performance has been found across many different expertise domains. Knowledge structures have been found to be mainly domain-specific (Ericsson & Smith, 1991; Schmidt & Boshuizen, 1993). 'Domain-specific knowledge' is a concept that covers a large spectrum of knowledge types such as facts, concepts, if-then procedures, schemata, etc. that are related to a specific expertise area (Sternberg, 1999).

Traditionally, formal knowledge is divided into categories such as facts, concepts, principles, and heuristics. In the present study we investigate both formal and 'practical' knowledge types. A typical example of what we refer to as *practical* or 'dynamical' knowledge is '*inferences*': transformations of parts of information into meaningful statements such as conclusions and summaries. The 'cognitive knowledge units' that are generally considered in research on (managerial) expertise are (a) facts, (b) concepts, (c) principles and (d) inferences. *Facts* are observations that are either true or false. *Concepts* are defined as a class or a category of phenomena or 'issues', like: 'bureaucracy' and 'distribution channel'. *Principles* can be defined as underlying mechanisms, rules or laws. *Inferences* are transformations on information.

Above we have argued that the (correct) use of domain-specific knowledge underlies managerial expertise. Our exploration of the nature of such domain-specific knowledge was accomplished by using cognitive methods, in stead of questionnaires. As much of a manager's problem-solving knowledge is tacit, it is nearly impossible to elicit this knowledge through direct methods such as interviews or observations of behavior (Wagner & Sternberg, 1985) and cognitive methods are needed to capture human thoughts in an indirect way. Therefore, we assessed handwritten problem-solving protocols. First we analyzed how participants process and represent managerial information of typical problem situations. Next we examined of the use of managerial knowledge for producing problem solutions (Ericsson & Smith, 1991). For deriving our hypotheses we will discuss previous findings on both dimensions (representation and knowledge use) in more detail below.

2.2.1 Representing information

A problem representation reflects how an individual has interpreted and processed problem information into a 'mental model'. A representation reflects consecutive problem states and the goals and constraints the problem solver has identified. A correct problem representation is crucial as with a wrong representation, the problem cannot be solved, or a wrong problem is solved (Elstein, Shulman, & Sprafka, 1978; Newell & Simon, 1972). The quality and coherence of a representation determines the efficiency and accuracy of further thinking and problem solving (Glaser, 1984). Expertise research has generally demonstrated that experts make better problem representations than novices when they are asked to recall a studied problem (e.g., Chi et al., 1981). Experts remember information better (Ericsson & Smith, 1991), and make more 'inferences' of problem data (Coughlin & Patel, 1987). A better problem representation also implies that experts characterize the semantics (meaning) of a problem in underlying mechanisms such as principles. Novices rather tend to focus on the superficial aspects of a problem, such as literal facts embedded in the problem (Chi et al., 1981). One explanation of a superior problem representation is that experts invest more time in the stage of problem orientation ('data scanning') than novices (Voss, Tyler, & Yengo,. 1983). Another consistent finding is that experts have a more extended and better-structured knowledge base that enables them to recognize patterns of information and to further select, filter, interpret and transform information into a meaningful representation. A related finding is that experts are more powerful than novices in distinguishing relevant and irrelevant case information (Coughlin & Patel, 1987; Patel & Groen, 1991). Due to this higher selective perception ability, experts make better representations (Ericsson & Smith, 1991). Thus, it can be concluded that experts make qualitatively better (more meaningful and more relevant) representations of problem information. For the present research this leads to the following hypotheses:

> *H_1: Managerial experts will represent problem information by using more relevant problem information, as compared to less experienced managerial participants.*
>
> *H_2: Managerial experts will represent problem information by focusing on the meaning (semantics) of information rather than superficial and literal aspects (the syntax).*

2.2.2 The use of managerial knowledge during reasoning

Current theories on expertise development consider the application of theoretical knowledge to practical experiences to be extremely important. In the 1980's, researchers such as Anderson (1987) developed the important view that declarative knowledge precedes procedural (or 'practical') knowledge. Practice allows declarative knowledge, as acquired in schools, to transform into practical knowledge types (Eraut, 1994). In fact, most acquired formal discipline knowledge develops further after students have graduated and entered the workplace (Eraut, 1994). In this paper we use the term declarative knowledge for formal discipline knowledge. We define ‘dynamical knowledge’ as acquired discipline knowledge that is being applied. Dynamical use of discipline knowledge indicates the idea that formal discipline knowledge is not used to only label situations, but that information encountered is meaningfully interpreted and actively transformed into inferences.

In the managerial domain, a limited number of studies on expertise have been conducted that used cognitive methods. The Isenberg studies (1984, 1986) were among the first in the field of management sciences that researched expertise using methods similar to those used in chess, medicine or physics research. Isenberg found that experienced managers differed from management sciences students in the knowledge applied during problem solving; experts used more causal inferences than students. Following the Isenberg studies (1984, 1986), Lash (1988) compared novices in marketing with a group of marketing managers from a large petrochemical organization. Similar to findings of Isenberg, experts typically demonstrated the ability to make inferences on information (by making summaries). Novices in contrast concentrated more on declarative knowledge: they recalled many facts based on management principles. Several expertise studies in other areas have investigated the cognitive units used during reasoning and problem solving. A surprising finding is that experts demonstrate less declarative knowledge during problem-solving than novices do; during the development from novice to expert, the use of declarative knowledge (facts, concepts, principles) initially increases, reaches a high plateau during graduate school and decreases with expertise development. For instance, Patel, Evans, and Groen, (1989) have found that with increasing levels of expertise, fewer and fewer concepts are used during reasoning despite consistent accurate responses. Especially during routine cases, an expert’s reasoning is driven by pure pattern recognition and the use of formal scientific knowledge is rarely demonstrated (Patel, Arocha, & Kaufman, 1999). Van Leeuwen, Mol, S., Pollemans, Drop, Grol, and Van der Vleuten (1995) found that participants’ demonstration of declarative knowledge peaks when students graduated. In general, such studies support the idea that higher levels of expertise are less demonstrative in formal knowledge types, although their quality of reasoning continues to grow. In line with this, it has been repeatedly found that experts demonstrate large amounts of practical (‘applied’) knowledge such as inferences during reasoning (Patel et al., 1989). The use of inferences appears to increase linearly with level of expertise (Boshuizen, 1989; Coughlin & Patel, 1987).

H_3: Managers with higher levels of managerial expertise (as compared to novices) will be less demonstrative in declarative knowledge types during reasoning, while at the same time, they will use more practical (‘dynamical’) knowledge types.

2.3 Method

2.3.1 Sample

We had 115 participants, representing nine different levels of expertise, ranging from younger novices to older well-experienced experts (see table 1). First, there were five different student groups. None of these students had work experience longer than one year. Secondly, there were four different expert groups whose members held management functions. We based the definition of our expert levels on labor market research, where it is common to investigate expert groups with two, five and more than ten years of working experience (e.g. Raffe, 2000). Each of our selected groups consisted of randomly selected individuals meeting selection criteria (i) years of education, (ii) work experience and (iii) age (see table 1). Such criteria are logical in defining different levels of expertise (Lash, 1988). We aimed for a gender distribution in the groups that reflected the true gender distribution in a business degree program and in the workplace. All participants followed the same data collection procedure during the study, and every participant received a small monetary compensation.

Table 1: Distribution of participants

	Novices	Students End of 1st year	Students End of 2nd year	Students End of 3rd year	Students End of 4th year	Junior Experts 2 year	Junior Expert 5 year	Senior Experts 12.5 year	Senior Experts 25 year	Total
Male	14	10	18	8	12	5	5	6	7	85
Female	4	4	4	8	4	3	1	2	0	30
Total	18	14	22	16	16	8	6	8	7	115

The participating students attended the business degree program of the Faculty of Economics and Business Administration, Maastricht University, the Netherlands. The *novice* group consisted of students in the first weeks of their business degree program. We selected the 1st and 2nd year student groups within the business degree program (which consists of a general introduction in business sciences, including management). The selected 3rd and 4th year students followed a degree specialization in organizational sciences. We selected the 4th-year students a few months before graduation. In expertise research, this group is normally defined as the group of *intermediate* expertise.

Experts were individuals with at least two years of post-graduate experience in managerial practice. A distinction was made between *sub-experts* (participants with on the average of two and five years of managerial experience) and two groups of *full-experts* (representing either 12.5 year or 25 years of managerial experience).

2.3.2 Instruments

Managerial, cognitive performance was measured by following typical procedures in cognitive research on expertise (see for a comprehensive discussion Ericsson and Smith, 1991). The first step in our studies involved finding and designing a collection of realistic *business cases* together with realistic assignments. These realistic case materials should *evoke* the realistic cognitive managerial performance, and activate participants' managerial knowledge. The second step in the present studies was to use an appropriate cognitive method to 'capture' the cognitive performances of our participants. We asked participants to write down the case analysis on paper. The third and final step was to find out appropriate cognitive *indicators* for analyzing and interpreting the outputs of the participants (see coding procedures below).

2.3.3 Materials

The materials consisted of two authentic cases on organizational development. Two university professors of management sciences designed the cases and two expert management consultants verified them. For both business cases, the participants received two assignments: (a) case recall, and (b) a problem analysis. For both assignments, we used the same case study materials, consisting of an instruction and the case description.

The cases we used may be found in the real business world and the case-stories resembled cases in typical managerial casebooks (e.g., Ashworth, 1985). The cases satisfied some constraints (Schunn & Anderson, 1999). First, the cases and solutions were unknown for all participants, as science involves the discovery of solutions through experimentation. Second, the cases were free of domain-specific jargon and understandable for novices. The cases contained neither interpretations nor analysis; case information was merely presented as a series of authentic data and events without any typical managerial concepts. This also resembled the management domain where most problems are ill-structured and where few consistent solutions exist (Lash, 1988). For many managerial problems, the available information is often incomplete and ambiguous and may prove to be redundant. As the case information was ill-structured, the importance of making inferences increased. The participants' task was selecting relevant information, analyzing the ill-structured situations and defining problems. To increase authenticity cases contained both case-relevant and case-irrelevant cues. Irrelevant cues did not contain false information; their only purpose was to better distinguish experts from non-experts (Boshuizen, 1989).

Case information was stated in the format of a business story: The two cases began with a section in which the leading character is introduced and the context in which he or she is working, followed by a set of factual information.

The case authors also developed the 'case answer models' that consisted of a description and a diagnostic explanation of the main problems in the case.

2.3.4 Procedure

After studying a case text for a limited period of time, the text was removed and participants got the two assignments. The case text reading time was restricted to .4 seconds per word. In total, participants were allowed 2.15 minutes for Case A (339 words), and 2.50 minutes for Case B (426 words) [1)].

For the *first* ('case recall') assignment, we asked participants to write down as much as possible as they could remember from reading the case. The goal of this assignment was to investigate how information in initial problem-solving stages was selected and represented. In a *free recall* method, participants are asked to recall as many items as they can remember in any order. Free recall is a validated method in cognitive psychology (e.g., Ericsson & Smith, 1991). The task is 'free' because unlike most other memory tasks, the experimenter exerts minimal control over the retrieval process. The idea of free recall is simple, but its power is the freedom of the subject in its personal behavior (Kahana & Loftus, 1999). The responses of participants can be analyzed on order, number, quality, the time spent, etc. The free recall method assumes that the aspects of information to which meaningful attention is paid are remembered by subjects (Boshuizen, 1989). Thus, the recall method provides information about (a) what kind of case information is selected, (b) how much information is processed, and (c) how it is stored or represented.

The *second* case assignment asked participants to analyze and diagnose the case: We asked the participants to explain the underlying problem mechanisms in the case. The participants needed to explain the causes and consequences of the case problems. An important assumption was that this cognitive process required understanding of the relevant domain of knowledge and therefore elicited the domain-specific knowledge that participants possess and use (Boshuizen, 1989). Therefore, this method should provide information about the use of managerial knowledge by students and experts during problem solving, i.e., the goal of this second assignment.

2.3.5 Data-analysis

2.3.5.1 Inter-rater agreement

The inter-rater agreement between two raters was calculated on the interpretation of the verbal case protocols. We selected a randomly chosen series of case protocols (21 protocols, distributed over the nine levels of expertise). Two raters analyzed the protocols regarding all the dependent variables (the managerial knowledge indicators). The average correlation of the scores of the two raters was sufficiently high (Pearson correlation coefficient = .847), implying that the scores of the two raters were strongly related. This outcome allowed that a single researcher scored the remaining protocols.

We compared the nine different expertise groups by using ANOVA analysis of variance (SPSS 11.0). In addition, we used the SPSS procedure 'Polynomial contrast-analysis‘ to analyze the direction of the relationships between the nine studied groups and hence to test the hypotheses.

2.3.5.2 Coding procedures

We analyzed the handwritten text protocols (that the participants had made with the two case assignments) by focusing on the cognitive units: (a) case facts, (b) managerial concepts and (c) inferences. We derived these indicators from earlier studies of expertise in expert-novice problem solving as previously discussed. Facts and concepts belong to declarative (‘formal’) knowledge types. The second category of knowledge considered, procedural or ‘practical’ knowledge, was in the present study embodied by inferences.

Facts. This indicator is related to case company facts literally recalled by participants. An example is: ‘The firm has a turnover of 150 million and 50 employees’. We refined further the facts in *high-critical* and *less-critical* case-facts. ‘Critical case information’ refers to case facts that are highly relevant for analyzing and solving the case.

We scored the case facts in the written protocols of the participants by following the technique of proposition analysis. We defined propositions as a small meaningful unit of information in a sentence that can be true or false (e.g., Boshuizen, 1989; Patel & Groen, 1986). The definition of propositions was operationalized as a combination of words containing at least one topic and a connected relation. First, we divided all sentences in both the original case study and the written participants’ protocols into propositions. One case sentence could contain more than one proposition. For instance, the original text of case A (27 sentences) was split up into 41 propositions. From these propositions, experts labeled 32 as high-critical and 9 as low-critical. Next, we matched the protocols of the participants by comparing these with the original case text. For a proposition that was (almost) completely recalled, we gave the score ‘2’. For a partial recalled proposition we gave a score of ‘1’. I.e. for a case sentence ‘*Decision-making was complex and time-consuming’*, participants could recall the proposition: ‘*Decision-making was complex*’. In that case we provided a score ‘2’. If participants *also* recalled remaining missing parts of this case sentence (the word ‘*time-consuming*’ in this case), we gave an *additional* score of ‘1’. We gave a score of 0 for incorrect reproductions or for repeating a proposition. We calculated percentage recall scores by dividing the recall scores by the maximum recall score (for case A 107 points, for case B 94 points). For more details of the technique of proposition analysis see Patel & Groen (1986).

Concepts. We defined managerial concepts as a class of managerial phenomena. Concepts in general enable us to reduce and characterize (managerial) phenomena into powerful and rather short labels. Examples of managerial concepts are ‘*job satisfaction*’, ‘*bureaucracy*’, and ‘*diversification*’. We considered the number of concepts produced as an indicator of possessing and retrieving declarative knowledge. Next to that, the use of concepts indicates that knowledge is applied in terms of recognizing and labeling managerial situations.

Inferences. We defined inferences as transformations on literal information given in the original case text. Examples of two case propositions are: 1) The turnover of the company is 150 million, and 2) The company has 50 employees. Here, an example of an inference is ‘*The productivity in this company is high*’. When inferences are produced, prior knowledge must come in action: As inferences link several parts of information into a new statement they indicate the ability of interpreting and transforming facts into meaningful statements, by using prior knowledge (Van Dijk & Kintsch, 1983). The number and quality of inferences may therefore be considered as an indicator of understanding and using domain specific knowledge. In scoring all protocols, we counted one correct inference as 2 points (partial correct: 1 point, incorrect and irrelevant inferences: 0 points).

2.4 Study 1: Processing and representing managerial case information

This first study was aimed at investigating differences in selecting, processing and representing typical task information between the nine levels of managerial expertise. In using a recall assignment, we investigated the knowledge base that the participants used for representing the management cases. To enhance the reliability, the present research used two cases. To compare the results on the two cases, we carried out a two-factor analysis of variance on case A and B with the factors 'Level of expertise' and 'Case'. We analyzed the variance to determine if the means for each sub-sample group differed significantly from the means of the other eight sub-sample groups. This analysis of variance showed that the relative scores of the participants on the two cases did not significantly differ. Therefore, the data of both cases were combined.

2.5 Results study 1

2.5.1 Relevant and irrelevant recall

In Figure 2 both the amount of *relevant* and *non*-relevant recall is depicted (in percentages), as produced by the participants on both cases.

First, for the *relevant* recall a significant effect of level of expertise was found [$F(8,95) = 4.47$, $Ms_e = 12.3$, $p = .00$]. Experts recalled fewer case propositions than intermediates and novices. No significant case effect was found [$F(1, 172) = .94$, $MS_e = 35.4$, $p = .33$], and no significant interaction effect between cases and level of expertise was found [$F(5, 172) = .81$, $MS_e = 35.4$, $p = .54$). For the 'workplace' section of the curve in Figure 2, a significant *negative linear* effect was found ($p = .001$) on the relation between level of expertise and the recall of relevant case items. Next, over the whole range of expertise levels, a significant quadratic component ($p = .000$) was found, implying that the middle of the slope has a non-linear relation, and looks like an inverted U-curve.

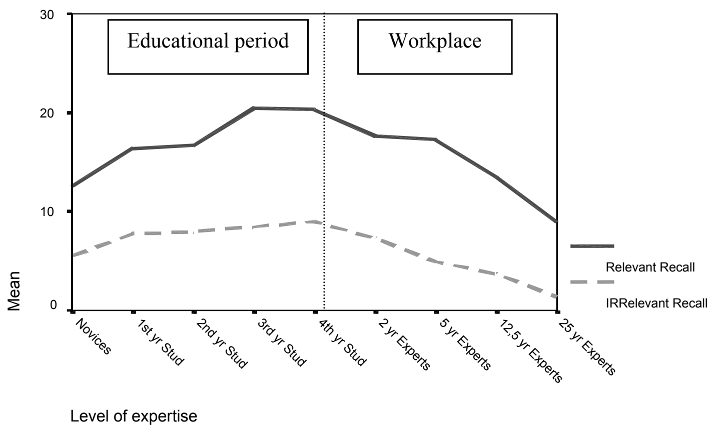

Figure 2: Mean Percentages of Relevant and Irrelevant Recall as a Function of Expertise

Concerning the *ir*relevant recall, again a significant effect of level of expertise was found [$F(8,95) = 7.25$, $Ms_e = 26.2$, $p = .01$]. No significant case effect was found [$F(1, 169) = 1.51$, $MS_e = 13.5$, $p = .22$], and no significant interaction effect between cases and level of expertise [$F(5, 169) = 1.3$, $MS_e = 13.5$, $p = .27$]. Interestingly, for both cases, experts rarely recalled irrelevant case facts. This demonstrates that experts filtered out most irrelevant case information. Again, the number of irrelevant propositions recalled showed a significant linear component (p = .03), and a significant quadratic component (p = .045). This implies that the relation between level of expertise and the recall of non-relevant case facts indicates a non-linear effect (in the middle of the slope) upon a linear effect.

These results as a whole suggest that expert managers recall very few propositions and select and operate more on relevant information when reading the case than novices and intermediates. This confirms Hypothesis 1: Managerial experts will build a mental image of problem information by using more relevant (more critical) problem information, as compared to less experienced managerial participants. Due to the findings that (a) experts filter out irrelevant information and (b) recall relative few relevant case items it seems that experts represent case information in a compact format.

2.5.2 Inferences in the recall

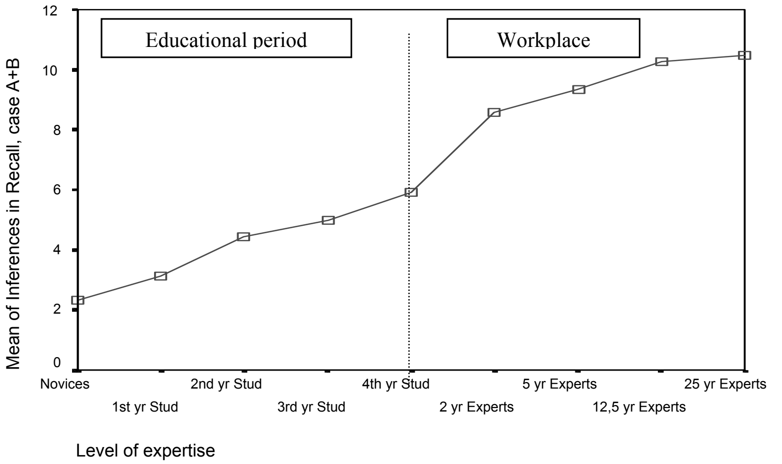

Figure 3: Inferences by Level of Expertise

For the (absolute) number of *inferences* produced during recall, a significant effect was found for level of expertise [$F(8, 95) = 27.32$, $Ms_e = 2.99$, $p < .00$]. The data in Figure 3 show a significant linear trend [$F(1,105) = 125.65$, $MS_e = 3.893$; $p = .000$], implying that there is a continuous increase in the number of inferences made as expertise increases. More importantly, the data in Figure 3 suggest that as participants become better trained in management, they increasingly represent case information as inferences. That is, a distinguishing feature between experts, intermediates and novices lies within an increased comprehension of the problem at hand, instead of the sole representation of literal information (through recall of factual case propositions, see Figure 2). These results lead to the acceptance of Hypothesis 2: Expert managers will represent problem information by focusing on the meaning (semantics) of information rather than superficial and literal aspects (the syntax).

2.6 Conclusions and discussion study 1

Study 1 shows that managerial experts (as compared to novices) select and process more *relevant* (instead of *irrel*evant) case information. This is in line with previous research showing that experts are more powerful than novices in distinguishing relevant and irrelevant factual case information. Novices process both irrelevant and relevant information (Coughlin & Patel, 1987; Patel & Groen, 1991). A second finding is that experts need relatively *few* case items to make problem representations: Experts represent case information in a compact format. Students at graduate level process the most information and therefore represented more case information than both novices and experts. A third finding is that in a problem representation, experts produce significantly more correct *inferences* than intermediates and novices. A monotonic increasing relation was found between the level of managerial expertise and the number of inferences produced. Similar results have been found in other expertise research. Chi et al. (1981) found that in representing information, novices focused on literal aspects while experts interpreted situations in a meaningful way by making correct inferences.

The present study shows that managerial experts differ from novices and intermediates by the quality of their problem representation. We also found that experts represented managerial cases more effectively by (a) selecting relatively *little* case information and (b) using *relevant* information types. A possible explanation for this 'selective performance behavior' is that experts can recognize typical situations and quickly generate potential diagnoses. Previous research has shown that experts store such previous experiences in patterns of information and knowledge or so-called 'chunks' (Chase & Simon, 1973). Experts only need a few textual cues to recognize these patterns and to activate an appropriate diagnostic schema. Therefore they can work with a small number of relevant textual cues. The idea that experts can activate patterns of knowledge based on earlier represented experiences can also explain why Isenberg (1986) found in his studies that experts acted on very little information and did not necessarily need additional information.

The experiences of experts combined with their ability to recognize patterns enable them to evaluate information relevancy. Experts process limited amounts of irrelevant information, which may explain the relative low recall of experts (Patel & Groen, 1991). *Novices* in contrast simply lack the knowledge to identify patterns. Since they can not discern between relevant and irrelevant, they fail to fully understand the case at hand. *Intermediates* will recognize several cues and attribute meaning to these cues, but they lack the practical experience to link the cues with patterns and corresponding solution models. As a consequence intermediates have to perform more (irrelevant) search efforts and process *more* information. Patel & Ericsson (1991) and Boshuizen & Schmidt (1992) showed that due to the inability of intermediate students to discriminate between relevant and non-relevant information, they made operations ('inferences') on both high and low relevant information, leading to many irrelevant searches. This excessive processing may explain why graduate students recalled relatively more case information than all other groups.

A final finding of the first study is that experts represent case information in a more *meaningful* way (through inferences). As experts possess prior knowledge and experiences, they are able to rapidly link case data and make inferences. Experts represent the underlying meaning. Instead, novices lack prior knowledge and cannot link their knowledge with the case data and must therefore rely on more literal propositions and hence represent surface aspects of the case. Intermediate students do have prior knowledge but lack sufficient experience to link their prior knowledge with practical case data.

It is generally known that good problem-solvers make good (short, relevant and meaningful) representations of managerial problems in the beginning of a problem solving process. Researchers including Isenberg (1986) and Voss et al. (1983) have found that (managerial) experts concentrate their time and efforts at the beginning of the problem-solving process. The present study supplements their work by demonstrating that expert's efforts are accompanied by high qualitative problem representations.

2.7 Study 2: Knowledge use in reasoning and managerial problem solving

The second study focused on identifying the cognitive knowledge units that managerial novices and experts use while reasoning about typical problem-solving tasks. It further aimed to identify how the use of managerial knowledge *develops* over time (from knowledge acquisition and application in business schools to further use in a workplace context). In this study, the second case assignment was considered: We asked participants to write down how they explained and typified the case situation. We scored the resulting case analysis protocols by counting the correct number of (a) managerial facts, (b) managerial concepts used, and (c) inferences.

2.8 Results study 2

2.8.1 Use of Managerial Facts, Inferences and Concepts during Reasoning

In Figure 4, the use of facts and inferences during managerial problem solving is depicted for the nine levels of expertise.

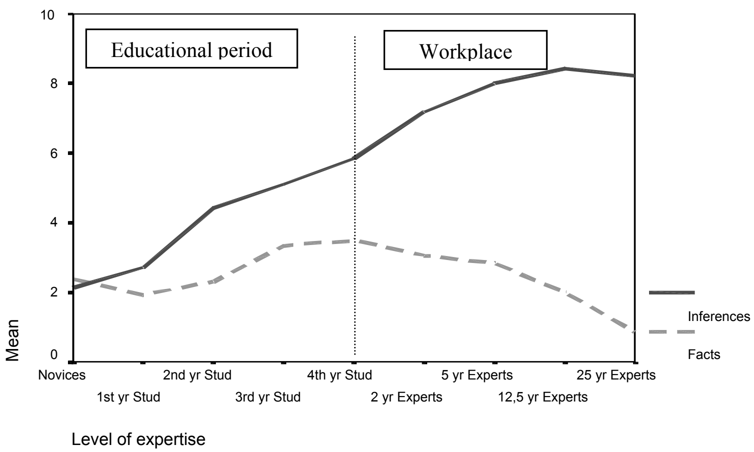

Figure 4: Means of Counted Facts and Inferences as a Function of Expertise Level

Managerial facts. The level of expertise had a significant effect on the number of correct case facts reported by participants in their case analysis [$F(8,105) = 3.55$; $MS_e = 12.72$, $p = .001$]. We further found a significant quadratic component (p = 0.00) and a non-significant linear component (p = .193). This implies that the number of facts used in reasoning reaches a highest point and then decreases. The relationship between the level of expertise and the number of case facts suggests an inverted U-form: after an initial increase, the number of facts reported actually decreases strongly.

Inferences. The number of inferences made was also significantly related to the level of expertise [$F(8,105) = 28.31$, $MS_e = 69.94$, $p = .000$]. As in the recall assignment, the number of inferences in the problem-solving protocols increased continuously with level of expertise (linear significant component with $p = .000$). This implies that the expert groups made significantly more meaningful transformations than the novice groups. The maximum number of correct inferences was reached after more than 10 years of working experience, and then remains stable (revealed by the significant quadratic effect (p = .000).

Managerial concepts. In Figure 5, the use of managerial concepts during problem solving is depicted for the nine levels of expertise.

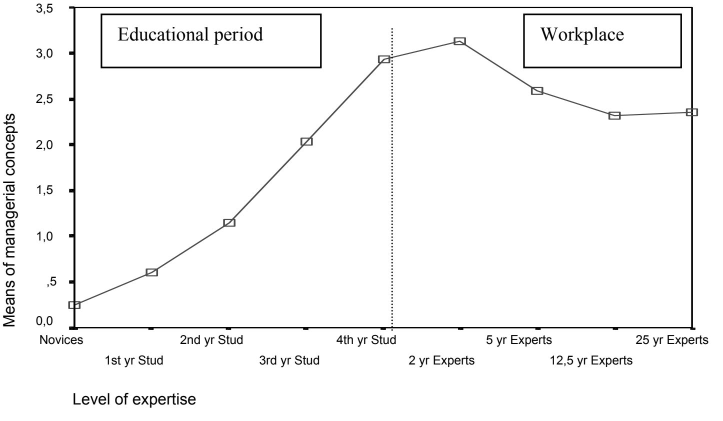

Figure 5: Means of Counted Managerial Concepts as a Function of Expertise Level

The level of expertise was also significantly related to the use of managerial concepts [$F(8,105) = 16.35$; $MS_e = 14.23$, p = .000]. Between the 1st and 4th year of study, there is a significant linear growth in the use of concepts (p = .000, Figure 5). A significant quadratic component (p = 0.00) implies that the number of concepts reaches a highest point and then decreases. Figure 5 shows that the use of formal discipline knowledge (managerial concepts) increases during the educational period; a maximum is reached two years after graduation, after which the number of domain concepts slightly decreases. Visually, the shape of the curve can be characterized as an ‘inverted U-relationship’.

Summarizing, the number of facts and concepts during reasoning increases until the participants enter professional practice, after which it stabilizes or decreases. Also, once participants have entered the workplace, the number of inferences increases significantly. These findings confirm Hypothesis 3: Managers with higher levels of expertise (as compared to novices) utilize relatively few declarative knowledge types while reasoning, but at the same time they use more practical (‘dynamical’) knowledge types.

2.9 Conclusions and discussion study 2

Study 2 investigated the cognitive knowledge units that managerial novices and experts use during reasoning. The results shows that the amount of *discipline* knowledge used by management students while reasoning increases significantly from the freshman year through graduation. After graduation, managers at the sub-expert level use less and less discipline knowledge as they gain experience. In contrast, the use of *dynamical* knowledge during reasoning (denoted by the number of inferences) significantly increases and continuously develops in a monotonic, linear way until the higher levels of expertise. Basically, the results in the second study imply that from a low toward a high level of expertise a *shift* occurs from ‘knowing what’ (by using declarative knowledge) toward ‘knowing how’ (by using practical knowledge). When participants enter professional practice the focus switches from the *reproduction* of factual information towards making meaningful *transformations on* case information into inferences. In table 2 the results of study one and two are summarized.

Table 2: Summary of results

Cognitive indicators:	**Novices**	**Intermediate/ graduate level**	**Experts**	**Relation between levels of expertise**
Use of discipline knowledge during reasoning.	Low	High: maximum.	Medium	Inverted U-curve
Processing of case information	Medium	High	Low	Inverted U-curve
Ability of selecting relevant information	Low	Medium	High	Monotonic increasing
Use of dynamical knowledge.	Low	Medium	High	Linear

These overall results are in line with previous research in other domains that also shows that during reasoning, experts use relatively little formal discipline knowledge while at the same time they provide accurate responses (e.g., Patel et al., 1989). These authors also found that experts make more inferences during reasoning (Patel et al., 1989).

The fact that experts make many inferences indicates that they are able to integrate their prior knowledge with actual case information (Van Dijk & Kintsch, 1983). Intermediates and graduates possibly have difficulties linking their academic knowledge to the real-life cases. Our results suggest that *intermediates* and *graduates* possess and use extensive amounts of discipline knowledge but are not yet able to *apply* this knowledge in a dynamic way by making inferences.

We provide three possible explanations for the finding that experts demonstrate relatively few knowledge types during reasoning. First, experts have more experience in discerning relevant information and in recognizing typical situations. Accordingly they can easily link practical situations with their well-organized knowledge base (Ericsson & Smith, 1991). As a result, experts can better select the knowledge that is relevant to a certain situation (Patel & Groen, 1991). As they are thus able to work with less knowledge, experts work more efficiently than novices. Secondly, an expert's knowledge organization becomes more compiled (Anderson, 1987). For instance, although the number of inferences increases with level of expertise, the length of these inferences becomes progressively compiled into shorter chains of inferences (Sternberg & Horvath, 1999; Van de Wiel, 1997). A related explanation for this compact way of processing information has been put forward by Schmidt and Boshuizen (1993) in the theory of 'knowledge capsulation'. According to this theory, low-level, detailed concepts are subsumed ('encapsulated') into a smaller number of high-level concepts that have great explanatory power. According to Schmidt and Boshuizen (1993) the use of summaries (inferences in the present study) are indicators of processing information in an encapsulated mode. A third possible explanation for the fact that experts demonstrate fewer knowledge types is that managers know more than they say or express. According to Wagner (1991), it is a consistent observation in expertise research that higher expertise levels have a more condensed communication style. A study by Sweller, Mawer and Ward (1983) may be illustrative. These researchers studied the development of expertise in solving mathematical problems. They found that initially, the participants wrote the entire original formula down, but when expertise level increased, they only noted the application and outcomes of the formula (Sweller et al., 1983). Such research illustrates that higher expertise levels use their knowledge in a more tacit or implicit way then novices.

2.10 Implications for managerial problem solving and management education

The present research develops further insights on how managerial problem-solving can be conceptualized and examined. Accordingly, we found evidence for the view that domain specific knowledge types play an important role in solving managerial problems. We demonstrated that practical or 'dynamical' knowledge types (such as causal inferences) are linearly related to level of managerial expertise. We showed that the ability to make inferences from relevant business data is important to distinguishing between management novices and management experts. Furthermore, we concluded that practical (dynamical) knowledge (which is the result of *applying* discipline knowledge) lies at the heart of managerial cognitive performance. This conclusion emphasizes the importance of linking learning at business schools to workplace situations since it suggests that the field of management learning is related to the accrual of practical knowledge based on theoretic and academic knowledge.

The case materials used in the current research were developed based on the underlying idea that in an unfamiliar business environment the importance of making inferences increases. That is, when case information is not clearly pre-structured, the demand for interpretation and elaboration is higher. Considering this, we think that business schools should design learning experiences that compel students to link managerial practice with the knowledge taught in classroom and text books. However, in current educational practice, many business schools prefer the use of pre-structured case texts that *reduce* the need for making inferences! To make matters worse, case studies (typically included at the end of a chapter) are often used for illustration purposes or short analyses rather than to develop critical thinking. Such cases often *present* pre-framed problems rather than challenge students. Crainer and Dearlove (1998, p 241) chastise business schools for their teaching practice: "Even utilizing the latest technology, case studies remain a limited and superficial method of teaching tomorrow's business leaders." Similar arguments have been raised by business educators such as Milter and Stinson (1994) and management strategist Mintzberg (1973; 2004). Several business educators have plead that students should be confronted with the ill-structured problems found in business practice instead of Harvard Cases (Milter & Stinson, 1994). Similar arguments were raised by Mintzberg as early as 1973. He noticed that numerous management schools which use the case-based method, train students in handling structured rather than unstructured problems or cases. Both data, issues and problems are provided in package, not derived or found by students themselves (Mintzberg, 1973). Real managerial decision-making is however characterized by ambiguity which implies that little information is given to the manager and that hardly any of that is structured. The management student should learn the skills necessary for finding, defining and diagnosing unstructured problems, searching for solutions, managing the dynamics of decision-making and juggling parallel decisions (Mintzberg, 1973). This statement delineates a core ideal for managerial education and training: by confronting students with 'authentic' (ill-structured) cases, students will be stimulated to form active (team) dialogues around these business cases and hence be stimulated to elaborate and infer upon the information.

In order to place our results on domain-*specific* knowledge in a larger perspective, we will discuss the role of domain-*independent* knowledge (such as generic methods). In our study we noticed that the use of domain-general ('generic') problem-solving methods (such as a SWOT-analysis) was limited. We noticed that a number of experts demonstrated the use of 'general mental checklists' or 'generic approaches' to structure data analysis while in the protocols of our novices, we found no traces at all of such generic approaches. Nevertheless, we think that such 'generic' methods *do* have their *own* purposes, in contrast to some authors who see limited usefulness in the domain-independent methods. As Wagner (1991) argues, the purpose of these generic methods can be that managers use them for approaching *new* (non-routine) problems. We think that such generic methods do not provide the '*content*' but the *tools* for (a) structuring problem data (goals, restraints, etc.) and (b) mobilizing necessary content knowledge. Domain-specific knowledge on the other hand is a necessary prerequisite for reasoning and problem solving. Stated differently, problem solving cannot be performed solely with general methods, but these general tools can structure the process. Nonetheless, the core units that explain expertise lie in using smaller units of managerial knowledge, especially practical ('procedural') knowledge types, e.g. causal if-then inferences, as investigated in our study.

A final category of generic (managerial) knowledge that we distinguish are generic *heuristics*. For a long time, it was assumed that many managerial tasks could be specified into pre-defined heuristics (Newell & Simon, 1972). While this may be true for a certain number of *well*-structured tasks that have a routine or repetitive nature, many problem-solving tasks in managerial practice are *ill*-structured and complex (Mintzberg, 1973; 2004). An additional feature is that for a business problem, few consistent problem solutions are known (Lash, 1988), as a business problem may have different causes. Consequently, generic heuristics are often not applicable to ill-structured business problems. Furthermore, Mintzberg, Raisinghani, and Theoret (1976) contend that heuristics become almost too complicated as tasks becomes more intricate and as more people and interest groups become involved, as is often the case in management. As most managerial work is *context*- or *situation*- dependent (Reuber, 1997), this implies that a procedure that has been found to work successfully for a certain task, does not guarantee applicability to a similar task in another context. In sum, we think that in the managerial area heuristics have limited use. By contrast, in certain domains (e.g. for dentistry) where the *context* is often the same object (a patient) and therefore heuristics of how to treat patient Y with illness Z are possibly easier to generate than heuristics of how to help company Y with problem Z.

As a limitation, we recognize that our research relied on a cross-sectional design. This design was however necessary for investigating a wide range of expertise levels. A research suggestion is to conduct a longitudinal research examining cognitive changes over a short period of 2-4 years. This may allow researchers to follow individuals from of graduation until the first years in the work force.

The present research contributed to previous research by demonstrating the importance of certain knowledge types as determinant for individual managerial performance. Future research could focus on the social aspect by adapting our approach to management *teams*, to further enhance understanding of what makes managers experts in their field.

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CHAPTER 3: UNDERSTANDING MANAGERIAL PROBLEM-SOLVING, KNOWLEDGE USE AND INFORMATION PROCESSING: INVESTIGATING STAGES FROM SCHOOL TO THE WORKPLACE[2]

3.1 Introduction

Research on expertise examines how learners make progress in the knowledge and skills that are needed to function effectively on real-life situations (Chi, Glaser, & Farr, 1988; Eraut, 2000; Ericsson & Smith, 1991). Many studies on expertise have focused on differences between the lowest ('novices') and highest expertise levels (Lajoie, 2003). Many of these studies, however, used a *dichotomous* approach and consequently had difficulty extrapolating practical implications from their results, as these studies did not include *intermediate* participant levels - such as students (Alexander, 2003). As current expertise research includes intermediate levels of expertise, this research permits to investigate how the *trajectory* from novice to expert develops, not only during formal education but also in a professional, authentic context (Hakkarainen, Palonen, Paavola & Lehtinen, 2004).

Research on expertise development is based on the premise that when moving from one level in education to another, or gaining increased experience at the workplace, expertise automatically progresses. However, recent cognitive research on the transition from school-to-workplace has identified several problems that typically occur when people move from education to the workplace (Boshuizen, Bromme & Gruber, 2004). It seems as if there is a stagnated progress - in the development of professional's expertise as soon as individuals are confronted with problem solving in practice. Some researchers have attributed this stagnation to a socialization process at the workplace (e.g. Austin, 2002). Others have criticized professional education for its apparent lack of facilitating expertise development. Indeed workplace-related studies regularly criticize education on the grounds that graduates are not prepared to respond to work situations in ways for which employers are calling (Bigelow, 2001; Hansen, 2002). For example, a recurring criticism about the competencies of management graduates concerns their apparent lack of problem-solving abilities needed to deal with difficult situations in the managerial workplace (Boyatzis, Cowen, & Kolb, 1995; Business-Higher Education Forum, 1999; Mintzberg, 2004).

In the past, many researchers assumed linear advancement of problem-solving skills (e.g. in the model of Dreyfus & Dreyfus, 1986). However much of this research was based on only a limited number of expertise levels: Beginner, Intermediate, Expert. Findings in the medical domain have shown that progression from novice to expert is not so straightforward and cannot be modeled as a simple linear sequence. For instance, Patel and Groen (1991) and Schmidt and Boshuizen (1993) have demonstrated that intermediates (students in final classes, just before graduation) reach higher cognitive outputs than novices and experts. Their finding was called the '*intermediate effect'*: After reading a medical case, students of an intermediate level of expertise not only recall more information than novices but typically they also recall more than experts. This 'intermediate effect' was one of the first indications that the development of expertise doesn't progress in a linear way.

Therefore, other researchers have suggested that expertise should not only be studied by focusing on the endpoints of expertise, but also how it evolves over different expertise levels (Alexander, Sperl, Buehl, Fives, & Chiu, 2004; Boshuizen, 2003). Recent research on expertise development has indeed evidenced that experts go through certain developmental trajectories or stages in the acquisition of knowledge (Alexander, 2003; Boshuizen 1989,

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[2] *Published in Contemporary Educational Psychology,* 31 (4), *pp. 387-410.*

2003; Eraut 2000). Some stage theories have focused on the development and change of knowledge structures or schemata (Patel, Arocha & Kaufman, 1999; Schmidt & Boshuizen, 1992). In this article, we will use theories on development of knowledge structures to explain our findings. Others (Ericsson, 2004; Ericsson & Smith, 1991) take problem-solving performance as a starting point. Although individual progress involves maturation, growth, and change in various systems, we will focus on cognitive stages of progress. We define progress as advances in adequate cognitive performance during solving realistic problems. We define adequate cognitive performance as the ability of providing accurate problem diagnoses and solutions, and appropriately using knowledge. The design of our study was set up to measure several information processing and cognitive *output* variables simultaneously (e.g. knowledge and skills).

Stage models that resemble our approach in analyzing expertise are those of Dreyfus and Dreyfus (1986; 2005), and Alexander (2003; Alexander et al., 2004). The six-stage model as developed by Dreyfus and Dreyfus (1986; 2005), assumes that an individual goes through six stages of acquiring problem-solving skills, before expertise is acquired: *Novice*, *Advanced beginner*, *Competent*, *Proficient*, *Expert* and *Mastery*. The main dimensions of cognitive progression in the Dreyfus' model can be summarized as: (1) reasoning on problems, and (2) use of knowledge during problem-solving. Reasoning on problems develops toward effective, quick, and unconscious reasoning. Knowledge use develops from acquiring facts and rules toward *using* the rules in a context (Dreyfus & Dreyfus, 1986; 2005). The Dreyfus model can be mapped on the Model of Domain Learning (MDL) of Alexander (2003). In using empirical and theoretical research, the MDL describes the development of expertise in three increasingly advanced levels (stages): Acclimation, Competency, and Proficiency. Within these stages, three interrelated dimensions are proposed: (i) subject-matter knowledge, (ii) learning strategies and (iii) interest. We will mainly discuss the cognitive dimensions knowledge and strategies, the focus of our study.

Concerning *knowledge*, in the first, 'acclimation' stage a focus is on the acquisition and reproduction of domain knowledge, covering the 'breadth' of knowledge: the underlying concepts and principles of a field. In the second stage ('competency') experiences lead to a deeper form of subject-matter knowledge: 'topic knowledge'. An individual truly understands topics and can relate several topics to each other. In the final proficiency or 'true expertise' stage, individuals extend their capabilities beyond their learned knowledge since they are able to derive new and personalized inferences and knowledge when encountering problems.

Concerning *strategic knowledge* use, when progressing to advanced expertise levels a trade-off occurs between surface-level strategies and deep processing strategies (Alexander, Jetton, & Kulikowich, 1995). Surface-level strategies aim to make sense of novel texts (such as paraphrasing texts) diminish. On the other hand, the deep processing strategies (that involve more critically delving into a text, such as author credibility) emerge (Alexander, 2003). In Table 1 we have summarized relevant dimensions of the Alexander's MDL.

Table 1: A summary of the cognitive and (strategic) information processing dimensions of Alexander's (2003) Model of Domain Learning

	Acclimation	**Competency**	**Proficiency**
Expertise indicators:	**Beginners**	**Beginning Experts**	**True Experts**
Amount of Domain Knowledge	Low	Medium	High
Amount of Topic Knowledge	Low	Medium	High
Knowledge organization	Low (Fragmented)	Medium	High (Well-structured)
Recall of information	Low	Medium	High
Ability of distinguishing relevant from irrelevant *information*	Low	Medium	High
Surface-level strategies	High	Medium	Low
Deep processing strategies	Low	Medium	High

In the present study we address the following research questions:

1) How does cognitive problem-solving performance, with respect to diagnostic and solution accuracy, vary from managerial beginners (students) to experts?
2) How does the use of underlying knowledge and time used during problem solving, vary from managerial beginners and experts, and can this explain differences in cognitive performance?

Previous expertise research has shown that problem-solving abilities, knowledge use, information processing, and use of time are related cognitive output variables (Boshuizen, 1989; 2003; Rikers, Schmidt & Boshuizen, 2002; Sternberg, 1997). In this study we will use these dependent variables. First, concerning *problem-solving abilities,* we investigated diagnostic and solution accuracy, as these have been shown to be relevant measures of adequate cognitive performance in managerial problem solving (Lash, 1988; Walsh, 1995). Second, we investigated the use of managerial *knowledge* underlying adequate cognitive performance in the management domain. The importance of investigating managerial knowledge is illustrated in several papers that demonstrate that while management education delivers graduates that seem to *possess* a large amount of knowledge, graduates are not yet able to *use* the appropriate knowledge in a business context (e.g. Arts, Gijselaers & Boshuizen, 2000; Business-Higher Education Forum, 1999). Third and fourth we considered the amount of *information* that participants processed and the amount of 'time' that was used during problem-solving. Rikers et al. (2002) conclude that time used during problem solving is one of the main differences between novices and experts. Below we elaborate our hypotheses.

Diagnostic accuracy concerns making accurate problem diagnoses. It can be understood as the identification, definition and explanation of case problems in terms of sources, causes and managerial phenomena encountered. Classical studies in the medical domain have demonstrated that diagnostic accuracy develops in a linear, monotonic way as a function of increasing expertise (Elstein, Schulman, & Sprafka, 1978; Patel & Groen, 1991). Research has shown that experts generally make more appropriate diagnoses than novices (Boshuizen, 1989). Given these results on diagnostic performance we hypothesize: *Accuracy of managerial diagnosing will be positively related with increasing levels of managerial expertise (H1).*

Solutions accuracy refers to the capacity to provide accurate case solutions. We defined a case solution as directions or decisions for further action. Whereas problem diagnosis requires analytic activities, offering solutions is a deductive activity and depicts another aspect of expertise (Eraut, 1994). Research in the social sciences on experts' problem-solving has demonstrated that experts provide more accurate problem solutions than novices do (Voss, Tyler, & Yengo, 1983). Additionally, Voss et al. (1983) have found that experts rather provide one solution while novices tend to give several solutions. Considering these results we hypothesize: *Managerial experts will provide fewer but more accurate solutions than management students (H2).*

Studies of expertise suggest that it takes roughly 10 years of work experience before expert performance is achieved (Ericsson & Smith, 1991). For the present study, we consider expert performance to have occurred when both accurate diagnoses and accurate problem solutions have been provided. Accordingly, an additional question is: *Will managers display expert problem-solving performance after they have gained more than 10 years of work experience?*

Processing factual case information. As a knowledge base of students is quite fragmented and incohesive (Alexander et al., 1995) and not yet adapted to practical situations, students are not well able to discriminate between relevant and non-relevant information (Arts et al., 2000; Boshuizen & Schmidt, 1992). Students reason on both relevant and irrelevant information (Patel & Groen, 1991). This can lead to excessive processing of information. Therefore we hypothesize: *After* problem-solving, *management students will retain (a) relatively more case information and (b) relatively more irrelevant case information than experts (H3).*

Managerial knowledge use. A surprising finding of expertise research is that experts demonstrated less use of theoretical (discipline) knowledge during problem solving than novices. For instance, Patel, Evans and Groen (1989) have found that with increasing levels of expertise, fewer and fewer theoretical concepts are used during reasoning, despite consistently accurate responses. Consequently, we hypothesize that *managerial experts will demonstrate less theoretical managerial knowledge than students do (H4).*

The knowledge use that experts show in problem solving is practical and 'dynamical' in nature (Arts et al., 2000; Eraut, 1994) which differs from theoretical knowledge. Theoretical knowledge use refers to 'labeling' situations by linking theoretical concepts to factual information. Dynamical knowledge occurs at a deeper and more implicit level (Caine & Caine, 1997; Patel et al., 1989). For instance, several case facts are linked and the original information encountered is transformed into newly produced inferences such as conclusions. We hypothesize: *Managerial experts will demonstrate more dynamical knowledge than students do (H5); An expert's problem-solving performance will be more strongly related to dynamical knowledge than theoretical knowledge (H6).*

Time used during problem-solving. Boshuizen (1989) and Elstein et al. (1978) have investigated the factor *time* in the process of problem solving and found that experts often used less time to provide a diagnosis, than students. These authors suggest that differences in the speed of problem solving can be explained by the possession of well-organized knowledge structures: The expert's knowledge base, which is adapted to practical problems, contains scripts (patterns of knowledge) that enable fast recognition and interpretation of symptoms and situations, and rapid retrieval of relevant knowledge. Therefore, we hypothesize: *The time used for problem solving will show a negative relationship with level of expertise (H7).*

3.2 Method

3.2.1 Participants

In order to obtain a detailed picture of how expertise evolves over different levels, we examined transitions in three stages: (a) formal education, (b) the transition from formal education to the first years of workplace experience, and (c) the final stage towards 'true expertise'. A cross-sectional design was set up to measure experience- and knowledge-related differences among individuals having various levels of expertise. We used nine expertise groups, ranging from younger novices to older well-experienced experts (115 individuals in total, see Table 2). Years of education and years of work experience (in the field of organizational consultancy) determined expertise level across nine groups.

We covered all years of the business program, and hence distinguished five student groups (including freshmen). None of the students had significant, relevant work experience of one year or longer. In addition, four different levels of expert groups were identified.

We aimed for a gender distribution in the different groups that mimicked that of the average distribution in our business degree program (two third male and one third female). All participants followed the same data collection procedure during the study. Each participant received a nominative compensation for participation.

Table 2: Distribution of participants

	Novices	*Students End of 1st year*	*Students End of 2nd year*	*Students End of 3rd year*	*Students End of 4th year*	*Junior Experts 2 year*	*Junior Expert 5 year*	*Senior Experts 12.5 year*	*Senior Experts 25 year*	*Total*
Male	*14*	*10*	*18*	*8*	*12*	*5*	*5*	*6*	*7*	*85*
Female	*4*	*4*	*4*	*8*	*4*	*3*	*1*	*2*	*0*	*30*
Total	*18*	*14*	*22*	*16*	*16*	*8*	*6*	*8*	*7*	*115*

The student groups did *not* participate on a voluntary base but were randomly selected from students attending the business program of the Faculty of Economics and Business Administration, Maastricht University, the Netherlands. The *novice* group consisted of students in the first weeks of their study. We selected the 1st and 2nd year groups from students taking introductory courses in management. Only 3rd and 4th year students with a specialization in organization sciences were included in the study, and 4th-year students were selected a few months before graduation. In other expertise research, this group has been defined as 'intermediates'.

Labor market surveys in western-European countries are normally held after about 2, 5 and more than 10 years of graduation (Raffe, Biggart, & Brannen, 1999). Similarly, we selected participants with about 2, 5 or more than 10 years after graduation. *Junior-experts* had two or five years of post-graduate experience in managerial practice, specialized in the domain of organization sciences. These junior-experts were randomly selected from a list of graduates with a degree in Organization science (a Management specialization).

Senior-experts served as a reference in our study. All the experts held academic degrees in Management, and held management and/or consultancy positions requiring expertise in Organization science. We selected a first group of senior experts with about 12.5 years of working experience. A second group of senior experts had about 25 years of relevant experience, a level that is in expertise literature referred to as the 'mastery' level of expertise. For instance, in the Dreyfus model (2005) 'mastery' is the highest level.

3.2.2 Instruments

Managerial cognitive performance was assessed by procedures typical to cognitive research on expertise (see for a comprehensive discussion Ericsson & Smith, 1991). The first step in our studies involved finding and designing realistic *business cases* together with representative assignments. The second step in the present study was finding appropriate *indicators* for analyzing and interpreting the cognitive outputs of the participants (see coding procedures below).

3.2.3 Materials

Managerial problem-solving is a complex process with a high degree of ambiguity, since very little information is available to the manager, almost none of which is structured (Mintzberg, 1980). Nonetheless, the ability to cope with fragmented information and unpredictable situations is in fact a core competence of managers (Mintzberg, 1980; Walsh, 1995). We intended to construct realistic case materials with authentic characteristics (Lave, & Wenger, 1991). These case materials should evoke realistic cognitive managerial processes and performance.

To increase authenticity, our case contained both problem-relevant and -irrelevant information to better distinguish experts from non-experts (Boshuizen, 1989). The case did not include false information. The participants' task was to select relevant information, analyze the ill-structured situations, and to identify and solve problems (Leenders & Erksine, 1989).

A case description on organizational development was designed by two university professors in management sciences and two expert management consultants verified whether the case was realistic. The materials consisted of (a) instructions, (b) the case description, and (c) blank pages for the answers of the participants. The case contained only authentic data and events, without interpretations. The case was also free of domain-specific jargon and on the surface-level, understandable for novices. The case-story resembled those found in typical managerial casebooks (e.g., Ashworth, 1985). The business case began with a section in which the leading character is introduced, and the context in which this person is working is described. Next, we presented the reader a set of factual information about the firm (case history, employees, future goals, turnover, etc).

We developed a case 'answer model' in advance, that contained a description of the main problems in the case and a diagnostic explanation. In an ill-structured domain as the management sciences, obtaining a consensus about the correct solution of the business problems is difficult (O'Rourke, 1998). For that reason, two management experts developed several plausible case diagnoses and solution directions (the answer model).

3.2.4 Procedure

We informed the participants that they would get two individual assignments after studying a text. To further increase the authenticity of the case, we restricted the reading time (0.4 seconds per word, i.e. 2.50 minutes for the business case of 426 words). For the *first* assignment, participants were asked to make an analysis and a diagnosis, based on the case information. At this stage, the causes and consequences of the core problems needed to be stated. For the *second* assignment, participants were asked to propose (one or more) advices or 'solutions' for the diagnosed case problems.

3.2.5 Data-analysis

We compared the nine different expertise groups by using ANOVA analysis of variance. As a follow-up test, we used the SPSS procedure 'Polynomial contrast-analysis', to test for trends that can describe the shape of the relationship (e.g. linear or quadratic) between the dependent variables (e.g. knowledge use) and the nine different expertise levels. ANOVA and Polynomial analysis were used to test all hypotheses (except for hypothesis 6, where correlations were used). Another way to look at the relationship between levels of expertise and is to consider the 'effect size' (ES). We calculated the ES as a ratio of explained and total variance. An ES of .2 is considered small, .5 medium, and .8 large.

3.2.6 Coding procedures

We analyzed the 115 case handwritten protocols, as produced by the participants, by considering the number of accurate case diagnoses/solutions, case facts, concepts and inferences.

1. *Diagnostic accuracy*. We defined diagnostic accuracy as the degree of accurately identifying and explaining a case problem in terms of sources and causes.
2. *Case solution accuracy.* We defined case solution accuracy as providing accurate case solutions in terms of advice or decisions that the case company could take for further action. We scored 'accuracy' by giving 2 points for an accurate diagnosis or solution, 1 point for a partially accurate case diagnosis or solution and 0 points for an inaccurate diagnosis or solution. We considered the participants' case diagnoses and solutions as '*accurate'* when the main ideas in the participants' answers matched (for at least ⅔ or more) the model case solutions. We provided the label '*partially accurate'* when the main idea of participants' only partially (between ⅓ – ⅔) matched the case solutions. We labeled participants' case diagnosis and case solution as *'inaccurate'* when the participant's diagnosis did hardly or not (less than ⅓) match with the model case solution.
3. We counted the number of accurate managerial *case facts*, *concepts* and *inferences* as indicators for analyzing the problem-solving exercises of participants. We derived these indicators from earlier studies in expert-novice problem-solving (Boshuizen, 1989; Isenberg, 1986; Lash, 1988; VanFossen & Miller, 1994).

   Case facts. The original case text consisted of case facts only. The number of case facts reproduced in the protocols served as an indicator for the amount of information that participants selected and maintained from the case. The case was split into 107 small, meaningful units, so called *propositions* (Van Dijk & Kintsch, 1983). Similarly, the participants' analysis protocols were split up into propositions and matched with the original case proposition list. This match resulted in the 'facts' score for every participant. We expressed case facts as a percentage of the maximum score of 107 points.

   Concepts. We defined managerial concepts as a class or category of managerial phenomena. We counted the number of accurate management concepts used in the protocols. We considered the use of concepts as an indicator for the possession and use of theoretical discipline knowledge, in the sense of 'characterizing' case information. An example of a managerial concept as used by a participant is: 'this is a *bureaucratic organization*', or 'this is a *manager*'.

   Inferences. Inferences are the outcome of *transformations* on factual information, while applying prior knowledge. By making inferences, concepts and case facts are *related* (e.g. Alexander, 2003), often through (causal) reasoning, which goes beyond the cognitive activities associated with the mere use of concepts. Therefore, we considered inferences as '*dynamical*' knowledge. Inferences were recognized mostly in the form of a conclusion or a summary. An example of an inference is '*The productivity in this company is very high*'. It is based on two original case data facts: (1) The turnover of the company is 150 billion dollars, and (2) the number of employees is 50.

3.2.7 *Inter-rater variability*

We calculated the inter-rater agreement by selecting a series of randomly chosen case protocols (21 protocols, divided between the nine levels of expertise) that were coded by two raters. The correlation between the two raters was sufficiently high (Pearson correlation coefficient = .847; significant at p = .01) to allow a single rater to score the remaining protocols.

3.3 Results

In describing the data in Figures 1-6 below, we will refer to three main stages: (1) formal education, (2) the transition from of the moment of graduation until the first years of experience at the workplace, and (3) the stage towards 'true expertise'. Only statistically *significant* effects found in the data analysis are presented.

3.3.1 *Analysis 1: Accuracy of case-diagnosis in problem-solving*

To assess *diagnostic accuracy*, we considered both *in*accurate and accurate diagnoses produced by all participants.

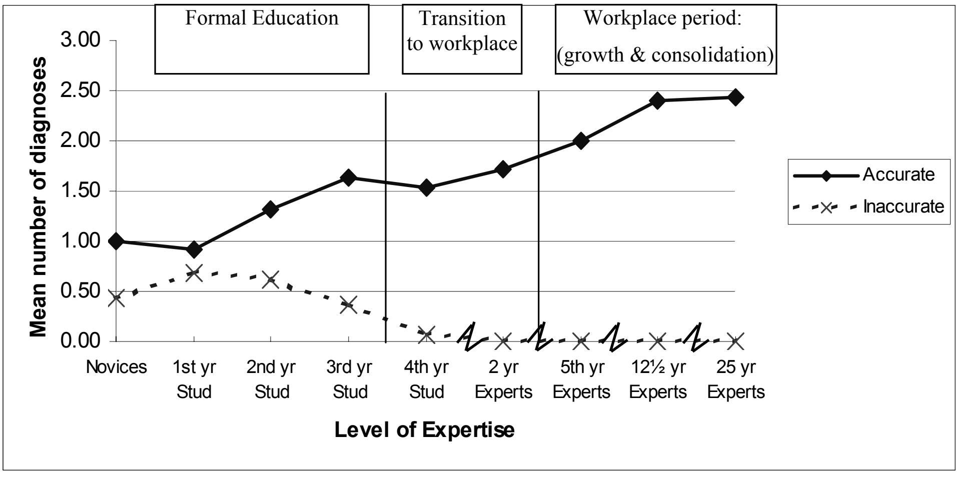

Figure 1: The number of both accurate and inaccurate case *diagnoses* related to level of expertise

Inaccurate diagnoses. Figure 1 depicts the number of accurate and inaccurate diagnoses. Interestingly, only the student groups produced inaccurate diagnoses, while the experts produced solely accurate diagnoses. The relationship between expertise level and making *in*accurate diagnoses was negatively related [$F(8,93) = 3.29$; $MS_e = 0.25$, $p = .003$], (measure of association $r = -.280$). Correspondingly, we found a low Effect Size (ES) of .25.

Accurate diagnoses. We found significant differences between the groups concerning the number of accurate diagnoses [$F(8,91) = 2.22$; $MS_e = 1.12$, $p = .033$. ES = .69]. A significant linear component was found ($p = .001$), indicating that the production of accurate diagnoses has a monotonic increasing relation with level of expertise. During the first stage (of formal schooling), diagnostic accuracy grows rapidly. At intermediate student level and in the transition to the workplace, diagnostic accuracy initially seems to stagnate but is ultimately enforced. During the third and final 'workplace' stage, diagnostic performance seems to reach a maximum. The results of this analysis confirm hypothesis 1: accurate diagnostic performance shows a positive relationship with level of expertise.

3.3.2 Analysis 2: Accuracy and number of solutions provided while solving case problems

Total number of case solutions provided. First, as a *quantitative* indicator of cognitive output, we counted the total number of solutions. We found a significant effect of level of expertise [$F(8,105) = 15.76$, $MS_e = 9.60$, $p = .000$, ES = .94].

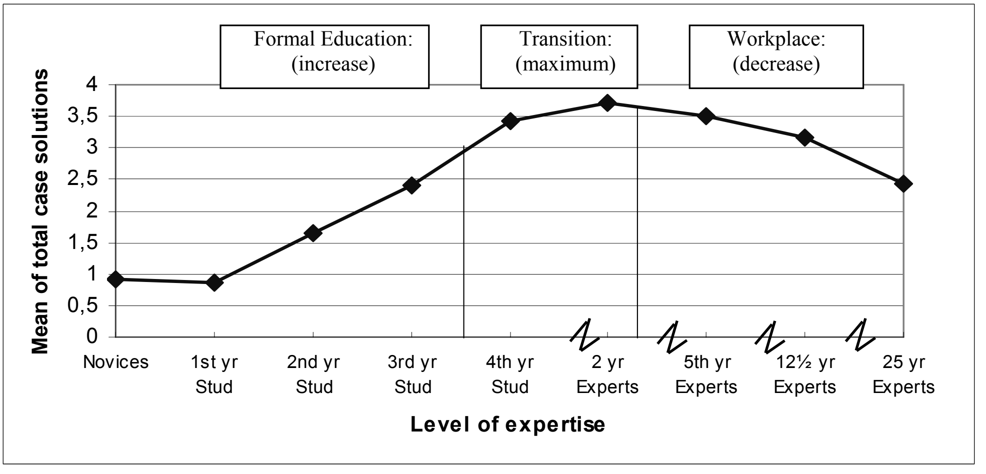

Figure 2: The mean number of total provided case *solutions* as a function of expertise level

Further analyses showed both a significant linear (p=.000) and quadratic (p=.000) component, indicating on the one hand that the output level of experts is *higher* than the novices', while on the other hand that (after two years of graduation) in the transitory stage a *maximum* is reached in the number of solutions produced. Figure 2 shows a rapid growth in the number of solutions produced during the educational period, while as participants gain professional experience, a decrease occurs in the absolute number of solutions provided. Overall, this suggests that the relationship between expertise level and the number of solutions follows an 'inverted U-curve '. Interestingly, the number of solutions provided after 25 years of professional work experience equals the (low) number provided by third-year students.

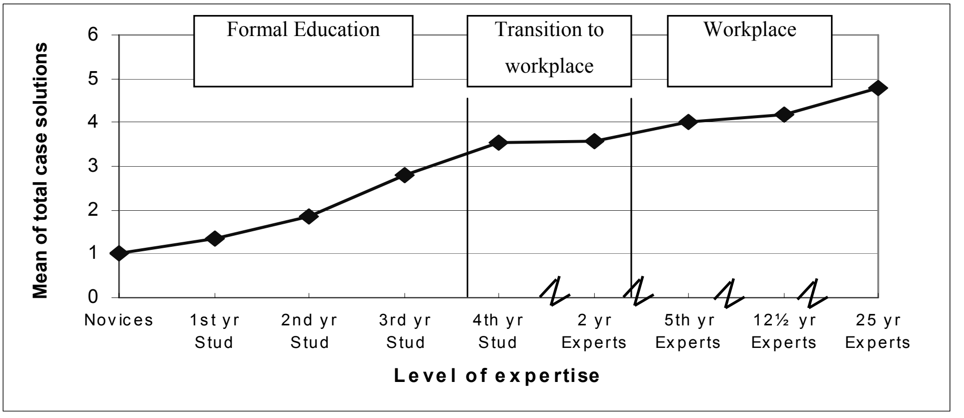

Figure 3: The mean accuracy of case *solutions* as a function of expertise level

'Total accuracy score' of the case solutions. Besides analyzing the *number* of solutions, the *accuracy* of case solutions was calculated by tallying the *weighted* scores. Figure 3 shows that after a period of increase, during the workplace transition a period of confusion seems to occur, after which, the accuracy of case solutions increases again. Where Figure 2 showed a decline in the *number* of solutions during the highest expertise stages, Figure 3 shows a significant positive relationship between the nine levels of expertise and solution accuracy [$F(8,91) = 7.73$, $MS_e = 16.91$, $p = .000$, ES = .89], with a significant linear component (p = .000).

Until here the results indicate that the *accuracy* of solving managerial problems has a monotonic increasing relation with managerial level of expertise (Figure 3) while an analysis on the *quantity* of solutions provided suggests an *inverted U-curve* effect (Figure 2). These data lead to the acceptation of hypothesis 2: *Managerial experts will provide fewer but more accurate solutions than management students.*

Accurate, partially accurate, and inaccurate case solutions. In Figure 3 we have presented the aggregated score of (a) inaccurate solutions, (b) partially accurate solutions, and (c) accurate solutions, in Figure 4, these three solution types are presented separately. We found significant differences between the levels of expertise for (a) the mean number of *accurate* solutions [$F(8,91) = 5.51$, $MS_e = 2.96$, $p = .000$, ES = .98], (b) the mean number of *partially* accurate solutions [$F(8,91) = 6.92$, $MS_e = 4.63$, $p = .000$, ES = .87], and (c) the number of *in*accurate solutions [$F(8,91) = 2.56$, $MS_e = 2.94$, $p = .015$, ES = .72]. Figure 4 shows that progress of these three measures different trajectories. After an initial increase in the number of *inaccurate solutions*, a sharp decline occurs already after the first year in business school. Once participants achieved two years of work experience, no inaccurate solutions were made.

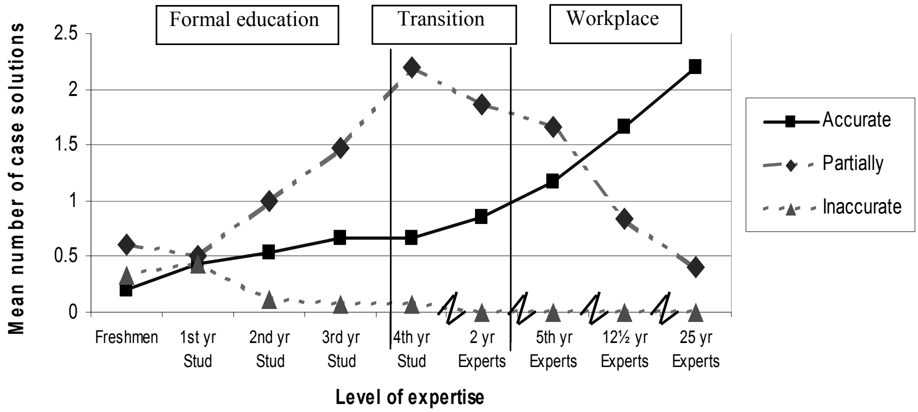

Figure 4: The mean number of a) accurate, b) partially accurate and c) inaccurate case *solutions* as a function of expertise level

The mean number of *partially accurate* solutions grows continuously during the educational stage and reaches a maximum at the graduation level, after which it decreases until, at high levels of experience, the initial low levels are reached again. The significant linear (p = .000) and quadratic components (p = 0.00) describe the skewed, inverted U-shaped relation with level of experience.
The number of *accurate solutions* increases continuously over the three stages (significant linear component, p = .000). Initially, during the educational period improvement is small; the main gain takes place after graduation, while simultaneously the mean number of partially accurate solutions decreases with comparable rate. It seems as if students have to pass through an educational period of making inaccurate solutions before developing better problem solving abilities. And apparently, after graduation participants learn to perfect their solutions, as a *trade-off* occurs between the number of accurate and partially accurate solutions. Finally, after about 10 years of work experience, the mean number of accurate solutions surpasses the number of partially accurate solutions, leading to a stage of proficiency.

Taken together, the results of analysis 1 (on problem diagnosis) and analysis 2 (on solution accuracy) demonstrate that managerial expert-like performance occurs after at least 10 years of work experience. This confirms findings in several disciplines where an expert is defined as someone with at least 10 years of specialized work experience. These results confirm our research question that after more than 10 years of experience, organizational consultants perform at an expert level.

3.3.3 Analysis 3: Information-processing and managerial knowledge use in problem-solving

This analysis aimed at investigating the processing of case facts and the use of managerial knowledge during problem-solving. We counted the *accurate* number of (a) case facts, (b) of managerial concepts, and (c) inferences in the protocols (see coding procedures).

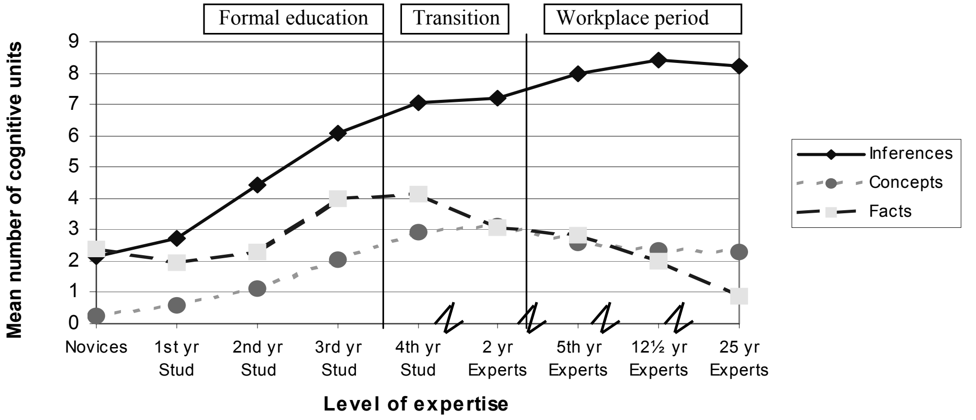

Figure 5: Means of counted case facts, concepts and inferences as demonstrated by participants

Case facts. The level of expertise had a significant effect on the number of accurate case facts reproduced by participants in their case analysis [$F(8,105) = 2.99$; $MS_e = 12.70$, $p = .004$, ES =.75]. We also found a significant quadratic component (p = 0.00), implying that the number of facts reaches a maximum and then decreases. The relationship between the level of expertise and the number of case facts suggests an inverted U-form: after an initial increase, the number of facts reproduced actually decreases beneath the level of intermediate participants. Typically, experts reproduced less factual case information than *intermediate* students, who reproduced the maximum amount of case information.

A more detailed analysis revealed that interestingly, experts rarely reproduced any *irrelevant* case facts. Concerning the irrelevant case facts, a significant effect of level of expertise was found [$F(8,95) = 7.25$, $MS_e = 26.2$, $p = .01$, ES = .87], implying that novices and intermediates selected more irrelevant case facts than experts. Almost all case facts that experts reproduced were relevant case facts. For the *relevant* case facts a significant effect of level of expertise was found [$F(8,95) = 4.47$, $MS_e = 12.3$, $p = .00$, ES = .81]. This demonstrates that experts filtered out most irrelevant case facts. In sum, managerial experts selected more relevant case facts, filtered out more irrelevant case information, and operated more on *relevant* information than lower levels of expertise. The results confirm $H_{3:}$ *Management students will retain (a) relatively more case information and (b) relatively more irrelevant case information than experts.*

Managerial concepts. The level of expertise was also significantly related to the use of managerial concepts [$F(8,105) = 13.23$; $MS_e = 14.28$, $p = .000$, ES = .93]. Further analysis revealed both a significant linear (p = .000) and a quadratic component (p = 0.00), implying that the number of concepts reached a maximum and then decreased. Figure 5 shows that the use of theoretical knowledge (concepts) increases during the first (educational) stage. A maximum is reached two years after graduation, after this transition the number of domain concepts slightly decreases.

Inferences. The number of inferences produced was also significantly related to the level of expertise [$F(8,105) = 26.63$, $MS_e = 69.92$, $p = .000$, ES = .79]. The number of inferences in the problem-solving protocols increased continuously with level of expertise (linear significant component with $p = .000$) implying that the expert groups made significantly more transformations (inferences) than the novice groups. The maximum, revealed by the significant quadratic effect (p = .000), was reached after more than 10 years of working experience. We conclude that demonstrating *dynamical knowledge* develops in a continuously increasing way. This result is in agreement with expertise research in other domains such as medicine and physics (e.g. Boshuizen, 1989; Coughlin & Patel, 1987).

Overall, Figure 5 shows that when participants enter professional practice a transition occurs: it reveals a *decrease* in the number of reproduced case facts at the higher levels of expertise while simultaneously the number of inferences grows. As participants progress towards expertise, focus switches from the *reproduction* of factual information to *transformations on* case information.

Our findings confirm the hypothesis that - during reasoning - managerial experts use less theoretical *discipline* knowledge (H_4), but at the same time demonstrate more *dynamical* knowledge than beginners (H_5).

To assess the role of knowledge in relation to diagnostic and problem-solving performance (H_6), we calculated correlations between (a) the use of different knowledge types, and (b) diagnostic and problem-solving performance (see Table 3) for students and post-graduates separately.

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Table 3: Correlations between managerial knowledge and problem-solving accuracy

		Providing *In*accurate Diagnoses	**Providing *In*accurate Solutions**	**Providing Accurate Diagnoses**	**Providing Accurate Solutions**
Factual case information	Students	-.395**	-.219	.027	.013
	Experts	[1])	[1])	-.233	-.147
Managerial theoretical knowledge (concepts)	Students	-.150	-.417**	.254*	.247*
	Experts	[1])	[1])	.222	.284
Dynamical knowledge (inferences)	Students	-.208	-.416**	.183	.342**
	Experts	[1])	[1])	.235	.407*

** Correlation significant at 0.01 level (2-tailed)
* Correlation significant at 0.05 level (2-tailed)
[1]) Cannot be calculated: experts made too few inaccurate diagnoses/solutions.

Table 3 indicates that managerial knowledge about a task significantly correlates with problem-solving performance on that task. The results indicate that inferences are the most important indicator of managerial problem-solving performance at the expert level. The correlations in Table 3 indicate that knowledge in dynamical mode is needed for providing accurate solutions. Moreover, inferences seem to play a more important role for devising a solution than for diagnosing the problem.

Additionally, we found that the use of theoretical knowledge is associated with problem-solving performance among *students*. Nonetheless, reproducing *case facts* was not associated with problem-solving performance among students. These results can indicate that beginners (students) take up case information but do not process it further for problem-solving.

In sum, the data suggest that both theoretical and dynamical knowledge do play a role in the accuracy of *student* diagnosis and problem solving, while *expert* problem solving reveals a relation with dynamic knowledge use. These results both support and extend hypothesis 6: *An expert's problem-solving performance will be more strongly related to demonstrating dynamical knowledge than to the use of theoretical discipline knowledge.*

3.3.4 Analysis 4: Time used during problem solving

For the time needed to diagnose and solve a problem, we found significant differences [$F(8,95) = 4.40$, $MS_e = 61.34$, $p = .000$, ES = .81] between managerial novices and experts. We only found a significant quadratic component (p = 0.00), implying a maximum, which happened to be at intermediate student level. Figure 6 shows that third-year students used the most time for working on problems, while experts required even less time than novices to diagnose and solve the case. As hypothesized, experts needed fewest time (about half of the time needed by intermediate students) to work on the problem.

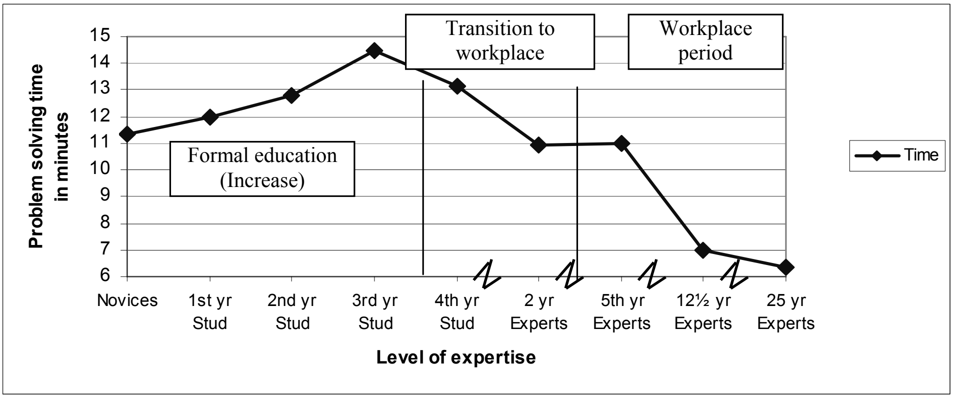

Figure 6: Average time used by the subject groups during case problem-solving

The excessive time used by intermediate students suggests an inverted U-curve relation and requires a reformulation of hypothesis 7 *(The time used during problem solving will show a negative linear relationship with level of expertise*).

3.4 Discussion and conclusion

Our goal was to develop a better understanding of transitory stages in managerial problem-solving, such as the transition from school-to-workplace.

In discussing our findings we will refer to three stages (educational, transitional and workplace) and compare our findings with the Alexander's (2003) Model of Domain Learning MDL.

3.4.1 Accuracy of case diagnoses and solutions

With increasing levels of expertise, we observed a movement from ineffective toward effective working. The high number of low quality solutions ('breadth') that dominates the performance of lower level participants, is making place for few but, high quality solutions ('depth'). In the educational stage, we observed a *quantitative* growth of case diagnoses and solutions.

The transition to the workplace-stage (after graduation) was characterized by '*confusion',* and followed by '*consolidation'*; The analysis of solution accuracy provides evidence that junior-experts encounter an 'experiential shock' in the sense that solving workplace problems requires different thinking and different knowledge than the problems during the educational period. For instance, our study suggests that during formal schooling students learn to diagnose realistic problem situations and to generate *many* solutions (maybe inadvertently as many as possible solutions), but do not learn to choose between these and how to develop accurate problem solutions. Although the formal knowledge that they acquire is a good basis for problem solving, it is insufficient by itself for generating accurate solutions. Once graduates have entered the work force, we hypothesize that they re-organize their knowledge base and re-think their problem-solving behavior, finally leading to 'consolidation'. It is typical in this process of expertise development that one's competence in problem-solving decreases because of increased demands of knowledge integration (Lesgold, Rubinson, Feltovich, Glaser, & Klopfer, 1988). Thus, the transition from school to work is erratic rather than seamless.

A related explanation for this '*confusion stage*' that may occur when graduates enter the work force is that their knowledge base and their problem-solving behavior is influenced by the *socialization process* (Austin, 2002; Heinz, 2002). Graduate students experience several socialization processes *simultaneously*; socialization to the role of graduate student, to the academic life, to the profession; and to a specific discipline or field (Golde, 1998). When new employees pass through a social internalization process, they adopt norms and values of a new group. In this process, graduates often adopt methods of the new workplace context, instead of applying the educational knowledge that they have acquired. This transitional (learning) process is also influenced by characteristics of job-tasks and the labor market (Heinz, 2002). Taken together, this socialization process requires re-organization of the knowledge base of the junior-experts in our research.

Similarly, in Alexander's MDL, the transformation into the second stage ('competency') is also marked by quantitative and qualitative changes in the knowledge base. Knowledge is better organized in scripts and (therefore) better fine-tuned to practical situations. As a refinement we suggest that the competency stage (Alexander, 2003) is characterized by 'confusion, and followed by consolidation' rather than a progress of uniform competency in problem solving. Another refinement of the MDL is that we found that the *number* of case solutions produced follows an inverted U-curve (Figure 2), while we concur with the MDL that *accuracy* of problem-solving progresses in a monotonic way (Figure 3).

In the third *'workplace' stage* our findings show that only after about eight years of work experience, the experts produced more accurate solutions than partially accurate solutions. The ratio between accurate and partially accurate solutions seems to distinguish senior-experts from junior-experts. Therefore, similar as to Alexander's model we entitle our third 'workplace' stage as proficiency or: 'accomplishment of qualitative expert performance'.

3.4.2 Demonstration of theoretical versus dynamical knowledge

We found that while progressing toward the level of experts (at the 'workplace' stage), a shift occurs from the demonstration of large amounts of theoretical knowledge towards the production of dynamical knowledge.

Our results further indicate that the use of knowledge about a task significantly correlates with problem-solving performance on that task. The results suggest that dynamical knowledge is the most important indicator of managerial problem-solving performance at the expert level. These findings indicate that in the managerial area, not (only) domain-independent (generic) heuristics are important (as often argued in this domain) but also that domain-specific managerial knowledge is of crucial importance. We further suggest that *causal* inferences are an important type of inference as we noticed that in our transcripts the inferences were mostly of a causal form.

In the transitional stage, participants demonstrated weak application of knowledge. A possible explanation for this (*transfer)* problem of linking their academic knowledge to the real-life case information is that intermediate students and junior-experts have not enough experience to recognize *which* knowledge is required by practical situations.

Within Alexander's MDL model it is hypothesized that during the *first stage* of domain learning, students possess little, and ill-structured knowledge. It is assumed that students focus on the acquisition and reproduction of knowledge. Our data confirm this idea of knowledge formation by beginners. We add that intermediate students demonstrated many domain concepts, but without appropriately demonstrating dynamic knowledge use in problem solving.

Considering MDL's *second stage*, our data confirm the MDL's view that individuals work toward *understanding* of knowledge. Our junior-experts, having some years of working experience ("competent individuals") demonstrated indeed increased understanding of the managerial domain by making inferences and relating concepts to each other within these inferences. Compared to the previous stage, participants seemed to have made a progression from a focus on reproduction of case facts toward understanding and application of knowledge. From a MDL perspective the conclusion may be drawn that participants develop from a focus on 'breadth of knowledge' towards 'depth' (understanding) of knowledge.

In the *third stage* of Alexander's MDL (proficiency or 'true expertise') the individual is able to derive personalized inferences and new knowledge when encountering problems and deep processing strategies emerge. As predicted in the MDL model, we found that a trade-off has occurred from the demonstration of large amounts of (theoretical) knowledge (at students' level) towards a more effective use of knowledge and toward deep processing strategies such as (personalized) inferences at the senior expert level.

3.4.3 Information processing

The results of the present study on processing 'case facts' suggests that when *all* (both relevant and irrelevant) case information is considered, the relation rather follows an inverted U-curve and that students at intermediate level process most information. Next, towards the expert level, a transition seems to occur from processing as much case information as possible towards selecting and processing *relevant* information. Similarly, in the first stage ('acclimation') of the MDL, individuals will likely experience difficulty discriminating between information that is relevant versus tangential (Alexander et al., 1995). We agree with Alexander et al. (2004) that beginners in a domain process much *irrelevant* information. We propose that the ability of distinguishing high and low critical case information is an important dimension and a possible refinement of the MDL.

3.4.4 Use of time during problem-solving

We found that students at intermediate level used most *time* in solving their cases while experts required even less time than novices to diagnose and solve the case. Below we will discuss the findings on use of time in relation with other indicators of expertise.

3.4.5 The workplace transition

Finally, can we explain the erratic transition from management education to the workplace with our results?

We have found that participants just before and just after the level of graduation: (a) used very much *time* during problem solving, (b) reproduced relatively many non-interpreted case facts, (c) generated most case solutions, while their diagnoses and solutions were moderately accurate, i.e., not yet correct, and (d) demonstrated significant amounts of theoretical textbook knowledge (but were not yet able to make inferences with this knowledge).

The fact that intermediate students reproduced more case information than the other groups may be explained by an excessive selection of (ir)relevant case information. Next we hypothesize that intermediate students perform many (irrelevant) problem solving searches on *both* relevant and irrelevant information (Arts et al., 2000). This process may lead to many solutions and many faults during reasoning (Boshuizen & Schmidt, 1992; Patel & Groen, 1991). Overall, this ineffective process may explain why participants at intermediate levels used so much *time* in solving their cases.

Next to this behavior of intermediate participants just before and after the level of graduation, we observed that younger (novice) students and older experts demonstrated *different* problem-solving behavior. Firstly, we found that participants in the educational stage, (novice) students, reproduced less case information than intermediate students. An explanation is that the knowledge base of novices is limited and incohesive (e.g. Alexander et al., 1995). Novice students simply lack well-organized knowledge and consequently the knowledge structure of novices cannot interpret and retain much information.

Secondly, in the stage of true expertise, our expert groups worked efficiently and effectively: Although they provided a relatively small number of solutions, they made qualitatively better problem diagnoses and solutions than the less experienced groups. One explanation is that experts start reasoning on more relevant information (Arts et al., 2000; Patel & Groen, 1991). Consequently, the experts have fewer solution alternatives, which reduces their *problem space* from the start so that they can concentrate their efforts on fewer solution paths. In sum, this can explain why senior-experts produced only a few but very accurate solutions.

Further, the senior experts made many inferences but demonstrated relatively little use of disciplinary knowledge. As experts' knowledge is better organized (or: better adapted to practical problems, Eraut, 1994) they recognize situations and quickly retrieve *appropriate* knowledge for practical situations. Consequently, they perform very few *ir*relevant searches and save time. Another possible reason why our experts used less time, is that some procedural steps are compiled during problem-solving (Anderson, 1990) skipped or automated. In sum, the reduction in the number of steps used during problem solving and their effective use of knowledge can explain the speed experts are able to achieve.

The idea of 'automation' brings us to a related explanation for the speed of experts that we observed during problem solving. Cognitive research has shown that when managers are unable to *formally* explain certain decisions, often *automated processes* are involved (Morgan, 1997). As such automated processes are often not visible, the knowledge becomes 'tacit' and the process is explained as 'intuition'. Therefore, in our view '*intuition*' is the use of knowledge structures, which are activated in an *unconscious* way (Dreyfus & Dreyfus, 2005). The process of automated *expertise*' (Hitt, Barney, Miller, Zahra, & Govin, 2002) can explain why participants in the highest expertise stages of our research demonstrated little knowledge and worked rapidly during reasoning.

In sum in this study, the experts outperformed all the others (novices, intermediates and junior-experts) by the quality of their solutions, the time needed to perform the task, and the amount of dynamical (applied) knowledge. We have summarized our findings in Table 4.

Table 4: A summary of our findings on indicators of expertise

Problem solving indicators:	**Beginners**	**Intermediate Level**	**Experts**	**Relationship between levels of expertise**
Diagnostic accuracy	Low	Medium	High	Monotonic increasing
Problem solving accuracy	Low	Medium	High	Monotonic increasing
Total number of case solutions provided	Medium	High: maximum	Low	Inverted U-curve
Use of discipline knowledge during reasoning.	Low	High: maximum	Medium	Inverted U-curve
Use of dynamical knowledge	Low	Medium	High	Monotonic increasing
Amount of both (ir-)relevant) case information processed	Medium	High	Low	Inverted U-curve
Strategic information processing ability (selecting relevant information).	Low	Medium	High	Monotonic increasing
Time used during problem solving	Medium	High: maximum	Low	Inverted U-curve

Above, upon the results of this study we conclude the following:

1. The fact that we found indications for several inverted U-curve relations demonstrates that progress in expertise is not so *straightforward* (linear) as often suggested by studies with a dichotomous approach, but a road with ups and downs and trade-offs. For instance, our findings confirm the hypotheses raised by researchers like Boshuizen (2003) concerning *discontinuous* cognitive progress of young employees as they enter the workplace after graduation.

2. Our data show that the path towards expertise in fact cannot be characterized 'in general' but depends on the indicator of expertise that is considered. For instance, problem-solving abilities such as selecting, representing, inferencing and diagnosing) develop in a rather linear way. However, the demonstration of theoretical knowledge did not show a linear path but reaches a maximum at intermediate level. These results support the notion that expertise is a concept with various aspects that develop at different rates. Therefore, several indicators of expertise must be employed (e.g. both knowledge and skills) when studying expertise.

3. Our studies were conducted in the rather young academic domain of management. In this ill-structured social sciences field (Osana, Tucker, & Bennett, 2003), studies on expertise are limited to a few (Arts et al., 2000; O'Rourke, 1998). We conclude that findings on expertise in traditional and 'mature' domains (physics, biology, mathematics) and rather well-structured domains (e.g. medicine) hold for the management sciences. Also, by matching our results with Alexander's model, we (at least) partially validate the MDL's relevance in a heretofore limited explored context, the managerial workplace. Our research results and our refinements on the MDL might be useful for other (ill-structured) academic domains.

4. In this study we employed nine different levels of expertise (divided over three stages). The Dreyfus model employs six levels. For studying and describing future

expertise development in detail, we suggest using at least six or more expertise levels.

5. Lastly, our results demonstrate that managerial knowledge is not static but that theoretical knowledge significantly develops after qualification. These findings support Eraut's (2000) claim that the significance of formal learning is commonly overemphasized.

3.5 Educational implications

Expertise research in general has resulted in few instructional implications (Patel et al., 1999). Investigating different expertise stages may lead to new insights for instruction. Once different stages are identified in detail, educators can adapt a specific learning strategy to each specific stage (Alexander et al., 2004). The present study revealed some major challenges for education related to problem solving expertise: We observed a rather weak use (transfer) of knowledge and ineffective problem-solving approaches by (intermediate) students and junior experts. As nowadays employees gain responsible jobs as early as five years after graduation, how can education address these issues? More *years* of working experience do not automatically guarantee that one reaches expert performance, but rather the *quality* of experience (Ericsson, 2004). Therefore, below we provide some suggestions for enhancing this quality of working experiences and for accelerating expertise.

1. *Feedback from senior experts to stimulate reflection on performance.* Based on empirical evidence, Ericsson (2004) concludes that ideal conditions for improving expert performance are activities such as detailed and immediate feedback on performance. Therefore, for improving and accelerating the (erratic) problem solving performance of recently graduated employees, we suggest more senior expert guidance at the workplace to provide employees *feedback* and *reflection*. Monitoring and reflecting on one's own performance can refine cognitive mechanisms, leading to continuous learning (Ericsson, 2004). Through reflection, tacit managerial knowledge can become conscious (Argyris, 1991).
   For professionals who pursue additional courses after several years of working experience (for instance in the field of teacher education), we suggest that *senior*-experts help them to *reflect* on the (erratic) stages they passed through, and the lessons learned. The transitions presented in this article may stimulate this reflection. We suggest that the senior-experts that guide junior employees have at least ten years of workplace experience in a domain.

2. *Solving problems in different and new* contexts. Bereiter and Scardamalia (1993) distinguish 'routine experts' that are experienced in solving *similar* problems, and 'dynamic experts' who continuously address more challenging problems ('progressive problem-solving'). For acquiring *dynamic* expertise, and for accelerating the quality in expertise development, students and employees should solve atypical, non-routine problems, in different contexts (Bereiter & Scardamalia, 1993).

3. *Improving knowledge use through practical experiences.* We have demonstrated that the balance between theoretical and dynamical knowledge shifted as graduates enter the workplace. As dynamical knowledge is a prerequisite for expert-like cognitive performance, we think that the use of dynamical knowledge needs to be accelerated. A framework for stimulating the applicability of theoretical knowledge into

professional contexts is the *situated learning* theory that emphasizes the importance of a situation (problem context) in which students are learning, and questions the idea of separating learning from practical situations (Lave & Wenger, 1991). An implication of this theory is that (a) we should either send students more to practice (e.g. apprenticeships), or (b) that we should bring more 'practice' into education.

Examples 'learning in practice' include '*dual learning'* and '*action learning'*. Dual learning implies that students divide their time between school and work such that knowledge acquired in a school context can be readily applied to a professional situation, and vice versa. Action learning involves real-life structured projects in organizations ('learning by doing') rather than performing projects in traditional classroom settings (e.g., Revans, 1980). Such approaches can circumvent the time delay between theoretical knowledge acquisition and knowledge application. Another approach is to "bring the workplace" in the context of professional curricula, for example by enhancing the *authenticity* of assignments and of the learning environment (e.g. Arts, Gijselaers & Segers, 2002; De Grave, Boshuizen, & Schmidt, 1996).

Nowadays, many institutions for higher education use educational approaches based on specific workplace problems (such as case-based or problem-based learning). Such educational approaches assume that knowledge acquired during formal schooling will be readily accessible and applicable in the workplace. However, transfer of knowledge does not occur spontaneously (Bereby-Meyer & Kaplan, 2005) and our work supports the claim of Eraut (2004) that the transfer of knowledge from to the professional workplace is more complex than just applying knowledge to another context. Therefore, Patel et al. (1999) argue that education should go beyond the acquisition and use of formal knowledge and that formal education should include '*professional actions*' like selection of relevant cues, evaluation of context information, and assessment of courses of action. Linking formal knowledge with practical contexts can only be effectively carried out, when appropriate situations resembling the workplace have been experienced. We suggest that education engages students in *similar* cognitive activities as required at the workplace.

4. *Acquiring meta-cognitive strategies*. Students are often not automatically equipped with metacognitive or self-regulatory strategies (Alexander, 2003). With the results of the present study, we support the claim of Alexander and Judy (1988) that - when students are left to their own devices - strategic processing will often be ineffective and inefficient. Therefore, we suggest that meta-cognitive strategies are acquired and practiced in early educational stages.

3.5.1 Limitations and future research recommendations

Further research can examine whether our findings in the managerial sciences can be cross-validated in other (academic) domains, especially in professional domains with a strong diagnostic orientation such as the health sciences or law.

For the present study a *cross-sectional* design was necessary for investigating a large range of expertise levels. We recognize that with a cross-sectional design, we must be cautious in translating the results into 'developmental lines' over time. A research suggestion is to conduct a longitudinal study examining cognitive changes over a short period of 2-4 years (for instance with a focus on the school-to-work transition). This may allow researchers to follow individuals from of graduation until the first years in the work force. Such a longitudinal study could provide more detailed information on individual trajectories.

Finally we emphasize that expertise cannot be fully understood if disconnected from factors such as personal interest, goals, attitudes, or beliefs (Alexander et al., 2004) and social aspects. For future research we suggest to link the results of our study with these factors. An example of such research is investigating the influence of personal goals, interest and/or group problem solving on the quality of reasoning and problem solving.

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CHAPTER 4: COGNITIVE EFFECTS OF AN AUTHENTIC COMPUTER-SUPPORTED, PROBLEM-BASED LEARNING ENVIRONMENT[3]

4.1 Introduction

In the workplace of the 'Age of the Mind' (Heilprin, 1989; Todd, 2000), knowledge becomes the major force in society. In order to be successful in today's dynamic and competitive society, the use of existing knowledge and the development of new knowledge becomes a prominent prerequisite for solving the complex problems which are faced. Accordingly, working in teams supplants working alone. For education, this implies there is a growing need for graduates who are able to reason with and apply knowledge to efficiently identify and resolve complex problems (Segers, 1997; Tynjälä, 1999). Additionally, functioning as part of a team and working together to keep knowledge up to date is considered to be another key issue in education (Hmelo & Evensen, 2000).

In order to cope with societal challenges and their educational implications, the use of problem-based learning approaches in higher education has been promoted by many educators (Bowden & Marton, 1998; Taplin & Tsui, 1999; Tynjälä, 1999). In general, PBL refers in many ways to contextualized approaches of instruction, which take on different forms and are used in different domains (e.g., Williams, 1992; Wilkerson & Gijselaers, 1996). In PBL, it is essential that a problem initiates free inquiry by students working together in a group (Barrows & Tamblyn, 1980). PBL creates opportunities for students to work in groups to seek and acquire knowledge for problem solving, based on the use of authentic problems. To realize the full potential of PBL, teachers and course designers grounded their educational development in modern constructivist theories (Savery & Duffy, 1995; Tynjälä, 1999), or in research on collaborative learning (e.g., Slavin, 1997).

Nevertheless, up-to-date comparative research on the effects of PBL on learning outcomes does not present conclusive results (Hmelo et al., 1997; Norman & Schmidt, 2000). On one hand, empirical research on the effects of design variables in PBL curricula suggests some explanations of these results (Gijselaers & Schmidt, 1990). Additionally, as Koschmann et al. (1994) suggest, the way in which problem-based learning is implemented in various studies can itself produce a number of new issues and challenges. On the other hand, there is plenty of research on co-operative learning which offers insights into the different aspects of the social dimension of learning environments such as PBL. Using this research as background, a number of design variables for optimizing a PBL environment can be formulated. The present study explores to what extent a redesigned learning environment, taking into account these design variables, enhances cognitive learning outcomes, when compared to a regular PBL environment.

To date, only a few theory-grounded course intervention studies, measuring cognitive outcomes within a PBL context, have been carried out (Norman & Schmidt, 2000). The majority of them only investigate the effects of the manipulation of a single course element. Research, however, suggests strong interrelations between different learning dimensions (Brown, Collins, & Duguid, 1989; Kirschner et al., 2001; Williams, 1992) that may affect various outcomes of PBL, making it difficult to interpret outcomes unambiguously. The present study can be referred to as a 'design experiment' (Brown, 1992) as it is an attempt to explore cognitive effects as a result of a coherent set of changes (in the task, control and social dimensions of a PBL environment). The central idea in design experiments is to capture the design process of creating and evaluating an innovation in education by uniting cognitive research and concurrent design of learning technologies.

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[3] Published in: *Instructional Science, 30*, 465-495.

4.2 Research on the effects of design variables in PBL curricula

PBL, as initially developed by Barrows and Tamblyn (1980), typically involves students working on problems in small groups of five to twelve, with the assistance of a faculty tutor. Problems serve as a starting point for new learning activities. The analysis of these problems results in the acquisition of knowledge and of problem-solving skills. Problems are encountered before all relevant knowledge has been acquired, rather than after reading texts or attending lectures about the subject matter underlying the problems. This feature reflects one of the essential distinctions between PBL and other problem-oriented methods (Albanese & Mitchell, 1993). The teacher, called the tutor, coaches the group by monitoring the group process and helping the students to identify the knowledge which is needed to resolve the problem. The learning process starts with a preliminary analysis of the problem, based on the students' prior knowledge (the problem analysis phase). It results in the formulation of the students' learning goals or of the unexplained issues which students need to investigate during self-study before follow-up meeting(s). After completing the problem-solving cycle, students will start to analyze a new problem, again following the described problem solving procedure (e.g., Williams, 1992).

Over the past few years, empirical research has been conducted to identify effective design variables in PBL environments. Basing their studies on empirical work, Gijselaers and Schmidt (1990) attempted to identify a set of key variables in PBL that explain cognitive and motivational learning outcomes. These researchers identified three main input variables: the quality of PBL-problems; student characteristics; and the skills of the tutor. These three variables influence the tutorial group process, which in turn directs self-study, resulting in cognitive and motivational outcomes. The model of Gijselaers and Schmidt (1990) demonstrated the importance of problem descriptions and social interaction for determining students' behavior and learning outcomes. More recent empirical studies, using causal PBL models, have led to similar conclusions. Schmidt and Moust (2000), for instance, showed that, apart from the social functioning of the group, the quality of PBL-problems substantially affects the amount of self-study that is needed and the level of the students' interest. These researchers concluded that problems seem to influence almost all aspects of learning and are, therefore, central to learning in PBL curricula (Schmidt & Moust, 2000).

In analyzing curricula from a theoretical point of view, researchers cast social and task related aspects in a similarly prominent role. Based on the implications of research into learning and instruction, researchers such as Brown et al., (1989), Kirschner et al. (2001) and Williams (1992) have unified various key instructional design variables into coherent instructional design frameworks. These frameworks generally contain three dimensions that can be manipulated in order to influence cognitive outcomes: the task, control, and social dimensions. They are relevant tools for the analysis of PBL curricula.

In this context, the task dimension includes instructional methods, which can be divided into: instructional (problem solving) procedures; problem descriptions; and information and data sources. The control dimension refers to the degree to which individuals can control learning in terms of influencing content, path, pace, instructional difficulty, and feedback (Barrows & Tamblyn, 1980; Kinzie, 1990). The social dimension refers to collaborative aspects of PBL, or the ways that students interact together and with their tutor.

Apart from these studies, research which has explored models of effective design variables in PBL environments has primarily investigated single variables within the task, control, or social dimensions. Their results indicate potential improvements which could be made to PBL environments.

4.2.1 The PBL task dimension

In the problem analysis phase of PBL problem solving procedures, students brainstorm about a variety of potential explanations for phenomena or problems. It is assumed that, in explaining these phenomena, it is important for students to carry out a thorough problem analysis in order to elaborate on their prior knowledge. Elaboration on prior knowledge (such as exchanging ideas, answering questions and giving explanations) will lead to better knowledge structures, resulting in better understanding and recall of knowledge (Anderson, 1990).

The research of De Grave et al. (1996), however, indicated that in several PBL curricula the brainstorming phase is poor and/or short, resulting in one single problem explanation. The fact that explanations are often not provided, or compared, leads to a rather poor or superficial problem analysis phase, with few elaborations (De Grave, 1998). Additionally, deriving a hypothesis at a too early stage can result in prejudices or misconceptions (Barrows & Tamblyn, 1980). Houlden et al. (2001) described typical behavior of students in PBL-curricula in terms of rapidly focusing on the solution or 'right answer'. The emphasis in PBL is, however, not necessarily on solving the problem, but rather on analyzing and explaining the possible causes and characteristics of a phenomenon (Hmelo & Evensen, 2000), and the underlying principles. Such learning requires that explicit attention needs to be paid to abstracting knowledge, making generalizations from the problem and reflecting on the problem solving process to understand when the learned knowledge can be applied (Salomon & Perkins, 1989).

How can the problems related to a poor brainstorming phase be explained? Oliver and Omari (1999) argued that one explanation of a short pre-discussion in PBL curricula can be found in the problem descriptions that are used. They stated that problem selection appears to be the most influential component of the learning activity. The fact that students are initially only exposed to a short problem description tends to limit their ability to work in a meaningful manner with this information. The idea of having limited information can therefore limit working with, and understanding of, that information (Oliver & Omari, 1999). Following these arguments, the level of the pre-discussion can possibly be enhanced by offering more information, or by embedding more cues in a problem as a starting point.

Authors like Brown et al. (1989) and Williams (1992) have argued that authentic problems and case descriptions may provide a meaningful context, which may resemble future professional situations. An important implication of learning in authentic contexts, which offer relevant professional situations, is that this can foster the transfer and application of knowledge (Brown et al., 1989). In a review of small group learning, Cohen (1994, p.3) concluded that 'the relation of the total amount of interaction within a group and achievement differs according to the nature of the task'. Highly structured and closed tasks, which have one fixed answer, lead to low group productivity. By contrast, ill-structured and complex tasks provoked extended elaboration among group members and were associated with 'higher order' conceptual learning. Cohen (1994) concluded that this may be achieved by confronting small groups with ill-structured, complex problems.

Another aspect is the authenticity of the delivery format of problem descriptions. Hoffmann and Ritchie (1997) criticized PBL courses that strongly rely on written problem descriptions and learning resource materials on paper. In their view, transfer between the problem situations presented in a course and similar ones in real life may be adversely affected (Hoffmann & Ritchie, 1997, p.100). Bransford and Schwartz (1999) made similar comments when noting that sole reliance on written cases or verbal vignettes may have dysfunctional consequences for the learner in professional practice. For example, a business consultant who is solely trained in analyzing written business cases may be ineffective when working in real business practice. Multimedia can, therefore, provide a valuable contribution by offering realistic contexts which contain complex, authentic PBL problem situations (Hoffmann & Ritchie, 1997).

Although problem descriptions are generally considered to be a crucial PBL variable, not much empirical research to date has been carried out on the relationships between the characteristics of problem descriptions and the resulting cognitive outcomes. However, several authors have attempted to develop rules for effective problem formats from a theoretical viewpoint (Barrows & Tamblyn, 1980; Savery & Duffy, 1995), or from an experience-based viewpoint (Gijselaers, 1996; Stinson & Milter, 1996).

Gijselaers (1996) identified several problem formats that he considered to be ineffective. In his view, problem descriptions that include questions for students to answer stimulate them to substitute answering these questions for elaboration on their prior knowledge, resulting in non-productive brainstorming. Using a title for the problem assignment that is similar to the title of chapters in a textbook, or which indicate the assigned readings related to the problem, also leads to poor problem analysis (Savery & Duffy, 1995). If (due to these cues) all students study identical literature and come up with similar analyses, this does not foster a rich problem analysis, which is one of the goals of PBL. The characteristics discussed by Gijselaers (1996) and Savery and Duffy (1995) can be summarized as pre-structured PBL problem descriptions, providing students with too much direction and pre-analysis. Such problem descriptions violate the basic requirements that social learning in groups is associated with ill-structured problems (Cohen, 1994). Savery and Duffy (1995) argued that students need to be engaged in authentic learning activities by confronting them with problems that do not contain pre-specifications. Authentic learning requires, for instance that, as in business practice, students encounter ambiguous data in need of interpretation. When problems already contain obvious conclusions and interpretations, no authentic thinking will occur. Stinson and Milter (1996) made similar arguments, contending that good problems should mirror professional practice, be ill-structured, and contemporary, in order to initiate productive group sessions. In conclusion, effective problem descriptions should be authentic as the use of relevant authentic problems can foster higher order reasoning skills, relevant for practice.

4.2.2 The PBL control dimension

In discussions about the effectiveness of the PBL system, control in PBL environments is gaining more attention (e.g., Albanese, 2000; Vermunt & Verschaffel, 2000). Cognitive researchers have argued that a certain degree of learner control is an essential aspect of effective learning environments (Kinzie, 1990; Vermunt & Verschaffel, 2000; Williams, 1992). The claimed effects of a higher degree of student control (instead of teacher/program control) are intrinsically highly motivated students and more active and autonomous students.

In order to effectively exercise learner control, students should be able to handle autonomy and should possess self-regulation skills (Kinzie, 1990). The study of Vermunt and Verschaffel (2000) about dimensions of student control in learning environments was a case in point. They argued that effective educational systems should gradually offer higher levels of control over the process of learning to students. This implies that effective educational systems provide mature (graduate) students with a higher degree of control than is given to novice students. The researchers further argued that an important control dimension is the degree of 'independent student learning', expressed by all kinds of activities that students carry out by themselves. They described the degree of students' 'independent learning' in PBL settings as high when compared to traditional, lecture-based systems. But when compared to PBL practice, the degree of ownership over the problem and the degree of independent learning is not always developed at an optimum level (Vermunt & Verschaffel, 2000). However, as PBL is implemented in various ways, taking different forms of instruction (e.g., Albanese & Mitchell; Williams, 1993), the degree of student control is also dependent on the way PBL is actually implemented.

Offering more student control is related to the degree of scaffolding (Greening, 1998) and can be expressed by more freedom in the choice of problems, learning-goals, literature and by working more independently from a tutor (Vermunt & Verschaffel, 2000). Authors like Kinzie (1990), Savery and Duffy (1995) and Williams (1992) have expressed similar ideas. Savery and Duffy argued that with authentic problem tasks, a learner should have ownership over the process of problem solving, the problem itself and the learning goals. One way of enhancing ownership is to stimulate students in initiating problems themselves, so that the learner adopts the problem generated as their own (Savery & Duffy, 1995). When students are able to work independently, less scaffolding can be provided. Essential is that optimal levels of challenge (and motivation) in a learning setting are maintained (Greening, 1998). A question that arises is whether students who are working independently and who have more control over the learning process are able to find out for themselves what it is important to learn from PBL problems. A study by Duek et al. (1996) showed that, in a PBL context, second year students who independently met in teams, without their tutor, for the problem analysis, still identified the most important learning objectives, when compared with tutor guided groups. This study demonstrated that second-year students who gained more control over their learning process were at least as effective in identifying learning issues as PBL students who were given less control.

4.2.3 The PBL social dimension

Nowadays, there is a general belief that working in collaborative settings can enhance the learning outcomes of instructional settings (e.g., Slavin, 1997). Research has been conducted on the effects of Collaborative Learning (CL) when compared with individual learning, the effects of group size, and the effects of the use of computers to support the collaborative process.

Review studies of the research on the effect of CL offer major insights: solving learning tasks or problem assignments together with fellow students, rather than in individual situations, has positive effects on student achievement (e.g., Johnson & Johnson, 1989; Slavin, 1997). Researchers like Webb (1992) add that positive learning results of CL depend on the conditions (such as group size) under which CL is implemented (Webb, 1992).

In addition to the effects of collaborative settings, Qin et al. (1995) found that learners who are solving problems in collaborative settings with a common (shared) goal will exchange ideas and correct each others' ideas more frequently and effectively, compared to settings where individuals compete with each other. Research on team processes has consistently shown that the extent to which team members have to rely on each other and must communicate with each other is central to the development of shared goals and shared knowledge (Brannick et al., 1997). The question may be raised as to whether the social and cognitive conditions for PBL groups will result in increased awareness of the importance of sharing knowledge as a strategy for coping with problem materials.

Research by De Grave (1998) on group processes in PBL showed that problem analysis by a group, when compared with individual problem analysis, only had a slightly beneficial effect on remembering problem-related text information. When he tried to explain his research results, De Grave hypothesized that interaction in a group can also have a negative effect on achievement. Research on brainstorming by McGrath (1984) showed that indeed group interaction can have negative effects on the generation of ideas. Individuals not only generate many more ideas, but these ideas are more creative (diverging) than those produced by groups, when intellectual task outputs are considered (McGrath, 1984). Nijstad (2000) argues that, during a brainstorming phase, group members can even disturb individual ideas. The ideas of individual group members should therefore be used at the moment that they have finished their thinking (Nijstad, 2000).

ICT programs can provide help in exchanging information at the moment that individual brainstorming is finished, as such media can be used at any moment. When personal thinking has finished, asynchronous media such as mail and discussion lists can therefore facilitate the process of using the ideas of other group members (Whithworth et al., 2000).

Research on brainstorming with computers shows similar results to the studies above. For instance, when comparing face-to-face group interaction with separate brainstorming through computers, Whithworth et al. (2000) argued that face-to-face group interaction is less effective as it generally leads to a gain in the absolute number of 'common' ideas, but a loss in the number of different (divergent) ideas.

Group size is another variable that may affect the PBL process. Research into learning in very small student groups has demonstrated that in general these groups allow not only more intensive, but also more equal opportunities for participation, along with better monitoring of student progress (e.g., Keller, 1983). If students meet together in a small group face-to-face setting to discuss about the ideas generated, then what is an optimum size? According to Lohman and Finkelstein (2000) research suggests that very small student groups (three persons or less) achieved learning outcomes more effectively than medium or large groups. According to Kagan (1989), the ideal number of group members is four, as a higher number of group members tends to lead to greater possibilities of non-participation and 'group production losses'. An example of a 'group production loss' is the time needed for coordination. Oliver and Omari (1999) found similar results. In performing an experiment with small teams in a PBL-setting, they found that five students were too many to enable the members to share and work together, as these groups tended to leave one member overworked. As a result of natural attrition, the groups of three students often became two group members, who were then overworked. The researchers concluded that small teams tend to be most effective when group size is four (Oliver & Omari, 1999).

Research into the effects of Collaborative Learning (CL) supported by computers is mainly dominated by Computer Supported Collaborative Learning (CSCL) research, which investigates technology driven collaborative settings. Research suggests that computer technology increases opportunities for social interactions (Hoyles et al., 1994). The cognitive effects of CSCL environments are often related to the acquisition of higher cognitive skills. For instance, in an overview of CSCL studies, Hoyles et al. (1994) reported that collaborative, computer based tasks lead to higher order thinking. Lehtinen et al. (1999) concluded, in a review on the effects of CSCL environments, that although results were not conclusive, there were a number of experiments which showed the positive learning effects of CSCL, particularly in higher order cognitive processes and skills that are related to information handling (Lehtinen et al., 1999).

Pinsonneault and Kraemer (1989) found that both synchronous and asynchronous systems have the potential to increase a group's depth of analysis of problems, and the quality of decisions, when compared to face-to-face collaborative situations. In general, synchronous systems increased consensus in decision-making and asynchronous systems tended to increase the total group effort (Pinsonneault & Kraemer, 1989).

Oliver and Omari (1999) investigated a problem-based learning environment in which students worked with online learning technologies. Their study provided interesting additional insights concerning the impact of learning technology on the productivity of PBL environments. Students were put into small teams of four or five to work on the analysis of, and solutions to, problems. Internet was used for the presentation of ill-structured problems and to provide access to multiple sources of information for the problem solution. Web technology also offered students communication possibilities by allowing them to post problem solutions within a team, or for others, on a public bulletin board. Finally, within the web environment, students could exchange relevant Internet addresses (URLs) for others to use in their inquiries (Oliver & Omari, 1999). Student responses in their study indicated that the innovative learning environment 'had a substantial impact on students learning and problem solving' (Oliver & Omari, 1999).

These recent studies provide evidence that it is reasonable to expect that students' progress in PBL environments is affected by group size, working procedures, and the use of technology.

4.3 Design variables in PBL environments

Based on the results of the studies described, a number of instructional design implications can be suggested for the task, control and social dimensions of the PBL environment.

The task dimension:

- Students should be stimulated to perform a more thorough problem analysis in a setting that leads to more than one (diverse) problem explanation;
- The use of authentic (ill-structured, non contrived) problem descriptions and data sources, embedded in a real-life context, can lead to extended elaboration on problems (Cohen, 1994) and therefore stimulate the problem analysis;
- The reflective process of deriving generalizations and making abstractions on the knowledge studied can be more stimulated;
- ICT can be useful in offering students ill-structured, authentic case materials in multi-media formats.

The control dimension:

- The degree of learner control should be adapted to the maturity of the students;
- Learning control can be managed by offering students a setting for independent learning with freedom in time and place and responsibility for solving problems;
- Guidance and scaffolding through ICT tools can optimize the tutor's role as facilitator of the learning process.

The social dimension:

- The process of generating ideas or explanations should be carried out by individuals working on their own. The ideas generated can then be discussed in small teams of about four persons, instead of in relatively large tutorial groups;
- After the individual brainstorming is completed, ICT programs can provide help for exchanging ideas and with problem analysis;

The small teams that are created should work with a shared goal and have responsibility for a common product.

4.4 An innovative learning environment: problem-based, with authentic learning materials, small team collaboration, and technology rich

This section contains a description of a modified PBL course, based on the instructional design variables proposed. In the academic year 1999-2000, a regular marketing course at the business school was redesigned in the three previously discussed cardinal dimensions (task, social and control). This new approach was called 'Authentic Learning Environment' (ALE) and was compared in an experiment with a regular (control) PBL setting. In summary, firstly the authenticity of the PBL problem situations was enhanced: ill-structured problems and real-life data resources were used, coming from real companies. Secondly, the students' method of social collaboration was adapted more closely to teamwork in business practice. Apart from during regular PBL tutorial meetings, students worked in small teams of four persons. Thirdly, students were provided with more control over their learning activities as they worked in self-steering small teams, more independently from their tutors.

In designing this ALE, we departed from the standard PBL protocol that most courses at the Maastricht business school usually follow. In the standard protocol, students have two formal meetings with each session lasting for two hours. A tutorial group consists of about 14 students. A tutor coaches each group of students, a student chairperson hosts the discussion and a student secretary minutes the meeting. A typical course has about 200-400 students: hence there are about 20 to 30 tutorial groups.

4.5 The ALE Task dimension: authenticity of the learning materials

4.5.1 The problem tasks

In many PBL courses at the Maastricht business school, students are offered problem descriptions that contain rather limited information, next to many cues that provide students with hints for problem analysis. However, looking at the real life of business, graduates must be able to determine what information is needed for problem solving and interpretation of information (Stinson & Milter, 1996). Therefore, in the ALE, the students were offered a problem description and, at the same time, additional authentic business information. Both provided a larger context for brainstorming on problems than the regular PBL problems, with a pre-structured problem description and structured written company information being available after the students brainstormed on the small problem description. The real-company information used in the ALE setting contained non-interpreted sections of annual reports, authentic pictures, internal management presentations and company product information. The company materials were not adapted for educational use. This kind of information allowed students to simulate the real-life process of identifying problems from ill-structured data and required them to use cognitive activities, as in professional practice. In offering these rich problem contexts, computers can be an aid (Koschmann et al., 1994). In business practice, most information is in electronic formats, available from the intranet or Internet, making use of a variety of media such as databases, presentations, commercials, etc. Therefore, in the ALE, authentic company material was offered in a multimedia format via a CD-ROM. Additionally, in the ALE, the use of Internet for searching for resources was an integrated part of education.

Savery and Duffy (1995) argued that for fostering transfer, students should encounter examples of problems from diverse categories and apply knowledge in a variety of situations. On this point, Norman and Schmidt (2000) added that learners should be trained in identifying the features that discriminate an example of one class from another. Therefore, the ALE consisted of 'sidebar' information about various companies which was related to the concepts to be learned in the main problem of that week. Students had to relate the main problem of the company under study (on CD-ROM) with an additional company problem, found on Internet. For instance, globalization issues concerning L'Oreal were related to globalization issues concerning McDonalds. This comparison was intended to stimulate multiple views on business concepts and to detach and abstract knowledge acquired from one specific case, in order to stimulate transfer. In both the ALE and the regular PBL setting, students worked during one week on one business (marketing) theme on the basis of two problem descriptions.

Figure 1 shows one of the screens of the ALE course materials. It shows a problem situation, as presented in the first week on the subject of globalization, the additional company data available (links to 'consumer information', 'company research 1' etc), and a link to the (contrasting) McDonald's case on Internet. The data available are only partly relevant for the linked problem situation. It is students' task to select and interpret relevant information, as in a typical authentic activity.

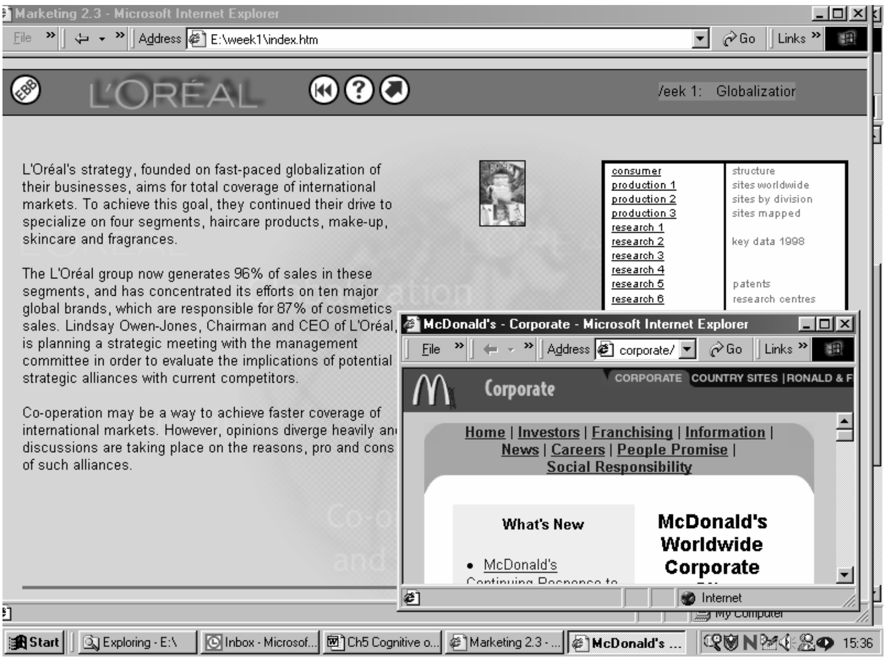

Figure 1: An illustration of a part of the authentic, multimedia company materials

4.5.2 The problem solving process

In order to improve the problem solving process within the ALE, an adapted problem solving procedure was implemented.

The brainstorm phase starts with individual preparation, followed by a discussion in small teams (three to five students), carried out face-to-face and/or via electronic communication tools. The meeting in small groups was intended to allow the exchange of ideas and to enrich the problem analysis. As the members of these small teams all performed their brainstorm separately, it was assumed that this method of problem analysis would lead to more diverse problem explanations than a problem analysis in one large group. As an outcome of the brainstorm phase, the student teams were asked to schematize their analysis of the business case study information on a form (see Figure 2).

Form for the problem 'Pre-analysis' *"For analyzing all problem situations, perform the following steps":*
1a Derive problem statements: → Identify problems or phenomena in the problem situations and in the case information. *Example: Firm x is not big enough to invest in country y.*
1b Provide relevant facts: → Provide factual evidence (symptoms) supporting the problems perceived. *Examples: 1. The sales of shampoo x are very low. 2. The turnover of unit A is high.*
2 Brainstorm about the explanation of the problem: → Give *tentative* explanations (hypothesis) for the problems found in the case information. Use your prior knowledge. Provide *more* than one tentative explanation for the problems found. *Example: Firm x is too small to be able to invest. The company is not specialized enough.*
3 Define learning goals: → Formulate learning goals for the phenomena you can not explain. *Example: What kinds of strategic alliances exist?*

Figure 2: The form the teams submitted to their tutor containing the results of the pre-discussion.

The form in Figure 2 was designed in such a way that students were forced to focus thoroughly on the problem analysis, not on solutions. The purpose of this structured format was to encourage students to state some explanations (causes) for problems, to explicate their arguments, and to formulate learning goals. The form was mailed to the tutor, who checked problem explanations and verified whether major goals were formulated. After revising the problem analysis, the tutors provided feedback by e-mail. After receiving the tutor feedback, students were expected, if necessary, to further reflect on their problem analysis and explanations. Next, the tutor brought together the results of the separate small teams and returned it as one integrated document to all teams, in order to stimulate the idea of multiple perspectives on a problem explanation. At the time when the small teams received the results of the pre-discussions of the other teams, all teams were assumed to be converging in the problem solving process. On the basis of this initial problem analysis process and the learning goals formulated, the students studied literature and prepared discussion points for the next meeting. In the mean time, students in the ALE, as in the regular (control) setting, all attended a lecture where they had the possibility of interacting with speakers from businesses. Next, the ALE students' answers to the learning goals were discussed during a tutorial meeting, which took place in a regular PBL setting. In this meeting, the members of the various small teams came together, into a group of about 14 members. In this meeting, the various student teams presented their findings to the whole group for discussion. The students also considered the discussion points that they had prepared. An example of a discussion point was: 'How does a different (competing) company cope with the phenomenon discussed?' The discussion points had two main purposes. Firstly, learning goals in a post-discussion (in the PBL reporting phase) are normally focused on explaining concepts that have arisen from the literature. The discussion points were, however, meant to go beyond comprehension of knowledge in order to bring the discussion to a more general level. For instance, the discussion points highlighted the differences and links between two course themes. Hence, the discussion points aimed to foster reflection through abstraction and could be considered as an important link at the end of the PBL learning circle to integrate more deeply the strategic use of the knowledge acquired. Secondly, discussion points were intended to foster the application of knowledge in contexts other than the current problem situation. For instance, students derived implications of phenomena studied for companies other than the one in the actual problem under study. Figure 3 shows the activities of students in the ALE setting, as compared to the regular PBL-setting.

	ALE	Regular PBL
Monday	• Small students teams meet face-to-face and/or on the web for the pre-analysis of the case information	• Regular tutorial group meeting under supervision of a tutor
Tuesday	• Student teams hand in a 'pre-analysis form' and receive feedback from their tutors	• Individual self-study
Wednesday	• Self-study for the Thursday discussion (individual or in collaboration with team members) • Lecture • Preparation 'discussion points' for the Thursday post-discussion	• Individual self-study for the Thursday preparation • Lecture
Thursday	• Regular tutorial group meeting in presence of the tutor (post-discussion of 2 problems)	• Regular tutorial group meeting in presence of the tutor

Figure 3: Activity schedule in the ALE compared to the regular PBL-setting

4.6 The ALE control dimension

In the regular PBL setting, the problem analysis is carried out within a fixed time span, at a fixed place, under the guidance of a tutor during all meetings. Students receive feedback from both their peers and their tutor during problem analysis in their tutorial group.

One purpose of the ALE was to provide students with a higher degree of student control related to aspects such as contents, instructional path, pace and feedback. This was addressed in different ways.

Firstly, when analyzing the problem situations and company information, the student could make decisions about which parts of the interactive material to use and to manipulate electronic (Internet) sources. The control of the learner over the company materials was facilitated by using electronic information with a non-linear hypertext structure to give access to all the case information. This implied that students had control over the sequence of the information, as the paths through the company information were non-linear (Reeves, 1993).

Secondly, the degree of control by the tutor was adapted, when compared to a regular PBL course. In the regular PBL setting, the pre-analysis and the post-discussion of two problems were divided over two tutorial meetings. In the ALE, students had only one weekly two-hour tutorial meeting, facilitated by a tutor. This meeting was only used for the post-discussion (reporting phase) of problems, and two problems were discussed. Additionally, in the ALE, students worked independently from their tutor in small student teams for the analysis of their problems. Students were responsible for the group process as well as for assigning the team roles.

The small teams could meet at any time, anywhere, and this was facilitated by electronic communication tools. The tutors acted as facilitators and, to a lesser extent than in a regular PBL setting, as a source. For the brainstorm during the problem analysis, tutors provided guidance at small-team level by giving feedback and hints on the results of the brainstorm. This implies that the scaffolding of the student learning process had a 'Just In Time' format, with students taking the initiative and defining the moment when they needed help. As soon as the student teams had completed their brainstorm and pre-analysis, they could send it to their tutor to ask for and receive feedback. Eventually, students could also communicate any other questions to their tutor. Although the small teams were given more control over the problem analyzing process in terms of place, pace and time, the teams had to respect the requirements of the problem analysis, and an accompanying deadline, strictly.

4.7 The ALE social dimension

In regular PBL settings, most interactions and problem solving activities take place in relatively large tutorial groups.

A purpose of the ALE was to improve the quality of interaction in collaborative problem solving. This collaborative aspect was addressed in different ways.

Firstly, students were allotted to small teams of three to five students to perform the brainstorm phase. The small team setting offered students a collaborative setting to experience authentic cases derived from professional practice. It was explained to students that they were working on a collaborative assignment, not an individual assignment. It was assumed that students in small teams had more individual participation than students in medium-sized or large tutorial groups. By working in small student teams with characteristics such as equal opportunities for success of all participants (e.g., Slavin, 1997), it was expected that this would lead to stronger links between the students. This would lead to mutual and positive interdependence (Johnson & Johnson, 1989), and the taking of responsibility for accomplishing a common task (e.g., Slavin, 1997). It was further assumed that, in these self-directed small team settings, students developed a greater sense of ownership, commitment and responsibility for the problem analysis than in larger PBL groups. For instance, the problems and learning goals that the small teams generated themselves could result in strong ownership (Savery & Duffy, 1995). All our claims on the changes in group processes intended to lead to higher cognitive outputs.

For the post-discussion, students met in a regular tutorial group of about 14 members, coached by a faculty tutor.

Secondly, the interaction of team members was facilitated and supported by electronic discussion tools. Students had the possibility of using both synchronous (chat rooms) or asynchronous tools (discussion lists) for exchanging brainstorm ideas, arguments or Internet addresses (URLs). Students were free to use the (synchronous) chat tool, although they were encouraged to meet virtually at times to be fixed by their teams. The asynchronous tool, the discussion list, contained topics related to the main themes of the course. The discussion on these topics was initiated by the tutors, after that the tutors did not intervene in the discussions. This electronic discussion list was during and after the course available 24 hours a day, so students also had access to it during self-study and re-sits. This offered the possibility of ongoing collaboration between the teams.

4.8. Expected cognitive outcomes of the ALE

Based on the results of previous research, as discussed above, it was hypothesized that the ALE students would perform better in a number of cognitive aspects than those on a regular PBL course.

With regard to the task dimension of the ALE, it was expected that the use of more authentic problems would lead to extended elaboration on problems and would therefore foster higher order reasoning skills (Cohen, 1994). Furthermore, it was hypothesized that learning in authentic contexts, requiring the cognitive activities that are used in professional practice, would foster the transfer and application of knowledge to novel problems (Brown et al., 1989). The use of 'sidebar' problem situations was also assumed to foster transfer of knowledge into new situations. Additionally, the use of 'discussion points', implemented at the end of the PBL-cycle, was assumed to stimulate comprehension of knowledge.

Concerning the control dimension, it was hypothesized that a higher degree of control over the problem tasks would stimulate students in performing their tasks and, accordingly, improve students' learning outcomes.

Concerning the social dimension, it was hypothesized that the use of small teams and the use of electronic discussion tools would lead to more elaboration and a higher interaction level. More elaboration on information can lead to better understanding of knowledge (Anderson, 1990).

4.9 Method

4.9.1 Research questions

The present research investigates the cognitive effects of the designed authentic, problem-based and computer supported learning environment (the ALE). The goal of the study is to examine whether the experimental ALE, when compared with a regular PBL environment, would yield different learning outcomes in terms of the applicability and the transferability of the knowledge acquired. The research question is therefore: 'Does the new learning environment (when compared to a regular PBL situation) lead to a better application of knowledge in new and authentic problem solving situations?

4.9.2 Subjects

Second year students from the Maastricht business school participated in the present experiment. Out of the 429 students that enrolled for the marketing course under study, 114 students participated in the experiment. This sample comprised 68 male and 46 female students, with a mean age of 21.5.

4.9.3 *Design*

A quasi-experimental, comparative design was set up, consisting of three randomized student groups: one experimental and two control groups (see table 1).

Table 1: Design for the evaluation of the Authentic Learning Environment

Group:	**Pre-knowledge Analysis (GPA)**	**Control Pre-test**	**Treatment: The experimental ALE**	**Treatment test: Case study**	**Control Post-test**
Experimental ALE group	O_0	O_1	X	O_3	O_2
Control group 1	O_0	O_1		O_3	O_2
Control group 2	O_0	O_1		O_3	O_2

In order to measure the main effects on the outcome of the course, an authentic case study was used as a post-test. It would not make sense to give a pre-experimental test to students who have never studied an international marketing course. Also, using a pre-test at the beginning of the experiment, could influence the outcomes of the experiment (Cook and Campbell, 1979). Therefore, we used an 'Untreated control group design with proxy pre-test measures'. In such designs a post-test is the main measure of treatment, and proxy measures should be found that correlate with the post-test scores. An example of such a pre-test is a general aptitude test in the subject area that is being investigated. Statistical power increases if the scores of the proxy pre-test are related to the post-test (Cook & Campbell, 1979). In the present study, as a proxy pre-test, students' GPAs (their performances on seven courses with a PBL-format) were used as a general measure of business aptitude. The correlation between the GPA and the post-test turned out to be .421 (Pearson, 2-tailed, significant at .01 level). This correlation is acceptable for using the GPA as proxy pretest measure.

4.9.4 *Sampling*

Before the start of the experimental course, a survey was administered to all students to investigate whether or not they were familiar with web-based technology. Out of all students who enrolled for the course (429), 70% of the students (300) showed to be familiar with Internet technology. Both the ALE group and control group 1 were randomly selected from this sample of 300 students with Internet familiarity. Differences in familiarity with the Internet could potentially confuse the results. For instance, students with Internet experience may possibly be more highly motivated to seek additional learning resources. A second control group (N = 39) was created by randomly selecting students out of the total student course population of 429 students. To summarize, the three groups in the experiment were:

- The experimental group, receiving the ALE treatment (N = 36);
- Control group 1, participating in a regular PBL-setting (N = 39);

All members of this control group and the experimental group were randomly selected students out of the group (N = 300) that had been shown to be familiar with the Internet.

- Control group 2, also participating in a regular PBL-setting. Control group 2 was created by randomly selecting students out of the total student course population of 429 students.

For a summary of key differences between the three conditions, see figure 4.

<table>
<tr><th></th><th>ALE-setting</th><th>Control group 1</th><th>Control group 2</th></tr>
<tr><td>Task Dimension</td><td>- Problem descriptions, not pre-analyzed.
- Ill-structured information from real companies.
- Brainstorm on problem description and company materials.
- Real company information in audiovisual, electronic format.</td><td colspan="2">- Pre-analyzed problem descriptions.
- Company information, structured for educational use.
- Brainstorm on the problem description only.
- Paper information.</td></tr>
<tr><td>Control Dimension</td><td>- Students work independently from their tutor in self-steering small teams.
- Students assign roles themselves.
- Tutors act as facilitators, students take the initiative in communication.</td><td colspan="2">- Tutorial meetings of groups of about 14 students.
- Roles assigned by tutors.
- Tutors act as facilitators.</td></tr>
<tr><td>Social dimension</td><td>- One tutorial group meeting a week, for the post-discussion only.
- Self-directed small student teams for the PBL pre-discussion.
- Electronic tools: discussion list & chatting to facilitate communication in small teams and with tutor.</td><td colspan="2">- Two tutorial group meetings a week
- The tutorial groups consisting of about 14 students.</td></tr>
<tr><td>Sampling</td><td>Sample of students familiar with Internet.</td><td>Sample of students familiar with Internet.</td><td>Random sample of students out of the course population of 429 students.</td></tr>
</table>

Figure 4: Key differences between the three instructional conditions

4.9.5 *Course context and content*

The specific context was a marketing management course, part of the International Business Studies degree program. The experimental course was structured around seven major themes, each lasting for one week. The course concerned international marketing issues such as globalization, standardized marketing strategies, competitive positioning etc. The course contents (books, articles) and all content assessments were identical for all three experimental settings.

4.9.6 Tutors

For each of the three conditions, three tutorial student groups were set up, leading to nine tutorial groups in total. Tutors were crossed with the three conditions to apply a control for any 'tutor effect' during education. Table 2 presents the actual number of students in the three research groups, divided between the tutors.

Table 2: Actual student numbers in the three experimental conditions

	Experimental (ALE) group	**Control group 1**	**Control group 2**
Tutor A	13 students	13 students	13 students
Tutor B	11 students	13 students	13 students
Tutor C	12 students	13 students	13 students
Total (114)	N=36 (17 male, 19 female)	N=39 (26 male, 13 female)	N=39 (24 male, 15 female)

Initially, it was planned to use 39 students for each of the three conditions. However, as the experiment was carried out in an ecological context, natural attrition of students occurred. For instance, some students did not show up for the final course test. This explains the variance in the number of participants in the tables presented.

4.9.7 Instruments

For the three groups, several cognitive measures were used (see table 1). Firstly, the effects of the treatment (ALE) were measured by open-ended questions related to a case study, which was novel to the students. The subject of the case study concerned the European marketing strategies of tire manufacturers. The test was a problem-based test in that students were confronted with a problem description based on real cases, accompanied by data resources which consisted of original market survey tables from the tire companies concerned. The problems in the case studies have possibilities for different solutions, so they require divergent thinking abilities. In that sense, this resembled the characteristics of the ALE company case studies. The test part of the case study consisted of six large essay questions, each counting for a maximum of 10 credits. Two experts in the field constructed the case study, as well as the questions. The instrument measured the cognitive outcomes in terms of knowledge application and transfer. Typical questions were: 'Explain how the different companies can achieve competitive advantages'. 'How appropriate is a franchise system in the market in the case study? Explain'. Individual answers to each item were checked against a standard scoring key, by a team of 10 tutors. To enhance the reliability of scoring, each tutor rated one question for all students. An evaluation session was organized in order to eliminate differences in interpretations in cases where tutors rated more than one question.

Secondly, to provide a control for the probability that the experimental students had a higher level of prior knowledge than the control group students, a proxy measure was used that correlated with the post-test that was used with the treatment groups (Cook & Campbell, 1979). As proxy measure, the GPA was estimated on the basis of the students' performances on seven courses with a PBL format that the students had followed prior to the experiment.

Thirdly and finally, the students' prior knowledge was measured by means of a control pre-test and post-test. The pre-test and post-test were identical, containing 25 multiple-choice questions with a maximum score of 25. The questions had the format of 2 (true-false), 3, or 4 choices. The test reliability (Cronbachs alpha) was 0.58. The pre-test and post-test were related to 'research methodology' which was a part of the course and was studied by all students. The content of this control test was not changed by the instructional intervention. A typical question in this test was: ‘Marketing interviewers were told to select a fixed number of women and men from city areas. What kind of sample is this?’ (Choose answer: simple random, quota, stratified or cluster).

The (identical) pre-test and post-test were administered to different random samples of the three groups (ALE, control group 1, control group 2). From the 114 students that participated in the experiment, 80 randomly chosen students were asked to take either the pre-test or the post-test. From this group, 70 students actually participated in either the pre-test or the post-test.

4.9.8 Data analysis

To provide an answer to the research question, mean differences in achievement between the studied groups were compared by using ANOVA analysis of variance.

4.10 Results 1: Main treatment effects

Table 3 shows the mean scores of the three students groups for the essay questions in the case study test (results are collapsed over three tutors). These essay questions concerned the application of marketing knowledge.

Table 3: Mean student scores for the case study test

Group	**Essay questions score for case study test**		
	N	**Mean score (max = 60 pt)**	**Sd**
Experimental group	31	35.50	7.21
Control group 1	35	31.01	6.86
Control group 2	28	32.00	6.91

Sd = Standard deviation

A two-way ANOVA analysis was performed with three fixed levels for both tutors and instructional condition. The mean scores of the three conditions revealed significant differences between the means of the three groups [F(2,86) = 4.10; Mse = 45.14, p = .020]. A post-hoc analysis (Tukey) showed that the mean score in the experimental ALE condition differed only from the first control PBL condition (p = .028) and not significantly from the second PBL control group. The post-hoc analysis showed that the mean scores of the two control groups did not differ significantly. This implies that the two control groups did not substantially differ in cognitive performance. This result contradicts the idea that students having access to and experience with the Internet (control group 1) would perform differently from a group made up of less experienced Internet users (control group 2).

Analysis of variance showed no significant tutor effect on the course exam results [F(2,86) = 0.08, MSe= 45.14, p = .923]. A significant interaction effect was found between tutor and the three instructional conditions [F(4,86) = 3.402, MSe= 45.142, p = .012]. Comparison of cell means showed that interaction was caused by one tutor cell in control setting 2 with relative low cognitive outcomes at the final exam.

In general, researchers argue that when measuring knowledge gains, results need to be interpreted with caution. Additional measures like the ‘Effect Size’ of a treatment need to be calculated (e.g., Albanese, 2000). Therefore, the Effect Size (ES) was calculated for the ALE and the control conditions. The results confirmed and strengthened the differences found between the three mean scores. The effect size between the ALE group and control group 1 is stronger (ES = .65) than the effect size between the ALE group and control group 2 (ES = .43).

4.11 Results 2: Control studies

4.11.1 Control Study 1: A comparison of the GPA of the three groups in the experiment

This control test was designed to assess whether, at the start of the experiment, the three groups in the experiment were equal with regard to prior knowledge of business related to the treatment. The GPA of the students was expressed by the average scores of the students in the three groups on the PBL tests in the first and second years (see table 4).

Table 4: Students average score on all PBL-courses in year 1 and 2 (GPA)

Group	N	Mean (range: 1- 10)	Sd
Experimental group	33	6.88	0.78
Control group 1	37	6.76	0.63
Control group 2	39	6.62	0.57

Sd = Standard deviation

Table 4 shows that the three groups which participated in the experiment did not differ in business knowledge, acquired from PBL courses they had followed prior to the start of the experiment [F(2,106) = 2.150; Mse = .459, p = .142]. This suggests that, at the start of the experiment, the three student groups were equal with regard to relevant prior knowledge scores.

4.11.2 Control study 2: Analysis of the (non-treatment related) pre-test and post-test results

The purposes of the pre-test and post-test were twofold. Firstly, the pre-test was used to measure differences in prior knowledge of a marketing subject (‘marketing research’) related to the course content under study. Secondly, the tests were used to estimate differences in students’ cognitive abilities by assessing differences between the three groups in gaining knowledge about marketing research by the end of the course.

ANOVA analysis showed that the mean scores on the pre-test at the beginning of the experiment did not differ significantly [F(2,32) = 0.89; Mse = 6.174, p = .915] between the three groups. This implies that the three groups did not differ in their independent prior knowledge.

With regard to the post-test, a one-way ANOVA analysis showed that the mean scores on the post-test at the end of the experiment did not significant differ [F(2,32) = 0.061; Mse = 10.403, p = .941] between the three groups. This implies that all three groups benefited equally from course content that was offered in a regular format. Table 5 shows the scores of the three groups on the pre-test and post-test. The table shows only marginal differences between the three groups in cognitive gain. This indicates a comparable ability for the three groups in the acquisition of knowledge in a domain of marketing.

Table 5: Comparison of scores on the pre-test and post-test during the experimental course

Group in experiment	Pre-test scores		Post-test scores		Relative cognitive gain
	N=35	Mean (Sd)	Mean (Sd)	N=35	
Experimental group	10	9.30 (2.83)	11.00 (3.36)	13	+ 18.1%
PBL control group 1	13	9.53 (2.50)	11.27 (3.46)	11	+ 18.3%
PBL control group 2	12	9.75 (2.13)	11.45 (2.77)	11	+ 17.5%

Sd = Standard deviation

A general conclusion concerning the control tests is that the three groups in the experiment did not differ in cognitive measures before the experiment. This result strengthens the idea that the three groups were equal in their possession of prior knowledge. A second conclusion is that students did not differ in an independent post-test measure after the treatment. This implies that students' abilities to acquire knowledge did not differ between the three groups. Overall, it can be concluded that the three student groups are comparable.

4.12 Discussion and conclusion

Comparative research on the effects of PBL on learning outcomes does not present conclusive results. This could indicate that PBL has more potential than has been actually realized. A redesigned learning environment was therefore created, taking into account research on several design variables. The purpose of this study was to explore whether the redesigned instructional approach, when compared with a regular PBL environment, would lead to a better application of knowledge in new and authentic problem solving situations.

In the present experiment, scores on the case study instrument were analyzed for the measurement of treatment effects. This analysis showed that the students who experienced the redesigned PBL format had significantly better scores, compared to the control group with the same student background variables (control group 1). Comparisons between the scores of the experimental ALE group and control group 2 (students with limited Internet experience) did not differ significantly. The effect size (ES) between the experimental ALE group and control group 1 was found to be large (.65); the ES between the ALE group and control group 2 was lower (.43). In general, it can be concluded that the redesigned PBL format contributed significantly to better student learning when compared with the regular PBL setting.

Concerning effect sizes in intervention studies in general, Albanese (2000) argued that an ES between .80 and 1.0 is extremely high, and an unreasonable expectation from curriculum studies. The average ES reported in PBL studies is about 0.50 (Albanese, 2000). It can be concluded that the ES of .65 found between the experimental group and control group 1 in this study is satisfyingly high. The ES between the ALE group and the control group with Internet experience is lower (.43). Typically, the experimental ALE group performed significantly better than control group 1, but not significantly better than control group 2. This result is difficult to explain, especially as all control tests on student selection showed no significant differences between students at the start of the experiment. Comparison of cell means showed that one tutor cell in control setting 2 showed relative low cognitive outcomes at the final exam. Further research might determine differences in students' characteristics that were not examined (e.g. students' cognitive style differences).

Another issue is the validity of the instrument used. From the viewpoint of experimental validity, it can be argued that students should be assessed in a similar (real-life) setting to the one in which they acquired the knowledge. This would imply that students should have been confronted with an authentic technology test case, performed in a team setting, similar to the treatment setting, instead of an individual paper test case. In such an assessment setting, the transfer from knowledge acquisition to application would be optimal (see also Bransford and Schwartz, 1999). Bransford and Schwartz argued that tests which limit students to what they have in their heads, can provide a limited, low sensitivity measure of transfer. But as Honebein et al. (1993) argued, authentic environments are the ones which engage learners in activities that require the same type of cognitive thinking as the workplaces for which we are preparing the learner. It can, therefore, be assumed that a paper test case is a valid test instrument for assessing cognitive performances in authentic settings. Additionally, authors such as Johnson and Johnson (1989) argued that group-to-individual transfer occurs when individuals who learned within a cooperative group demonstrate mastery on a subsequent test, taken individually. In other words: what individuals learn in a group today, they are able to do alone tomorrow. Therefore, the individual paper test that was used (with authentic features such as ill-structured and real-life resource information) should be a valid measure.

In a similar discussion, Salomon (1996) argued that implementing new constructivist learning environments should also be accompanied by the assessment of new cognitive learning goals. For example, in designing a learning environment that assumes different group knowledge construction processes, one should also investigate process outcomes related to aspects such as shared understandings, as well as cognitive tests. Future research could investigate process related outcomes of the ALE. An analysis of the PBL process could also possibly reveal which components of the ALE were responsible for producing the cognitive gains.

A related issue to be discussed is the preparation of students for 'future learning', as addressed by Bransford and Schwartz (1999). The current case study measured students' cognitive outcomes as performances at one particular moment: that is, at the end of one particular course. However, Bransford and Schwartz (1999) argued that such knowledge tests do not capture the process of preparation for future learning. In the context of the present study, it may be that students in authentic (experimental) settings have acquired skills for more effective future learning. Future research into the processes of learning could demonstrate whether the students from the experiment can induce knowledge more effectively when confronted with authentic problem situations.

Two issues in the area of measurement are related to this discussion. One issue, related to 'future learning', concerns the short-term effects that were measured in this study. As is known from earlier research, educational innovations such as PBL often do not lead to cognitive gains in the short term, but do so in the long term (Norman & Schmidt, 2000). Further research could indicate to what extent the ALE leads to long term effects in our curriculum. A second issue is related to the scope of the measurement outcomes of the ALE that were studied. It is well known, from former intervention studies within the CSCL research domain that, next to cognitive achievement, affective or motivational changes may occur, along with changes in interaction. Although we collected subjective data, such as students' opinions, it was not within the scope of the main research question to report these qualitative data in this study.

A general implication of the results of this study for educators is that this new instructional design has the potential to improve the applicability of marketing knowledge in practical settings. This may encourage educators in marketing, or related social studies, to use elements of the redesigned PBL format and to further improve their educational settings. Suggested elements that can enhance learning are what Albanese (2000) referred to as the 'active ingredients' of constructivist settings.

Basically, the ingredients in the ALE were that students worked in small, self-steering team settings, using real-life problems, procedures and information sources. More research is necessary to examine how the positive results from the present experiment can be transferred to larger instructional settings. Studies replicating the current ALE setting and focusing on how dimensions interact are necessary to develop a better understanding of exploiting instructional potentials of PBL.

4.13 Acknowledgements

The authors thank Professor J. Lemmink and the university teachers M. Kleijnen and A. Lievens for their cooperation in collecting data within their courses and in conducting this study. We also thank the Instructional Science reviewers for their suggestions that strengthened the purpose of this article.

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CHAPTER 5: ENHANCING PROBLEM-SOLVING EXPERTISE BY MEANS OF AN AUTHENTIC, COLLABORATIVE, COMPUTER SUPPORTED AND PROBLEM-BASED COURSE[4]

An effect outcome comparison of a traditional and a refined PBL course.

5.1 Introduction

One of the main goals of higher education is to prepare students for professional life. As society changes, there is a growing need for competencies such as critical thinking and the ability to solve novel problems (Kember, Charlesworth, Davies, McKay & Stott, 1997; Tynjälä, 1999). However, higher education in general, and management education in particular, have been criticised for not developing such characteristics of problem solving expertise (ACNielsen, 2000; Boyatzis, Stubbs & Taylor, 2002; Business Higher Education Forum, 1995).

In the past, various case-based instructional approaches have been developed that situate learning in a meaningful context of real-world problems (Stepich, Ertmer & Lane, 2001). A promising instructional approach that reflects these ideas is Problem-Based Learning (PBL). PBL is a case-based, constructivist method that requires students, working together in small groups, to analyse realistic problems to acquire the knowledge and skills needed for professional practice (Barrows, 1996; Williams, 1992). Case-based methods such as PBL, have explicitly attempted to develop students' expertise related to solving problems. However, Albanese (2000), Hmelo, Gotterer and Bransford (1997), and Norman and Schmidt (2000) have argued, that comparative studies of PBL and traditional approaches have failed to demonstrate conclusive evidence of substantial gains in expertise as a result of PBL. Most reviews concerning the effects of PBL have reported mixed results on the cognitive merits of PBL (Albanese & Mitchell, 1993; Gijbels, Dochy, Van den Bossche & Segers, 2005; Vernon & Blake, 1993). Several explanations have been put forward to account for the varying outcomes of PBL studies. Firstly, researchers have referred to the weaknesses in the implementation of the PBL approach. For instance, some researchers argue that the problems used in PBL curricula are too much 'constructed for education' and do not require the cognitive activities that the workplace requires (e.g. Norman & Schmidt, 2000). Secondly, studies on the effects of instructional design often have poor methodological designs (Albanese, 2000; Norman & Schmidt, 2000). Thirdly, although interesting research has been done in the domain of case-based reasoning and on knowledge transfer (e.g. Kolodner, Gray & Fasse, 2003), only few PBL-environments have implemented the instructional design implications, deduced from these research studies. For instance, researchers argue that PBL can benefit more of the potential of small group learning (e.g. Lohman & Finkelstein, 2000). Moreover, up till now, only few PBL studies have integrated learning theories with computer technology (Koschmann, Myers, Feltovitch & Barrows, 1994).

Taking into account these considerations, in this study, we redesigned the initial PBL environment of a marketing course. The goal was to raise the level of expertise of the students to a higher level. We based our new instructional design on (a) research on expertise, (b) studies in the domain of case-based reasoning and knowledge transfer, and (c) our lessons on learning in PBL curricula.

We compared a 'traditional' and a 'refined' PBL course to find out the impact on student development of problem solving expertise. To appraise the effects of the refined

[4] Published in: *European Journal for Psychology of Education, Vol XXI* (1), 71-90.

instructional design, we measured students' performance on a novel problem-solving task, and represented it in a multidimensional expertise profile.

In the next section, we summarize the main dimensions of expertise and discuss the expertise outcome results of studies performed in and outside PBL curricula.

5.2 Dimensions of expertise, problem-solving and PBL

Already for a long time, problem-solving has been the focus of study in the area of expertise research. Within the framework of expertise research (Sternberg, 1997; Boshuizen, Bromme & Gruber, 2004) and academic domain learning (Alexander & Murphy, 1997), it is generally acknowledged that the primary requirements for solving ill-structured problems consist of (a) possessing a substantial amount of declarative and domain-specific knowledge, (b) good organization and use of knowledge, (c) effective reasoning, and (d) the ability to extend one's knowledge and skills beyond the context in which they were acquired. Following Alexander and Murphy (1997), the cognitive outcomes of students' learning are positioned as durable changes in learning on different characteristics such as knowledge organization and reasoning skills when students encounter tasks or problem situations derived from that domain. The present study examines 1) changes in the use of knowledge, 2) differences in reasoning directionality, and 3) gains in diagnostic and problem solving abilities.

Use of knowledge. Expertise research has shown that experts' knowledge bases are well-organized in patterns of experiences and refined conceptual categories. Compared with those of novices, experts' schemata are more elaborate: they contain more concepts and have more interconnections (Chi, Feltovich, & Glaser, 1981). However, the development from novice to expert is not straightforward. Researchers such as Arts, Gijselaers & Boshuizen (2000) and Patel, Arocha, & Kaufman (1999) have found that more advanced levels of expertise typically are less demonstrative in using declarative knowledge types during reasoning. By contrast, experts use large amounts of procedural knowledge such as *inferences* during reasoning (Arts et al., 2000; Boshuizen, 1989).

Reasoning directionality. A repeated finding in expertise research is that successful experts use inductive reasoning, i.e. they reason forward from data to a goal or solution (Norman, Brooks, Colle & Hatala, 1999), whereas novices tend to use deductive reasoning ('backward reasoning'). Novices 'jump right in', formulating a diagnosis or solution at a very early stage (even before analyzing a situation) and collecting supporting data afterwards. (Norman et al., 1999; Sternberg & Horvath, 1999).

Diagnostic/problem solving abilities. We define diagnostic ability as identifying and explaining a case problem in terms of correct sources and causes. Diagnostic ability develops in a linear way, as was demonstrated by classical studies in the medical domain by Elstein, Shulman, and Sprafka (1978) and Patel and Groen (1991). In other words, experts generally make a more appropriate diagnosis than do novices (Boshuizen, 1989). Tharpe and Biswas (1997) found that accurate diagnostic performance is related to initial analysis of symptoms and other problem data together with interpretation and further tests of the findings.

So far, the (limited) research published on expertise development in PBL has focused primarily on the direction of reasoning and on diagnostics. The review studies of Albanese and Mitchell (1993) as well as the study of Patel, Kaufman & Arocha (2000) have indicated that PBL rather stimulates a backward (deductive) reasoning strategy whereas traditional curricula tended to stimulate (inductive) forward reasoning.

Concerning problem diagnostics, research on problem-solving behaviour in PBL groups reveals that PBL-students do not analyse the problems thoroughly and rather develop one instead of multiple hypotheses (De Grave, Boshuizen & Schmidt, 1996). Patel et al. (2000)

found that medical students, who generated *more* hypotheses when the problem was initially presented, also generated more *accurate* diagnoses.

On the level of problem *solutions*, there is a paucity of evidence of effects of PBL on the quality of problem solutions (Heller & Hollabaugh, 1992). The reason is that in PBL, the focus is on learning through diagnosing and explaining problems, not by proposing accurate solutions. Nevertheless, what is found in relation to diagnosing is that novice PBL students try to find ‘the correct’ solution very quickly - and on a limited dataset - , instead of first analyzing phenomena in terms of underlying causes and knowledge (De Grave, Boshuizen & Schmidt, 1996). In other words, students focused on resolving rather than on analyzing the problem, even though analysis is crucial in acquiring underlying knowledge.

On the basis of these findings in expertise research, various suggestions for the optimisation of PBL have been proposed. In the next section we will discuss these suggestions for instructional redesign in a PBL-course.

5.3 Refining the PBL design

5.3.1 The traditional PBL design

The PBL design used at our School of Economics and Business Administration was predicated on PBL, as developed by Barrows and Tamblyn (1980). It can be characterized along three educational dimensions: the *task*, the *social* and the *procedural* dimension (Barrows, 1996; Williams, 1992; Wilkerson & Gijselaers, 1996).

With regard to the *task dimension*, students receive a set of problems as starting points for learning. The problems are short, linear, written cases presenting a problem description accompanied by relevant textual information. The problems are related to one or more course content aspects and are set within the context of one company.

The *social dimension* involves students working in groups of 14 students. Every week students attend two of such group meetings and in addition work on the problems individually. The teacher (tutor) facilitates the group meetings by monitoring the group process and helping students to identify which gaps in their knowledge they need to fill to be able to explain and resolve the problem. One student chairs the meeting and another one takes minutes, which are e-mailed to group members afterwards. Students are assigned to the roles of chair and secretary by the tutor.

The PBL *procedure* starts with a preliminary analysis of the problem (the pre-discussion and brainstorming phase) with students’ prior knowledge as the starting point. The group then formulates learning goals in the form of relevant unexplained issues to be elucidated through individual self-study. In the next meeting(s) students discuss the results of their self-study activities to the group (the ‘post-discussion’). Next, the group uses the same procedure to tackle a new problem. In Figure 1 this is summarized in the right column.

5.3.2 The refined PBL design

Insights from cognitive learning theories do not automatically translate into superior educational designs (Williams, 1992). Nevertheless, they may help us to improve our traditional PBL approach.

The task dimension. Mandl, Gräsel and Fischer (2000) argued that the limited information provided by the traditional PBL problem descriptions probably encourages students to go for a superficial problem representation and focus on one instead of multiple hypotheses, as evidenced by De Grave, Boshuizen and Schmidt (1996). Such outcome may hamper the potential learning gains of PBL, because Patel et al. (2000) showed that poor hypothesis formulation is associated with poor diagnostics. In another study Patel et al.

(1999) hypothesized that knowledge acquisition in a PBL context leads students to a process that may not resemble that in a real environment. This implies that realistic problem descriptions with a 'rich set of data' ('authentic learning contexts') offer better opportunities for developing forward reasoning. Similar arguments have been put forward by Mandl et al (2000), who showed that a rich case environment does not 'narrow down' and can prevent students from considering one hypothesis only.

These considerations have guided us in modifying the task dimension of the traditional PBL design. First, authentic and information rich materials were used consisting of (a) problem descriptions and (b) an array of accompanying materials from the company under study (henceforward these two components together will be referred to as 'case information'). The case information placed the brainstorming phase in a broader and more vivid context compared with the traditional design. The company materials consisted of real (irrelevant and relevant) information, such as un-interpreted parts of annual reports and internal management presentations. These context-rich and authentic materials did not contain interpretations, and were not adapted for educational use, so that students could simulate the real life process of identifying problems, comparing different sources and drawing conclusions from ill-structured data. We stimulated students to reason from raw data to general conclusions. We expected that this could enhance inductive, forward reasoning.

Furthermore, the realistic and rich case information could develop deeper and richer knowledge structures. The company materials were presented in a non-linear, multimedia format, as opposed to the linear, well-structured and written material of the traditional PBL setting. By clicking on buttons, students could obtain additional company information. This multimedia format enabled us to simulate features of problems that become apparent only as the situation unfolds (Lawrence, 1988).

In business practice, most information is available electronically on the intranet or Internet in the shape of databases, presentations, commercials, et cetera. Internet searches were an integral part of the learning process. Every week, students had to relate the main problem of the company under study (L'Oreal) to a similar problem facing another company found on Internet. For instance, globalization issues concerning L'Oreal and McDonalds were compared. This intended to stimulate multiple views on business concepts and facilitate transfer of knowledge acquired in the context of one case to other contexts. In sum, we made the stimuli for learning (PBL problems) and the problem solving context (the additional company materials) more authentic, while we did not change the learning content (textbooks and reader).

The social dimension. The necessity of our traditional group size of 14 students may be questioned. Authentic problem solving takes place in a professional team setting (Kagan, 1989; Nijstad, 2000). According to Lohman and Finkelstein (2000) research has suggested that very small student groups may yield better learning outcomes compared with medium-sized or large groups. Kagan (1989) advocated four as the ideal group size, because larger groups run a greater risk of non-participation and 'group production losses', such as time spent on coordination. Nijstad's (2000) investigated conditions that make small teams effective. He showed that the presence of group members during a brainstorming phase can restrict the generation of ideas. It follows that individual group members' ideas should only be presented to the group *after* their brainstorm is finished (Nijstad, 2000). In the new PBL design, the first stage of the brainstorm phase consisted of individual preparation by students. Next in the small team meetings about four students pre-analyzed the problems (without tutor). This approach resembled teamwork in real business settings. As in an authentic setting, students assigned the roles and tasks themselves. We thought that (a) an individual brainstorm and (b) several teams working independently (parallel), would stimulate the generation of *diverging* ideas, perspectives and problem explanations. This diverging process is important in initial problem analysis (Ge & Land, 2003). Only for the post-discussion the students did meet in groups of about 14 members, facilitated by a faculty tutor (see Figure 1).

Refined PBL design	Traditional PBL design
Task dimension:	
PBL-problems: - Problem descriptions, not pre-analyzed. *Case information:* - Ill-structured information from real companies. *Brainstorm:* - Brainstorm on the problem description and on ill-structured company materials. *Case information format:* - Real company information in multimedia, electronic format, only the course study materials were printed on paper. - Weekly analysis of a single case on Internet.	*PBL-problems:* - Pre-analyzed problem descriptions. *Case information:* - Structured for educational use. *Brainstorm:* - Brainstorm on the problem description only. *Case information format:* - Only paper (printed) materials: paper problems and paper cases.
Procedural dimension:	
Brainstorm: - Individual (diverging) brainstorm → discussion in small teams → converging ideas by exchanging ideas within all the small teams. *Problem analysis:* - A template to stimulate expert-like problem-solving. - After tackling problems, the student teams had to come up with 'discussion-topics'.	*Brainstorm:* - Brainstorm in a group of 14 students. *Problem analysis:* - In groups of 14 students facilitated by a tutor.
Social dimension:	
Group meetings: - One (2-hours) tutorial group meeting a week (instead of two), for post-discussion only. - For the PBL pre-discussion: self-directed small student teams of about three persons, with students working independently from the tutor. *Group member roles:* - Students assign roles themselves. *Electronic tools for collaboration:* - The use of electronic tools: discussion list & chatting to facilitate communication in small teams and with tutor.	*Group meetings:* - Two tutorial group meetings (of 14 persons) a week. Students meet and communicate only during these meetings. *Group member roles:* - Roles assigned by tutors. *Electronic tools for collaboration:* - The regular e-mail available to students.

Figure 1: Summary of the differences between the two PBL designs

Computer-assisted collaboration. Consistent with the study of Oliver and Omari (1999), we see interactive media as a 'catalyst of learning' (Light, Littleton, Messer and Joiner, 1994). Consequently, we used electronic discussion tools (such as discussion lists) to promote the depth of problem analysis; Computer support of the small team interaction was intended to provide students a *knowledge building community* (Bereiter & Scardamalia, 2000) that facilitates the exchange of prior knowledge and ideas, resulting in more *elaborated knowledge* (Koschmann et al., 1994; Pinsonneault & Kraemer, 1989). A study of Oliver and Omari (1999) is a case in point. Oliver and Omari studied the impact learning technology on the productivity of PBL environments. Students were put into small teams of four or five to work on problems. Internet was used for the presentation of ill-structured problems and to provide access to multiple sources of information for the problem solution. Web technology also offered students communication possibilities by allowing students to post problem solutions within a team, or for others, on a public bulletin board. Finally, students could exchange relevant Internet addresses (URLs) for others to use in their inquiries (Oliver & Omari, 1999). Student responses indicated that the innovative learning environment 'had a substantial impact on students learning and problem solving' (Oliver & Omari, 1999). This study suggests that students' progress in PBL environments is affected by group size and the use of technology.

The procedural dimension. In the traditional approach, company materials were not made available until after the brainstorm session. By contrast, in the refined design the problem description and authentic company materials were offered to the student teams simultaneously. This created a rich basis for individual brainstorming and the presentation of the results in the small team. In both the experimental and the traditional design, students discussed two PBL-problems a week. In the traditional design, the tutor was present at the meeting, which lasted the scheduled two hours. However, in the refined PBL setting students were free to decide how much time they devoted to the problem analysis, because for this stage, they worked independently from the tutor.

Starting a new problem: PRE-DISCUSSION (Monday)	
Teams: You work in teams of three or four persons. You assign individual student roles yourselves.	
1a. Find a problem in your data	
	From the data in your task and from your company data you can derive problems and/or typical managerial phenomena, related to this week's course theme.
1b. Define the problem and give underlying data as evidence	
	State not only the problem but also provide some data as evidence for the problem(s) in the company. Categorize data in causes and symptoms.
2. Brainstorm: give different hypothesized explanations	
	List relevant aspects and explanations for the problems you stated in (1). Give some (more than one!) hypothesized explanations for each problem.
3. State your group learning objectives	
	Formulate these learning objectives in clear, well-defined and concrete terms. Formulate the learning objectives within the goals of this course. (The different teams prepare (different) learning goals.)
	Send the (1) problems, (2) explanations and (3) learning goals, of your team by e-mail to your tutor before Tuesday 11:00 and you will receive feedback before 13:00 !
SELF-STUDY (Tuesday - Wednesday)	
4. Work out the learning goals for the post-discussion within your small teams. **5. Think of a 'discussion point' to relate this week's theory to previous theory.**	
	For the post-discussion on Thursday, each team must formulate a discussion point.
Post-DISCUSSION (Thursday)	
6. Discussing results of all the teams by having all small teams together	
	(all 4 teams together make a group of about 14 students).
	- The different students teams report what they have studied in literature. - Having all explanations of the different student teams, have we tackled the problem?
AFTER CONCLUSION OF PROBLEM	
7. Knowledge abstraction by using the 'discussion points'	
	- How can we relate what we have learned to previous chapters or lessons?

Figure 2: Problem solving 'template'

After brainstorm and problem analysis, the small student teams were asked to enter their analysis of the business case study on a case 'template' (see Figure 2). Students had to categorize data, symptoms and possible problem explanations. The template was intended to scaffold students' cognitive and metacognitive skills (Ge & Land, 2003) to stimulate a thorough problem-analysis (and not too rapidly focusing on solutions). The template we used consisted of prompts and questions, which encouraged generating multiple explanations (hypotheses) of problems and present sound arguments. The completed template was e-mailed to the tutor, who provided electronic feedback on the problem analysis and the learning goals.

Finally, the students were weekly asked to put so-called '*topics for further discussion'* to the group. These topics had to transcend mere comprehension and raise specific knowledge and skills to a more general, decontextualized level, thereby heightening students' awareness of their reasoning as they were learning. In this way students articulated what they had learned in a new context, and transfer of knowledge was promoted (Kolodner et al., 2003).

5.4 The experiment

5.4.1 Participants

The experiment was conducted in a mandatory International Marketing course in the second year of the International Business degree program of our Business School. The main goal of the course was students acquire International Marketing knowledge and develop reasoning skills to solve problems being typical for this domain. We randomly assigned 75 second-year students to the experimental or the control group (29 female and 46 male). The average age of the participants was 21.5 years.

5.4.2 Procedure

Design. A quasi-experimental, comparative design was used with students randomized to the experimental or the traditional group (see table 1).

Table 1: Research design for the evaluation of the Refined PBL Learning Environment

Group:	Pre-knowledge Analysis (GPA)	Control Pretest	Treatment: PBL refined	Treatment test: Authentic case study	Control Posttest
PBL Refined	O_0	O_1	X	O_2	O_3
PBL Traditional	O_0	O_1		O_2	O_3

An authentic case study was used to measure the main effects of the experiment on course outcomes. No *pre*-experimental test was performed, because the course in question was the students' first International Marketing course. Moreover, a pre-test at the start of the experiment might affect the outcomes of the experiment (Cook & Campbell, 1979). Therefore, we used a so-called 'untreated control group design with proxy pre-test measures'. In such a design a post-test is the main measure of treatment, and proxy pre-test measures must be found in the subject area under investigation. We used student's Grade Point Average (GPA) as a proxy pre-test and as a general measure of business aptitude.

Sampling. Before the start of the experimental course, a survey was administered to investigate whether or not students were familiar with Web-based technology. Of the enrolled students (429), 70% (300) seemed to be very familiar with Internet technology. In order to control for Internet experience, both the traditional and the refined PBL student group were *not* selected on a voluntary base. Instead, we randomly selected two groups from the sample of 300 students with Internet familiarity. The two groups in the experiment were:

- The experimental group participating in the refined PBL setting (N = 36);
- The traditional group participating in the traditional PBL-setting (N=39).

Of those 75 participants, for feasibility reasons, 36 students from both conditions took part in measurement based on an authentic case study. However, 29 students completed the authentic case study, as the experiment was carried out in an ecological context, and some natural attrition of students occurred. For instance, some students did not finish the course.
The pre- and post-test were administered to different random samples from the two conditions in the experiment. Of the 75 participants in the experiment, 52 completed either the pre- or the post-test.

Teachers. Each tutor facilitated two tutorial groups, to control for 'tutor effects'. Six tutorial groups were included in the study. At the start of the experiment, students and teachers were instructed about the revised task and the procedural and collaborative environment. This was done to prevent disturbance of the experiment due to surprise and confusion among staff and students about the modifications of the traditional course. Over the course of the experiment, teachers met frequently to evaluate the different teacher roles in different conditions.

5.4.3 Instruments

We used three cognitive measures for both groups.

First, as a 'proxy measure', we determined the GPA of seven traditional PBL courses, given before the experiment. We calculated this GPA on the end-of-course- exams from the first and second year of the mandatory business program. On this GPA, we compared the two groups in the experiment to control for potential differences between the two groups in prior knowledge of business at the start of the experiment.

Second, a pre- and posttest were administered to assess and control for differences between the two groups in their potential for acquiring new knowledge of *marketing methodology*. These tests were administered to students participating in the experiment, before and after a 'Marketing Research Methodology' course, which was programmed in parallel with the experimental marketing course. The pretest was also used to measure differences in prior knowledge of a marketing subject related to the content of the course under study. The questions of the pre- and post-test were identical, i.e. 25 multiple-choice questions with a maximum score of 25. The questions were of the true/false format or required a choice from 3 or 4 alternatives. Test reliability was 0.58 (Cronbach's alpha), which is acceptable for this relative low amount of test items. A typical question in the pre-post test was: '*Marketing interviewers selected a fixed number of women and men from city areas. What kind of sample is this?' (Answer alternatives: simple random, quota, stratified or cluster).*

Third, we measured students' cognitive outcomes of the course under study. Hmelo et al. (1997) argued that measures such as national standardized tests are possibly not sensitive enough to reveal cognitive effects such as changes in reasoning direction. The same applies for course tests consisting of multiple-choice items, which mainly measure knowledge reproduction and comprehension. The assessment format must be congruent with the goals of the course and the instructional approach used. Therefore, we used a case study simulating a representative and real professional situation for measuring the main treatment outcomes. This case study had authentic characteristics to engage students in the types of cognitive activities that are also required in real practice (Barrows, 2000; Savery & Duffy, 1995). Students were presented with a short case study containing only uninterpreted data from a real company. To simulate real life, the case information was ill-structured and the problems had several different potential solutions. The initial case information provided was not complete and consisted of high-critical and low-critical ('irrelevant') information. Subjects could decide to gather additional available information, such as a market survey table. The topic of the business case study was 'niche- versus mass-market strategy'. We asked students the following questions:

1. Diagnose and analyse the problems that you have identified in the case study.
2. Give possible solutions for the problems that you have identified in the case study.

The assignments required students to explain case problems in terms of underlying problem mechanisms and to propose solutions.

Our experts (faculty teachers and a business consultant) verified the final version of the case. Teachers analysed possible case solutions, which resulted in developing a '*case answer key*' consisting of (a) a case diagnosis containing a description of the main problems in the case, and (b) several 'directions' for case solutions. We used this answer key to quantify the quality of students' problem solving protocols (see the Appendix).

Procedure. A few days after the course under study, we gave each subject the description of the new marketing case and the problem solving assignments. The students had three minutes to carefully read the written case text and take notes. Students were provided with two blank sheets of paper, to write down the results of the problem diagnosing and the problem solution assignment. For both assignments the same case information was used, consisting of instructions and a case description. Using the constructed 'canonical' answer key, two assessors (a researcher and an assistant) blindly assessed students' written protocols (the analysis of the case problems) by using the indicators of expertise in Figure 3.

Inter-rater agreement was estimated by comparing the assessors' ratings of ten protocols. Both assessors used all the cognitive measures of Figure 3. For all the expertise measures used, the average agreement between the assessors turned out to be .71 (varying between .63 and .81), indicating an acceptable inter-rater reliability. During the analysis of the student protocols, most disagreements about interpretation were resolved by means of converging discussions.

5.4.4 Coding scheme

Examining the potential effects of a sophisticated redesign of a PBL course requires rethinking the method of analysis. Various studies have compared the results of PBL and traditional curricula on the basis of students' total score on problem-solving tasks. A more sensitive analytic method, based on key features of expertise, may reveal a more analytic profile of students' knowledge and skills compared with a uni-dimensional score.

Therefore we expressed students´ knowledge and skills in a multidimensional profile based on the key features of problem-solving expertise. We used various detailed indicators derived from expertise research (see Figure 3) to measure the multiple cognitive dimensions of expertise (Sternberg, 1997). Our generic (domain-independent) coding scheme to capture expertise consisted of four cognitive indicators of marketing expertise (in order of complexity): (a) use of theoretical knowledge during problem analysis, i.e. facts, concepts and principles; (b) reasoning i.e. the use of inferences, inductions, and deductions, during problem analysis; (c) diagnosis and (d) problem solutions.

We hypothesized that the students in the refined PBL condition would outperform the students in our traditional PBL condition on these measures of expertise: (a) quality of problem analysis (e.g. increasingly making relevant inferences); (b) forwards reasoning (i.e. more inductive reasoning); (c) the quality of diagnoses (more accurate diagnoses) and (d) the quality of problem solutions (more appropriate solutions). In the Appendix, these cognitive indicators are explained in more detail.

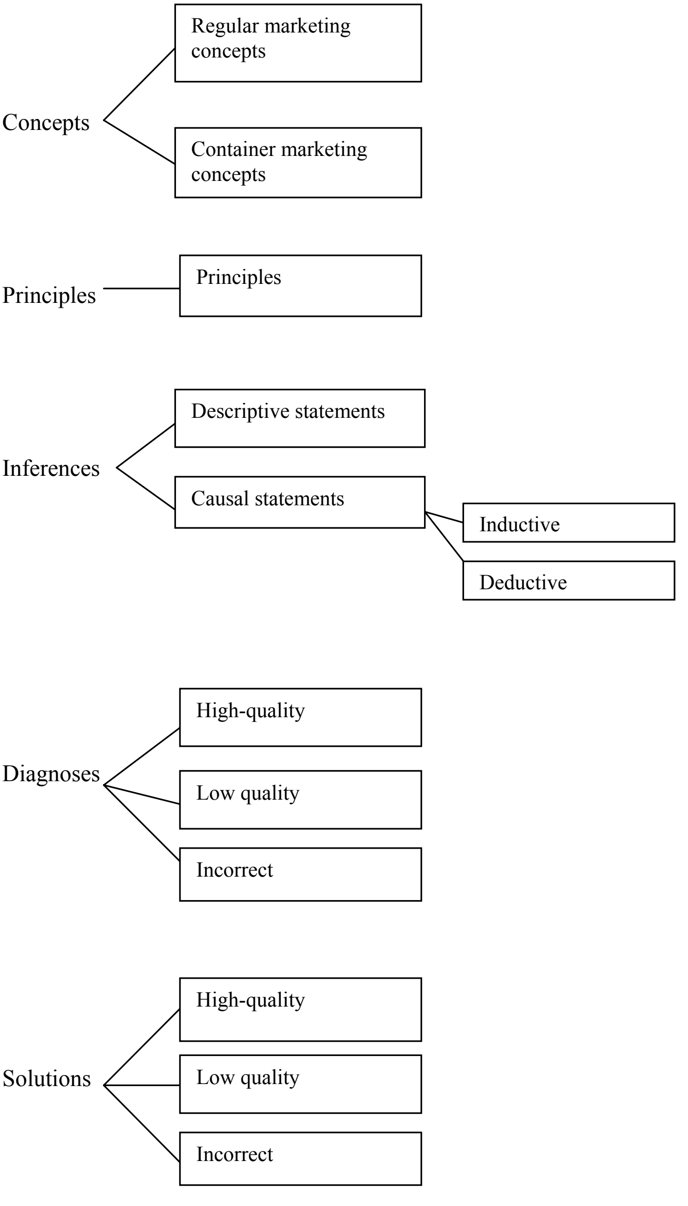

Figure 3: Generic indicators of expertise

5.5 Results (1): Control studies

5.5.1 Control study 1: Comparison of the GPA of the two groups in the experiment

Table 2 shows that the two groups did not differ in their GPA scores on business knowledge obtained before the experiment $F(1,72) = 1.45$; Mse = 0.492, p = .231. This suggests that the two student groups had comparable prior knowledge scores.

Table 2: Students GPA for seven PBL course tests in years 1 and 2

Group	N	Mean (range: 1- 10)	Sd
PBL refined	33	6.88	0.78
PBL Traditional	37	6.76	0.63

Sd = Standard deviation

5.5.2 Control study 2: Analysis of the pre-test and post-test results

An ANOVA-analysis showed no significant differences between the two groups in mean scores on a *pre*-test at the beginning of the experiment $F(1,31) = .083$; Mse = 6.224, p = .776. This implies that the two groups did not differ in prior knowledge, independent from the treatment.

With regard to the *post*-test, one-way ANOVA yielded no statistically significant differences between the two groups in mean post-test scores $F(1,32) = 0.004$; Mse = 11.866, p = .952. This implies that the two groups benefited equally from the 'control' course content offered in a regular format. Table 3 shows the scores of the two groups on the pre-test and post-test. The table shows only marginal differences between the two groups in cognitive gain. This indicates that the potential for learning in the marketing domain was comparable for the two groups.

Table 3: Comparison of scores on the pre-test and post-test during the experimental course

Group in experiment	Pre-test scores		Post-test scores		Relative cognitive gain
		Mean (Sd)	Mean (Sd)		
PBL Refined	N= 12	9.30 (2.83)	11.00 (3.36)	N= 13	+ 18.1%
PBL Traditional	N= 14	9.53 (2.50)	11.27 (3.46)	N= 13	+ 18.3%

Sd = Standard deviation

The results on the GPA and on the pre-test provide support for the assumption that before the experiment the experimental and the traditional group were comparable with regard to prior knowledge. The comparability of the outcomes of the independent post-test measurement after the treatment implies that the groups did not differ in potential for learning. In general, the results suggest that the experimental and the traditional group may be considered to be equivalent on the control measures.

5.6 Results (2): Main Treatment effects

5.6.1 Data analysis

The main treatment effects were determined by analyzing the performance measures of the two groups. For the comparison non-parametric tests were used. The main focus of the analysis was to assess differences between the two conditions. Therefore the results were collapsed over three teachers.

Plot analysis of the data revealed that the distribution of the results on the dependent variables was not normal. Therefore a Kruskal-Wallis test (the Chi^2-test for 2 or more groups) for independent samples was used. Kruskal-Wallis examines the likelihood of several independent samples belonging to the same population. We used the SPSS-11.0 procedure 'Tests for Several Independent Samples' to compare the two conditions in the experiment.

5.6.2 Results of the problem-solving study

Table 4 shows the mean scores of the two student groups on the cognitive indicators that we used to analyze the protocols of the problem-solving assignment. The third column in table 4 shows the outcomes of the Kruskal-Wallis test (significance level .05).

Table 4: Analysis of performance indicators in the problem-solving exercise

	PBL Refined	*PBL Traditional group*	*K-W test p*	χ^2
Cognitive expertise indicator:	Mean (SD).	Mean (SD)		
Total use of concepts (%, 28 max.)	11.17 (0.048)	7.14 (0.05)	.048*	3.875
Basic concepts (%, 17 max.)	14.51 (0.05)	9.8 (0.07)	.055	3.687
Container concepts (%, 11 max.)	6.06 (0.06)	3.03 (0.05)	.172	1.867
Marketing principles (%, 5 max.)	1.40 (0.05)	0.00 (0.00)	.355	0.857
Total inferences (#)	6.73 (3.10)	4.58 (2.19)	.019*	5.472
Inferences descriptive (#)	5.87 (2.66)	4.17 (2.20)	.029*	4.774
Inferences causal (#)	0.93 (1.14)	0.42 (0.66)	.261	1.266
Inductions (#)	0.42 (0.51)	0.08 (0.28)	.040*	4.236
Deductions (#)	0.00 (0.00)	0.00 (0.00)	1.0	0.000
Diagnoses (%, 27 max.)	24.4 (0.06)	21.0 (0.06)	.165	1.932
Diagnostic accuracy (%, 54 max.)	19.14 (0.05)	14.81 (0.04)	.045*	3.971
Solutions (%, 8 max.)	35.0 (0.15)	30.0 (0.08)	.434	0.613
Solution quality (%, 16 max.)	30.0 (0.15)	18.49 (0.05)	.015*	5.871
Total N = 29	(N=15)	(N=14)		

* = significant at the 0.05 level
K-W = Kruskal-Wallis non-parametric test
\# = calculation is absolute (count)
% = calculation is relative and expressed as percentage of the maximum score (observed count divided by the maximum possible score).

First, the analysis of the total use of marketing concepts showed that the experimental group used more marketing concepts (especially basic marketing concepts) compared with the traditional group (p = .048). No significant differences were found for the use of *basic marketing concepts* (p = .055), the use of *container marketing concepts* (p = .172) and the number of marketing principles (p = .355). A striking finding is the very limited number of *marketing principles* generated by the subjects in both conditions. These results suggest that there were few differences between the experimental and the traditional group in the use of declarative knowledge during reasoning.

We found significant differences between the experimental group and the traditional group for the *total number of inferences* produced (p = .019) and the *descriptive type* of inferences (p = .029). The differences between the two student groups in the number of *causal inferences* were not significant (p = .261). Apparently, students in the experimental setting generated more descriptive inferences.

Further analysis showed that the experimental group produced significantly more *inductions* than the traditional group (p = .040), although the absolute number of inductions was low in all groups. *Deductions* yielded no significant differences between the groups. We conclude that the students in the experimental setting used more inductive reasoning during problem solving compared with the students in the traditional group. This suggests that the refined PBL setting stimulated forward reasoning.

The *quality of the diagnoses* demonstrated significant differences between the experimental and the traditional group (p = .045). The results on diagnostic quality were superior for the experimental group compared with the traditional group. No significant differences between the two groups were demonstrated for the *number of diagnoses* produced during problem solving (p = .165). These results suggest that the experimental group did not produce *more* diagnoses but that the ones they did produce were qualitatively superior to the diagnoses of the traditional group.

The *quality of the solutions* demonstrated a statistically significant difference between the groups (p = .015), with the experimental group generating better solutions. Finally, the *number of correct solutions* produced during problem solving did not differ significantly between the groups (p = .434). Apparently, the experimental setting led to superior rather than more diagnoses and solutions compared with the traditional PBL setting.

5.6.3 Tutor effects
To identify any tutor effects, a Kruskal-Wallis test was used with the three teachers as 'independent grouping variable'. The analysis showed no significant tutor effect for any of the cognitive indicators of expertise in table 4 (with a p-value varying from .171 to .848 and χ^2 varying between 3.528 and .330). This strengthens the hypothesis that the results can be attributed to the treatment.

5.7 Discussion
There is a growing awareness that instructional practices in PBL curricula should be grounded in cognitive research on learning and instruction. The present study was intended as a step on the road towards that goal. For measuring the cognitive outcomes of the refined PBL environment, we used four cognitive indicators (knowledge use, reasoning directionality, the quality of diagnoses and problem solutions).

Concerning *knowledge use*, the results of our study shows that students participating in the PBL refined condition used significantly more inferential knowledge while working on the authentic case. On the other hand, the results of our research indicated that the PBL refined group and the conventional PBL traditional group demonstrated the use of equal amounts of *formal* knowledge concepts. The latter outcome seems to be in contradiction with the first. Patel et al (1999) however argue that more advanced levels of expertise are *less* demonstrative in using declarative knowledge types during reasoning. They assume the advanced levels of expertise are associated with increases in tacit knowledge (Patel et al., 1999). Patel et al (1999) found that at higher expertise level, the use of formal science knowledge during reasoning is hardly demonstrated (Patel et al., 1999). This may provide a relevant explanation for our findings.

As for *reasoning directionality*, the results indicate that students participating in the redesigned PBL course produced more inductions (indicators of forward reasoning) during problem solving. This is a striking result considering that recent studies have indicated that PBL rather tends to stimulate backward reasoning. The experimental instructional design differed from the traditional PBL design with respect to the information given to the students: a rich problem description with a variety of irrelevant and critical raw company data. Above, on the task dimension of the refined instructional design, we supported student's reasoning on realistic cases. We asked the experimental group to schematize their analysis of the business case study on a form ('template') aiming to scaffold students' (metacognitive) problem-skills during problem solving. Hereby, students were stimulated not to choose rapidly a solution. Instead, we stimulated students first to scan and evaluate data in order to sort out irrelevant data. Furthermore, in the procedural dimension we used a structured form guiding the steps for students to first thoroughly studying problem data, instead of 'jumping' right into case solutions and looking for supporting data (backward reasoning). Possibly, these aspects of the redesigned course are what Albanese (2000) referred to as the 'active ingredients' of constructivist settings and may have promoted expert-like reasoning directionality.

Concerning the *quality of case diagnoses and solutions*, we found that students from the refined PBL condition outperformed the traditional PBL students. Interestingly, no differences were found for the *number* of diagnoses and solutions. Apparently, the approach we used to refine our traditional PBL design, helped students to analyse and solve professional problems on a qualitative higher level. Such support enables the learner during an intellectual task to progress beyond its very boundaries of competence (Rojas-Drummond, Mercer & Dawbrowski, 2001). On the social dimension, we added a true collaborative learning component to the traditional PBL setting. For the initial problem analysis, students worked in small team settings of four students that had the characteristics of cooperative and professional *teams*. Next, in groups of 14 students a discussion of the different team results was discussed. It is likely that emphasizing this collaborative component during the initial analysis of the problems, has positively contributed to individual students learning. The learner's exposure to alternative points of view out of the different teams, possibly enhanced the quality of students' analysis and solutions. Above in the task dimension the use of a variety of cases may have stimulated a rich brainstorm of problem analysis. A rich problem analysis may have had a *leverage* effect on the final problem solution quality.

Overall, our research results indicate that the combination of all the changes in the design facilitated the acquisition of a more advanced level of knowledge and skills in problem solving. This result may encourage educators to use elements of the redesigned PBL format and to further improve their educational settings. For instance, Arts, Gijselaers & Segers (2002) suggest that working in a small team setting on authentic problems requires a rather mature attitude of students with a relative high degree of responsibility. They suggest that in *higher* years of their studies, students are increasingly put in small, self-directed teams and have *gradually* more authenticity in their tasks.

Moust, Berkel and Schmidt (2004) recently argued that all instructional elements of PBL are related and that it is difficult to isolate one instructional element, as PBL employs an holistic approach. Following this idea, in the present study we used a 'design experiment' (Brown, 1992) consisting of a 'cocktail' of instructional refinements. Our coherent combination of changes in three dimensions of instructional design (social, task and procedural dimension) has stimulated the acquisition of a more advanced level of knowledge and skills in problem solving. This result may encourage educators to use (elements of) the redesigned PBL format and to further improve their educational settings.

In our study the assessment of the students' problem-solving expertise was accomplished using an authentic task with measures based upon cognitive theories of expertise. We found that students became better prepared to approach authentic task situations as may be found in this particular domain. We agree with Hmelo et al (1997, p. 403) that "methods adapted from research in cognitive science can be used to assess the products and processes of problem-solving and learning." The results of this study indicated that the measures used are able to capture the effects of the redesign which more traditional measures might not have been able to (Gijbels et al., 2005). For educational practice this implies that a careful consideration of the assessment instruments used is necessary. An implication is that curricular goals are in line with the assessment instrument used ("constructive alignment", see Biggs, 1996).

Although the results from the present study are encouraging, a few limitations should be taken into account.

First, the redesign of PBL described in this study is implemented in only one course. The results may have been affected by the small-scale implementation of the refined PBL design: we investigated only one course. On the one hand, the students might have been highly motivated by the experimental, novel character of the approach in this course. This might have contributed to the positive results of this study. On the other hand, it is often argued that educational innovations intending to affect students' learning, take time. However, the fact that we already found significant cognitive effects of after just one course is promising. Future research could investigate the more long-lasting effects, especially when this redesigned PBL environment is implemented on a larger scale in the curriculum. A related research suggestion is to find out to which extent our redesign is appropriate for other topic domains as business sciences.

Second, leaving the laboratory in order to design ecologically valid studies faces researchers with unforeseen conditions. In the present study we were confronted with small attrition in our final measurement, the authentic case study. As a consequence the sensitivity and power of our measurement might have dropped, even though we still found significant differences between conditions. Also, the effect of the redesigned course on students' problem-solving expertise was measured with one single authentic case. In order to generalize our results, further studies must be conducted on a larger scale and must use multiple cases at multiple sites.

Finally, in order to gain more insight in the mechanism of the redesigned learning environment, further research might focus on the analysis of small group interactions as compared to larger student groups (e.g. differences in the type of questions asked and feedback given). Such studies might reveal how small group interactions bring students' problem analysis to a higher level than those in the traditional PBL tutorial groups.

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APPENDIX

Below we explain the indicators of expertise (see figure 3):

Concepts were defined as typical classifications of managerial situations. Concepts in general enable us to reduce and label complex information. Concepts were scored when subjects demonstrated a marketing concept, reflecting a characterization of case information. Within concepts, a refinement was made into (a) '*basic*' concepts and (b) '*container*' concepts. *Container concepts* (e.g. '*competitive advantages*') contained more (condensed) information than a basic concept. Experts' schemata include many container concepts, which enable experts to retrieve and apply knowledge with much greater ease (Tanaka & Taylor, 1991). The maximum number of basic concepts determined by experts in the case canonical solution was 17, for the container concepts the maximum was 11.

Principles were defined as phenomena based on underlying quantitative rules or laws. Examples are marketing phenomena such as 'homogenization of needs', 'price elasticity' and 'economies of scale'. The maximum of relevant principles to be used in the case solution was 5.

Inferences were defined as dynamic transformations on data, using prior knowledge. Examples of inferences are conclusions or short summaries. We distinguished two types of inferences, paramount to problem solving (Bromage & Mayer, 1981). First we distinguished statements that characterized a situation, like: '*It is clear that they joined a large, leading and profitable firm'*. Such newly derived statements were defined as *descriptive* inference. It was assumed that these statements provided indications of the subjects' amount and comprehension of domain-specific, declarative knowledge. Second, *explanatory* inferences were defined as statements with a causal relation of the type: 'If Y then X', or: 'X is caused by Y'. Explanatory inferences can be typified as indicators of procedural knowledge. All causal (explanatory) inferences were further divided into deductive and inductive reasoning forms. We only scored inferences that were correct and related to the case solution model.

Inductions and deductions. An induction was defined as the ability to compare individual propositions and make inferences upon these propositions into general laws or conclusions. Inductive reasoning was demonstrated when a subject first stated one or more facts, and then drew a general conclusion. E.g.: '*The firm has acquired other firms. The firm has doubled turnover. (Induction:) These facts have led to a situation where competitive advantages in general occur*. Inductions served as an indicator of forward reasoning. By contrast, *deductions* served as an indicator of backward reasoning. Deductions were interpreted as providing particular pieces of information and evidence, after a general rule was stated, e.g. 'Generality X is applicable here. Fact A and fact B support this generality.

Case diagnoses were defined as identifying and explaining a case problem in terms of sources and causes. Subjects provided diagnoses in the problem-solving assignment and the more a diagnosis matched the experts' diagnosis, the higher the scores they received. Case diagnoses were scored as 'good' (2 points), 'moderate' (1 point) or 'incorrect' (0 points). The score 'good' implied that the student's diagnosis almost fully matched with our expert's diagnosis (the case answer keys) the case ; 'moderate' implied a partial match and 'incorrect' implied that students' diagnosis did not match at all with our expert's diagnoses. The maximum number of diagnoses for the case study was 27.

Case solutions were defined as directions or decisions for further action. At the end of the problem-solving assignment, subjects gave advice concerning the diagnosed situation. The case solutions provided, were divided into good (2 points), moderate (1 point) and incorrect (0 points) solutions. We used the same criteria for solutions as for defining *good*, *moderate* and *incorrect* diagnoses respectively. The maximum number of case solutions for the case study was 8.

CHAPTER 6 MANAGERIAL KNOWLEDGE, REASONING AND PROBLEM SOLVING: GENERAL CONCLUSIONS, DISCUSSION AND IMPLICATIONS FOR EDUCATION

6.1 Introduction

Given the complexity of the problems managers face today together with the affluence of information offer, managerial problem solving has become a complex process (Forbes & Milliken, 1999, Van Riel, 2003). Management education is expected to educate graduates who can handle complex work situations in ways for which the employers are calling for (Bigelow, 2001). However, despite improvements in many educational programmes, employers complain about graduates' difficulties in using formal (theoretical) knowledge in practical contexts, and criticize their ability to solve problems in practical (ill-structured) settings (Boyatzis, Cowen & Kolb, 1995; Business-Higher Education Forum, 1999). Moreover, the employers' critics on graduates are in line with the findings from research on expertise. Studies in this field have indicated transitory problems from the school to workplace context (e.g. Boshuizen, 2003). In sum, it seems that there is a discrepancy between what students learn in management education and what is required at the workplace. A question that arises is: how can managerial learning environments be adapted in order to be more effective?

While conceptualizing the present thesis, we started from an educational perspective. We aimed for optimizing learning environments in management education in order to educate graduates who are able to effectively solve authentic managerial problems. Looking for appropriate criteria for the design as well as the evaluation of newly designed learning environments, we used former studies on expertise as a source of information. These studies indicate the characteristics of experts in comparison with novices and how expertise is developing. However, few expertise studies were conducted in the field of management. In order to (a) validate previous expertise research in the context of managerial expertise and (b) examine managerial expertise (chapters 2 and 3) we started our research by studying managerial problem-solving, and the knowledge related to this process. For these two studies, the cognitive information processing perspective on managerial knowledge and problem-solving played a central role. Drawn on the results of our novice-expert research studies (Arts, Gijselaers & Boshuizen, 2000), a learning environment was redesigned. Next in two studies (with an experimental and control groups, Arts, Gijselaers & Boshuizen, 2006; 2000) we evaluated the cognitive merits of this redesigned instructional environment (see chapters 4 and 5. In the next section we will summarize and discuss the findings of all four studies.

6.2 Managerial expertise (Chapters 2 and 3)

In two studies (Arts et al., 2006; 2000) we investigated managerial problem solving abilities and the nature, the role and the use of managerial knowledge. We addressed differences between novices and experts during problem solving by comparing 115 participants (ranging from managerial novice students to managerial experts). All participants were asked to recall and solve realistic, managerial problems. The research questions aimed at investigating how persons with different levels of managerial experience (a) process and represent information, (b) use knowledge (c) diagnose and solve problems.

In our first study (Arts et al., 2000) we found that managerial experts differ from novices and intermediates by the quality of their problem representation. Experts represented managerial cases more effectively by (a) selecting relatively *little* case information and (b) using *relevant* information. In fact, in representing a managerial case, managerial experts hardly selected any irrelevant case facts. Another finding was that managerial experts represented problem information by focusing on the meaning (semantics) of case information rather than on superficial and literal aspects. Taken together, experts made a qualitative better problem representation in a compact format. These results are in line with expertise research in other domains and hence confirmed our expectations.

Additionally, the findings showed that managerial reasoning (during typical problem solving) of *experts* is typically characterized by the use of many inferences. By contrast, intermediate students and graduated students produced fewer inferences and had difficulties in linking their academic knowledge with the case information. We have found evidence that it is the use of formal knowledge in a dynamic way or so-called 'dynamical' knowledge which is strongly related with experts' performance. Dynamical knowledge strongly correlated with the ability of providing correct case solutions, which underscores the importance of this knowledge as a determinant of managerial cognitive performance. The results indicate that while progressing toward the level of experts at the 'workplace' stage, a shift occurs from the demonstration of large amounts of theoretical knowledge (knowing 'what') towards the production of dynamical knowledge (such as 'knowing how rules/procedures', at the expert level).

Our conclusion is therefore that the outcome of inferential processes, dynamical knowledge, is the most important indicator of managerial problem-solving performance at the expert level and a key of managerial cognitive performance. It is this knowledge that differentiates novices from experts. Nevertheless, as 'linking' formal discipline knowledge with information encountered creates dynamical knowledge, formal discipline knowledge is a necessary prerequisite for producing dynamical knowledge. Therefore we argue that *both* dynamical knowledge and formal knowledge are necessary for outstanding cognitive performance. We concluded that it is '*practical experience*' which steers the transformation of theoretical knowledge into 'dynamical' or 'applied' knowledge.

With respect to the development of managerial problem-solving competences, the results of our study (Arts et al., 2006) indicate that solving problems develops from a *quantitatively* high output at student's intermediate expertise level (providing many, but moderate solutions) toward providing fewer but *qualitatively* better solutions at the higher expertise levels. Simultaneously, the experts demonstrated less theoretical knowledge while their problem solving accuracy continuously increased. The question arises: at which stage does excellent managerial cognitive performance occur? Will managers display 'excellent' expert problem-solving performance after they have gained more than 10 years of work experience?

We defined excellent or 'true' expert performance as providing both fully accurate diagnoses and fully accurate solutions problem. We found that only after about 8-10 years of managerial practice, the *solution* providing accuracy of graduated students is at a sufficiently high output level. That is, only after about 8-10 years of practice, the number of *correct* case solutions exceeds the number of *partially* correct solutions provided. On *diagnostic* ability we found that this develops in a linear way implying that experts demonstrate excellent diagnostic performance; only at the students' level incorrect diagnoses were made.

Overall, these results (in the managerial sciences) meet the criteria of definitions of experts in other domains such as medicine (Boshuizen & Schmidt, 1995; Patel, Arocha, & Kaufman, 1999) or chess (Simon and Chase, 1973). For instance Ericsson and Smith (1991) have defined experts as participants having at least 10 years of working experience. Finally, we addressed the question: What characterizes novices and experts on the use of *time* during problem solving? The results suggest the pattern of an inverted U-curve: We found that students at intermediate level used most time in solving their cases while experts required even less time than novices to diagnose and solve the case.

Table 1: A summary of the results of the studies on expertise development

Problem-solving stage:	**Novices**	**Intermediate/ graduate level**	**Experts**	**Relation between levels of expertise**
Amount of information selected during problem representation.	Medium	High: intermediate maximum.	Low	Inverted U-curve
Amount of critical information selected ('selective perception ability').	Low	Medium	High	Linear
Use of discipline knowledge during reasoning	Low	High: intermediate maximum.	Medium	Inverted U-curve
Use of 'dynamical' (applied) knowledge during reasoning: inferences.	Low	Medium	High	Linear
Diagnostic accuracy	Low	Medium	High	Linear
Problem-solving accuracy	Low	Medium	High	Linear
Number of case problems provided	Medium	High: intermediate maximum.	Low	Inverted U-curve
Time used during problem solving	Medium	High: intermediate maximum.	Low	Inverted U-curve

Table 1 summarizes the results of the expertise studies in Chapters 2 and 3. In Table 1 we observe a peak in quantitative cognitive output at intermediate expertise level with respect to the amount of irrelevant information selected, discipline knowledge use, number of case problems generated and time used during problem-solving. How can we explain these results?

The fact that intermediate students reproduced more case information than the other groups may be explained by an excessive selection of (ir-)relevant case information. Although students seem to have a large amount of discipline knowledge, they seem not to be able to use this knowledge in order to select the relevant case information. Students make operations on *both* relevant and irrelevant information (Arts et al., 2000, Patel & Groen, 1991). The selection of irrelevant problem information can lead to performing many (irrelevant) problem-solving searches resulting in many solution possibilities and many faults during reasoning (Boshuizen & Schmidt, 1992; Patel & Groen, 1991). Overall, this ineffective process may explain why participants at intermediate levels used so much *time* in solving their cases.

In contrast to this *intermediate* behaviour, managerial *experts'* problem solving was found to be much more effective than lower expertise levels. In general, we found that experts outperform all the others (novices, intermediates and junior-experts) by the quality of their solutions, the time needed to perform the task, and the amount of dynamical (applied) knowledge. One explanation is that experts start reasoning on more relevant information (Arts et al., 2000; Patel & Groen, 1991), selecting the for the problem relevant discipline knowledge and hence starting the reasoning process with a good problem representation (a small but relevant set of problem-solving information). This leads to fewer but very accurate diagnoses and solution alternatives. It is clear that, in comparison with novices and intermediates, the expert problem-solving process takes relative little time. Another reason why our experts used less time, is that they have executed certain problem-solving steps in other situations, some procedural steps are compiled (Anderson, 1990) skipped or automated. The reduction in the number of steps used during problem solving and their effective use of knowledge can explain the speed experts are able to achieve.

In chapters 2 and 3 we further concluded the following:

1. The fact that we found indications for several inverted U-curve relations demonstrates that progress in expertise is not so *straightforward* (linear) as often suggested by studies with a dichotomous approach, but a road with ups and downs and trade-offs. For instance, our findings confirm the hypotheses raised by researchers like Boshuizen (2003) concerning *discontinuous* cognitive progress of young employees as they enter the workplace after graduation.

2. Our results demonstrate that managerial knowledge is not static but that theoretical knowledge significantly develops after qualification. In our vision, dynamical knowledge (represented by inferences) is a demonstration of discipline knowledge that is further developed through the application in practical settings. Therefore, we agree with Eraut (1994), who argues that most formal knowledge acquired in a school context strongly further develops after qualification.

3. Our data show that the path towards expertise in fact cannot be characterized 'in general' but depends on the *indicator* of expertise (e.g. knowledge, or skill) that is considered. The notion that expertise is a concept with various aspects that develop at different rates is gaining influence. Therefore, several indicators of expertise must be employed (e.g. both knowledge and skills) when studying expertise. For instance, problem-solving *abilities* such as selecting, representing, inferencing and diagnosing, develop in a rather linear way. However, the demonstration of theoretical knowledge did not show a linear path but reaches a maximum at intermediate level.

4. Overall, we identify three cognitive stages in the development from managerial novice to expert:

- The first stage is characterized by a *quantitative* growth in the production of diagnoses, solutions and knowledge types during reasoning.
- A second stage (that generally occurs after graduation) is characterized by '*confusion', followed by consolidation* of the quantitative output and it seems as once graduates enter practice, they have to re-think their problem-solving behavior and re-organize the knowledge acquired and perform many irrelevant reasoning searches.
- We entitle the third stage as 'accomplishment of *qualitative* performance' ('competency').

Overall, we conclude that problem-solving expertise passes from a quantitative growth toward a more *qualitative* output.
We further conclude that findings on expertise in traditional and 'mature' domains (physics, biology, mathematics) and rather well-structured domains (e.g. medicine) hold for the management sciences. Management is a rather young academic domain with mostly ill-structured problems (Osana, Tucker, & Bennett, 2003).

Implications for instruction

1. Experts at the workplace can provide young employees more *feedback* and *reflection* on their performances. Based on empirical evidence, Ericsson (2004) concludes that ideal conditions for improving expert performance are activities such as *detailed* and *immediate feedback* on performance. Monitoring and reflecting on one's own performance can refine cognitive mechanisms, leading to continuous learning (Ericsson, 2004). Senior-experts may help junior experts them to *reflect* on the (erratic) stages they passed through, and the lessons they learned.

Through such reflection tacit managerial knowledge can become conscious (Argyris, 1991). In personal *portfolios* such reflections can be mapped as acquired competences.

2. The *authenticity* of cases and assignments should be more enhanced in order to meet the ill-structured nature professional practice. Too often cases are pre-interpreted or pre-formatted for educational purposes, or examples are presented as a 'dummy'. Authentic cases however can engage students in the cognitive processes *required* at the workplace. Such cases can evoke the pivotal process of interpreting and inferencing on 'raw' case data.

3. Next to 'bringing the packaged workplace to education (e.g. by offering authentic cases) students can be sent *more* and in *earlier stages* to the managerial practice. Mintzberg (2004) argues that MBA-education has little effect when students have no managerial experience. Similarly, Eraut (1994) proposes to postpone the discipline knowledge offered, until theoretical knowledge is encountered in a professional context. Practical experiences can possibly foster a meaningful interpretation of management theories. Such workplace experiences (in early cognitive stages) can possibly be a solution for bridging a gap between theory and practice.

4. In general an educational program should be adapted to the different *cognitive maturity stages* that students pass through. An example is that curricula can put *gradually* more authenticity in their tasks at higher or final years of education. We suggest incorporating in all bachelors programs an important 'practical' component such as an internship or an assignment in practice, lasting several weeks. The educational functions of such a practical confrontation are: better understanding and retention of to-be-learned theories (Arts, Gijselaers & Segers, 2002; Mintzberg, 2004), but probably also a good orientation on the workplace and a higher motivation to continue studying.

5. Considering the non-use of academic knowledge and slow development of problem-solving, we contend that higher education should also devote more attention in their curricula to *de-contextualizing* the practical (but *context*-related) knowledge that students have arrived at. De-contextualizing knowledge can bring the lessons learned from one typical situation to a higher level of general rules and principles. In our opinion, this process is the key for applying acquired knowledge in other, different contexts.

6. Our studies showed that transfer of knowledge does not occur spontaneously (Bereby-Meyer & Kaplan, 2005) and our results support the claim of Eraut (2004) that the transfer of knowledge from to the professional workplace is more complex than just applying knowledge to another context. Therefore, Patel et al. (1999) argue that education should go beyond the acquisition and use of formal knowledge and that formal education should include 'professional actions' like selection of relevant cues, evaluation of context information. Linking formal knowledge with practical contexts can only be effectively carried out, when appropriate situations resembling the workplace have been experienced. We think that education should engage students in *similar* cognitive activities as required at the workplace.

7. The *transfer* of domain-specific managerial knowledge (the usability of knowledge) in practical settings can be stimulated by applying recent learning theories that propose to *vary* and compare cases/problems (e.g. Bransford, Brown & Cocking, 1999). Problem-solving expertise can be fostered by practicing in *categorization* of critical features of practical situations case studies (Bowden & Marton, 1998). As a meta-cognitive strategy students can discern the 'critical' and 'strategic' aspects of practical situations, when they encounter 'typical' practical situations. In this context, Bereiter and Scardamalia (1993) distinguish 'routine experts' that are experienced in solving *similar* problems, and 'dynamic experts' who continuously address more challenging and new problems ('progressive problem-solving'). For acquiring this '*dynamic'* type of expertise that enables problem solving in different contexts, individuals should also solve *atypical, non-routine* problems, (Bereiter & Scardamalia, 1993).

The instructional guidelines above have steered the redesign of a learning environment (in chapter 4) that intended to improve students' quality of problem-solving. Our goal was to raise the level of expertise of the students to a higher level. We based our new instructional design on (a) research on expertise in PBL-environments (such as our studies in chapter 2 and 3), (b) expertise studies in general, (c) studies in the domain of case-based reasoning and knowledge transfer, and (d) our lessons on learning in PBL curricula. The leading question was to redesign a learning environment (a PBL marketing course) by using the outcomes of the expertise research in Chapter 2 and 3 and of previously performed expertise research.

6.3 A redesigned instructional environment and its' cognitive outcomes (Chapters 4 and 5)

With the two studies summarized in Chapters 4 and 5, we intended to enhance the development of expertise by redesigning a learning environment based on the instructional guidelines derived from expertise research. One of the central aspects of the redesign was the increased authenticity in terms of cases and assignments as well as processes. By using ill-structured cases we tried to evoke the pivotal process of interpreting and inferencing on 'raw' case data. Additionally, by using many cases, we stimulated students towards de-contextualizing the practical and context-related knowledge they have arrived at when analyzing one case. De-contextualizing knowledge can bring the lessons learned from one typical situation to a higher level of general rules and principles that are applicable in other contexts. Additionally, we used lessons learned from research on learning in authentic professional contexts (Brown, Collins, & Duguid, 1989) research on transfer (Bransford, Brown & Cocking, 1999) and from recent views on case-based reasoning (Kolodner, Gray & Fasse, 2003). Beside enhancing the authenticity of the case studies by using raw data from real companies, we (1) gave the students, in comparison with the first year of study, more control and responsibility over their tasks; (2) stimulated collaboration by working in small, self-steering teams, supported by electronic tools; (3) used a variety of authentic case studies as well as 'discussion-points' that students had to formulate in order to stimulate de-contextualization knowledge toward a more abstract and general level (Baets & Van Der Linden, 2000) and to enhance knowledge transfer; (4) assessed the cognitive merits with realistic business problem contexts.

We explored to which extent this redesigned instructional approach has resulted in cognitive *merits* in terms of knowledge acquisition and organization as well as the quality of the reasoning and problem-solving *process* of learners. The results (Arts, Gijselaers, & Segers, 2002) indicated that the redesigned PBL-format, as measured by the end-of-course case-based assignment, contributed significantly to improved *application* of managerial knowledge, as compared to the regular PBL-setting. No differences were found on *reproduction* of acquired knowledge.

Additionally, the analyses of student performances on an authentic case study indicated that the instructional intervention resulted in more production of '*practical*' knowledge, when compared with the regular PBL-setting. Above, the experimental students demonstrated superiority on: a) inductive reasoning behavior, b) diagnostic quality, and c) quality of case problems provided. Concerning *use of knowledge*, the results of our study show that students participating in the re-designed PBL-condition demonstrated significantly more inferential knowledge while working on the authentic case. On the other hand, the results of our research indicated that the 'experimental' and the 'conventional' PBL group demonstrated equal amounts of *formal* knowledge concepts. As for *reasoning directionality*, the results indicate that students participating in the redesigned PBL course produced more inductions (indicators of forward reasoning) during problem solving. Concerning the *quality of case diagnoses and solutions*, we found that students from the refined PBL condition outperformed the traditional PBL students.

Overall, the research results indicate that the combination of all the changes in the design facilitated the applicability of marketing knowledge in practical settings as well as students' problem-solving abilities in terms of reasoning, diagnosing and solving problems. This may encourage educators in marketing, or related social studies, to use elements of the redesigned PBL format and to further improve their educational settings. Suggested elements that can enhance learning are what Albanese (2000) referred to as the '*active ingredients*' of constructivist settings:

1. Concerning the redesigned *task* dimension, the enhanced authenticity of the problem descriptions may have contributed to more elaborated thinking upon information and better understanding of knowledge. In our studies, participants had almost completed two years of university education. As a result, these students had already encountered many PBL-courses with many problem-solving tasks. In this situation, that is, having students with experiences with the process of problem-solving, we think that authentic cases can be effective and stimulate learning. An example is a study from Vermetten, Vermunt, and Lodewijks (2002) who found that authentic materials worked on in groups, lead to improved performances of students if the authentic approach is a prominent element of the curriculum.
   A question is if students who are not experienced with working on problems would benefit from our approach. We suggest that curricula can gradually use more authenticity and complexity in their problem tasks, when reaching higher or final years of education.

2. Concerning the second dimension that we manipulated, *social collaboration*, it is likely that emphasizing this collaborative component (working in small teams) during the initial analysis of the problems, has positively contributed to individual students learning. The learner's exposure to alternative points of view and the discussion on these views in order to come to a first collaborative analysis possibly enhanced the quality of students' analysis and solutions. Therefore, in line with Vermunt and Verloop (1999), we suggest that students *gradually* work in small, self-directed teams on real tasks and projects.

3. The *procedural* dimension is related to 'how' students approach problem solving (meta-cognitive strategies), focusing on the processes of knowledge representation, diagnosing and solving problems. In our redesigned course we emphasized the

importance of first evaluating problem data in order to sort out irrelevant data (knowledge representation). First thoroughly studying data may prevent 'jumping' right into case explanations and solutions and looking for supporting data (backward reasoning).
Additionally, we focused on de-contextualizing practical (and *context*-related) knowledge. Therefore, we used a multitude of cases in order to stimulate students to evaluate the relevance of the previously used knowledge for the problem situation as presented in the novel case. Additionally, we suggest adding such a 'step of '*reflection*' to the final phase of any practical component in education (case, assignment or exercise). For instance, a step of reflection and focus on the question like 'what general rules have we learned' after solving a problem in case-based learning or after analyzing a problem during PBL-education, may possibly stimulate the de-contextualizing of knowledge.
Another suggestion related to the procedural dimension is providing students *expert* model cases that are already solved, to show students *how* experts successfully approach authentic cases, before students solve ill-structured cases themselves. In that way, students may become more conscious of expert-like aspects of problem-solving.

4. Similarly on the dimension 'student-tutor' *control*, students can progressively be given more control over the learning process as they advance toward the highest years of their studies (see e.g. Vermunt & Verschaffel, 2000). In that way, the level of student control during instruction can be congruent with the cognitive developmental stages (i.c. maturity) of students. In higher classes, the degree of students-tutor scaffolding can decrease and students can be gradually given more responsibility over their tasks.

5. A fifth instructional dimension that we consider is '*assessment*'. If educators aim to enhance the development of various aspects of expert problem-solving, they should not only consider the design of the learning environment but also of the assessment practices. It is well-known from former research that assessment drives learning (Dochy, Segers & Sluijsmans, 1999). This implies that only when the assessment is in alignment with the goals and the instructional approaches of the curriculum, students, effects of the design might be expected.

Finally, on the use of *electronic (web-based) tools* we conclude that such tools can support all five instructional dimensions. Especially, electronic tools scan support the delivery and availability of authentic company materials, and the collaboration between individuals.

Suggestions for future research
Our intervention study (Arts et al., 2002; 2006) can be referred to as a 'design experiment' (Brown, 1992) as it is an attempt to explore cognitive effects as a result of a coherent set of changes (in the task, control and social dimensions of a PBL environment). The central idea in design experiments is to capture the design process of creating and evaluating an innovation in education by uniting cognitive research and concurrent design of learning technologies. However, in our design it is not possible to disentangle the effects of specific factors of the learning environment on students' development of expertise. As a result our studies addressed the effects of the *overall* design of the learning environment, attribution of cognitive merits to specific context factors remained unclear to some extent. Other

(experimental) intervention studies can further investigate which *specific* instructional measure influences which cognitive outcomes.
Also, it is unclear by which *attitudinal* mechanisms the redesign has led to the observed expertise outcomes. Learning is basically making an interpretation of information out of reality, by using one's experiences, skills, but also personal attitudes. And expertise cannot be fully understood if disconnected from factors such as personal interest, goals, attitudes, or beliefs (Alexander, Sperl, Buehl, Fives, & Chiu, 2004) and social aspects. Therefore, it might be interesting to study the role of motivation, goal setting, and interest. An example of such research is investigating the influence of personal goals or interest on the quality of reasoning and problem solving.

Next, Salomon (1996) argued that implementing new constructivist learning environments should also be accompanied by the assessment of *new* cognitive learning goals. For example, in designing a learning environment that assumes different group knowledge construction processes, one should also investigate *process* outcomes related to aspects such as shared understandings, as well as cognitive tests. Future research could investigate such process related outcomes of the redesigned learning environment. An analysis of the PBL process could also possibly reveal which components of the ALE were responsible for producing the cognitive gains.

A related issue is the preparation of students for 'future learning'. We measured students' cognitive outcomes at one particular moment: that is, at the end of one particular course. However, Bransford and Schwartz (1999) argued that such knowledge tests do not capture the process of preparation for *future* learning. It may be that students in our authentic (experimental) settings have acquired skills for more effective future learning. Future research into the processes of learning could demonstrate whether the students from the experiment can induce knowledge more effectively when confronted with authentic problem situations. Also, as students acquired knowledge independent from a tutor, it may be that this has enforced their ability of future learning. A suggestion for future research is therefore to investigate the effects of our redesigned learning environment on students' ability for 'future learning'.

This also raises the question: what would be the effect of this redesign if the instructional approach is used at curriculum level, in many courses simultaneously. The fact that we already found significant cognitive effects of after just one course is promising. Future research could investigate the more long-lasting effects, especially when this redesigned PBL environment is implemented on a larger scale in the curriculum.

Suggestions for future *expertise research* are that such research can examine whether our findings in the managerial sciences can be cross-validated in other (academic) domains, especially in professional domains with a strong diagnostic orientation such as the health sciences or law.

For the present study a *cross-sectional* design was necessary for investigating a large range of expertise levels. A research suggestion is to conduct a *longitudinal* study examining cognitive changes over a short period of 2-4 years (for instance with a focus on the school-to-work transition). This may allow researchers to follow individuals from of graduation until the first years in the work force. Such a longitudinal study could provide more detailed information on individual trajectories.

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SAMENVATTING (SUMMARY IN DUTCH)

Om goed te kunnen functioneren in de huidige 'informatiemaatschappij' zijn cognitieve vaardigheden zoals het selecteren, analyseren en synthetiseren van grote hoeveelheden diffuse informatie erg belangrijk geworden. Een van de centrale doelstellingen van het huidige universitaire onderwijs is dan ook studenten te leren hoe ze authentieke problemen, die meestal een grote mate van complexiteit hebben, kunnen identificeren en oplossen. Ondanks het stellen van dit soort doelstellingen blijkt uit onderzoek dat veel afgestudeerden moeite hebben hun verworven kennis te koppelen aan praktijkproblemen.
In verschillende arbeidsmarktrapportages wordt gesuggereerd dat er mogelijk een discrepantie is tussen de soort kennis en vaardigheden die enerzijds het hoger onderwijs aanbiedt en anderzijds de werkplek vraagt. Een eerste aanleiding van het onderzoek in dit proefschrift is dan ook dat de overgang van het (universitaire) onderwijs naar de werksituatie soms problematisch (of: met schokken) verloopt. Een tweede aanleiding voor deze studies is dat er in het (relatief jonge) vakgebied management en organisatie weinig bekend is over hoe de ontwikkeling van kennis en vaardigheden verloopt van student tot expert. Hierbij dienen zich vragen aan als: welke soort kennis speelt nu een belangrijke rol bij het oplossen van management problemen? Welk kennisgebruik en welke probleemoplosvaardigheden kenmerkt de beginnende student, de vergevorderde student, de recent afgestudeerde of de expert met jarenlange werkervaring?

Het centrale object van de studies in dit proefschrift is de aard en het gebruik van de kennis en vaardigheden bij het oplossen van problemen door personen in verschillende fasen van hun expertise ontwikkeling op het terrein van management. Het geheel aan kennis en vaardigheden om op juiste wijze problemen in een bepaald vakgebied aan te pakken definiëren we als *expertise*. Met expertise *ontwikkeling* wordt bedoeld het over loop van *tijd* ontwikkelen van de vaardigheid in probleemoplossen (door juist gebruik van management kennis). Het gebruik van de management kennis en vaardigheden is bestudeerd via het oplossen van realistische ('slecht-gestructureerde') problemen uit het werkveld. Om dit object te bestuderen hebben we enerzijds de kenmerken van management expertise in verschillende fasen van expertiseontwikkeling in kaart gebracht. Anderzijds hebben we via een interventiestudie de invloed van een leeromgeving op expertise ontwikkeling

Dit heeft geresulteerd in twee studies over management expertise (hoofdstuk 2 en 3) en twee studies over het optimaliseren en testen van een leeromgeving (hoofdstuk 4 en 5). Hoofdstuk 4 en 5 analyseert de leeruitkomsten van de 'geoptimaliseerde' leeromgeving en er wordt onderzocht of er een verbetering is bij studenten in kennisgebruik en probleemoplosvermogen.

Hoofdstukken 2 en 3: onderzoek naar management expertise (kennis en probleem-oplosvaardigheden) vanaf de schoolcontext tot op de arbeidsmarkt

Het object van de expertise studies in hoofdstuk 2 en 3 waren negen verschillende expertiseniveaus: van beginnende studenten Managementwetenschappen tot en met zeer ervaren management experts met 25 jaar werkervaring. In totaal waren er bij deze expertisestudies 115 deelnemers betrokken. Aan deze deelnemers is gevraagd enkele business cases te analyseren en diagnosticeren. Alle handgeschreven uitwerkingen van deze casussen zijn geanalyseerd op informatie verwerking, gebruik van management kennis, probleemoplosaccuraatheid en gebruik van tijd.

In hoofdstuk 2 is het proces van verwerking en representatie (beeldvorming) van probleeminformatie onderzocht (de eerste stap tijdens het probleemoplosproces). Gevonden werd dat experts een kwalitatief hoogwaardig beeld van een probleemsituatie opbouwen. Experts selecteerden weinig èn ook relevante informatie terwijl de probleemrepresentatie van studenten ook veel irrelevante informatie bevatte. Een andere vinding was dat experts een situatie 'betekenisvol' vertalen in eigen bewoordingen, terwijl studenten veel letterlijk gegeven zaken onthielden.

In hoofdstuk 3 is het redeneerproces onderzocht tijdens probleemoplossen. Gevonden is dat het redeneerproces van experts wordt gekarakteriseerd door het gebruik van veel afleidingen of 'inferenties'. Inferenties beschouwen we als actieve ('dynamische') bewerkingen van informatie met kennis. Studenten en recent afgestudeerden demonstreerden tijdens probleemoplossend redeneren duidelijk minder inferenties dan experts. Hoewel studenten en afgestudeerden lieten zien dat ze over veel theoretische kennis beschikten, konden ze slechts beperkt deze kennis linken aan de gegeven praktijksituaties. Blijkbaar is het bezitten van een theoretische kennisbasis geen garantie voor daadwerkelijk toepassen van de kennis. Deze resultaten bevestigden onze eerder gestelde hypothese over problemen met kennistransfer van recent afgestudeerden in de transitie van onderwijscontext naar de professionele praktijk.
Samengevat lieten de resultaten betreffende kennisgebruik een transitie zien van het gebruik van veel theoretische kennis op studenten niveau naar 'dynamisch' kennisgebruik (veel transformaties op informatie met kennis) op de hogere expertise niveaus.

Betreffende probleemoplosvaardigheid, vonden we dat de lagere expertise niveaus zoals studenten een hoog aantal oplossingen genereren maar van lage kwaliteit, terwijl de hogere expertiseniveaus juist weinig maar goede oplossingen genereerden.

De vaardigheid in het volledig accuraat oplossen van problemen ontwikkelde zich vrij traag; Pas na tien jaren werkervaring lieten werkenden volledig accurate diagnoses en probleemoplossingen zien. In de onderstaande tabel zijn de bevindingen uit hoofdstuk 2 en 3 samengevat.

Tabel 1: Een samenvatting van de onderzoeksbevindingen gerelateerd aan de indicatoren van expertise

Probleemoplos indicatoren:	**Beginners**	**Intermediate niveau** (op of rond afstuderen)	**Experts**	**Relatie tussen expertise niveaus**
Diagnostic accuraatheid	Laag	Medium	Hoog	Monotoon toenemend
Probleemoplosaccuraatheid	Laag	Medium	Hoog	Monotoon toenemend
Aantal gegenereerde casus oplossingen	Medium	Hoog: maximum	Laag	Omgekeerd U-curve verloop
Gebruik van discipline kennis tijdens redeneren	Laag	Hoog: maximum	Medium	Omgekeerd U-curve verloop
Gebruik van dynamische kennis	Laag	Medium	Hoog	Monotoon toenemend
Hoeveelheid verwerkte (ir-) relevante) casus informatie	Medium	Hoog	Laag	Omgekeerd U-curve verloop
Vaardigheid van strategisch informatie opnemen (relevante informatie selecteren).	Laag	Medium	Hoog	Monotoon toenemend
Tijd gebruikt tijdens problem solving	Medium	Hoog: maximum	Laag	Omgekeerd U-curve verloop

Uit tabel 1 is af te leiden dat de experts alle andere expertiseniveaus (novices, intermediates en junior-experts) overtroffen in de kwaliteit van probleemoplossingen, de benodigde tijd om een taak uit te oefenen en de hoeveelheid daarbij gebruikte dynamische (toegepaste) kennis.

De resultaten uit hoofdstuk 2 en 3 suggereren verder dat studenten het proces van probleemoplossen niet erg effectief uitvoeren. Ten eerste voerden novice (studenten) geen kwalitatief hoogwaardige analyse uit van problemen. Ook in eerder uitgevoerd onderzoek is gevonden dat studenten in een probleemgestuurd (PGO) curriculum de neiging hebben naar oplossingen te willen zoeken, nog voordat ze een gefundeerde probleemanalyse hebben gemaakt. Het gevolg hiervan kan zijn dat veel irrelevante informatie wordt meegenomen in het redeneerproces wat kan leiden tot irrelevante redeneringen. Als geheel kan dit leiden tot inefficiënt probleemoplosgedrag. Dit kwam in het onderhavige onderzoek tot uiting in de verschillende 'pieken' die we vonden bij de intermediates' (personen op of rond het afstuderen); we concludeerden dat deze proefpersonen (a) erg veel tijd gebruikten om problemen op te lossen, (b) relatief veel onbewerkte ('ruwe') casus feiten reproduceerden, (c) en juist de meeste casus oplossingen genereerden, terwijl (d) hun diagnoses en probleem oplossingen van middelmatige accuraatheid waren. Verder demonstreerden deze zg. 'intermediates' een grote hoeveelheid aan theoretische leerboekkennis, maar waren ze niet in staat veel afleidingen te maken met deze kennis. Het lijkt het er op dat de onderzochte studenten in het onderwijs dat ze volgen wel leren een probleem te analyseren, maar dat ze daarbij erg in de breedte gaan, en veel mogelijke (en irrelevante) oplossingen genereren. Het lijkt er ook op dat studenten in het onderzochte (PGO-) curriculum juist minder goed leren om (a) correcte oplossingen te genereren en (b) om te *kiezen* uit verschillende oplossingen.

Op basis van de resultaten van de studies in Hoofdstuk 2 en 3 concluderen we het volgende:

- Het verloop (of: de ontwikkeling) van expertise verloopt niet zo rechtlijnig (lineair) als vaak wordt gedacht. Het verloop van afgestudeerde naar werknemer bijvoorbeeld laat een *discontinu* verloop zien. Meer in detail lijkt de weg naar expertise voor 'kwantitatieve' indicatoren een U-curve te vertonen (m.n. voor de hoeveelheid gebruikte kennis en het aantal gegenereerde diagnoses en oplossingen). Kwalitatieve expertise indicatoren lijken daarentegen een lineair verloop te vertonen (m.n. voor de vaardigheid van het kunnen toepassen van kennis en het genereren van kwalitatief goede probleem-oplossingen).
- De resultaten betreffende informatieverwerking laten een verloop zien van het opnemen van veel en (ook) irrelevante informatie bij beginners naar het opnemen van weinig (en relevante) informatie bij experts.
- De resultaten betreffende *kennis* laten een transitie zien van het gebruik van theoretische kennis naar het gebruik van inferenties (afleidingen en transformaties op informatie) op expert niveau.
- *De resultaten betreffende probleemoplossen* verloopt van kwantitatief (veel oplossingen genereren, veel tijd gebruiken) naar kwalitatief (weinig maar goede oplossingen genereren).
- Globaal zijn er drie cognitieve hoofdfasen te onderkennen in de ontwikkeling van beginner naar expert:
  1. De eerste 'onderwijs' fase wordt getypeerd *door een sterke kwantitatieve* groei in het aantal diagnoses, oplossingen and en kennis types tijdens probleemoplossen.
  2. Een tweede 'overgangs' fase (op en na afstuderen) wordt gekenmerkt door 'zoekend' en ineffectief probleemoplosgedrag, gevolgd door een zekere consolidatie Hier lijkt het dat als afgestudeerden eenmaal in de praktijk komen, ze enigszins verward lijken en hun probleemoplosgedrag moeten aanpassen.

3. De derde fase (na meer dan 10 jaar werkervaring) is te karakteriseren als *kwalitatief hoogwaardig* (competent) probleemoplosgedrag.

Met de resultaten van de expertise studies in hoofdstuk 2 en 3 zijn verschillende implicaties gemaakt voor leeromgevingen:
- Voor het verbeteren en versnellen van het probleemoplossen van recent afgestudeerden suggereren we meer *senior expert begeleiding* op de werkplek. Deze senior collega's kunnen als 'coach' *feedback* en *reflectie* geven op het functioneren van een jonge werknemer.
- De vinding dat hoge accuraatheid in diagnostisch vermogen en in probleemoplossen pas na 10 jaar of meer werkervaring optrad impliceert dat bepaalde banen met grote verantwoordelijkheden (bv. medische operaties of banen in de vliegtuigsector) pas 10 jaar ervaring volledig zelfstandig kunnen worden uitgevoerd.
- Voor het stimuleren van kennistransfer zouden lerenden en werkenden niet alleen prototypische problemen moeten oplossen maar ook juist *afwijkende, a-typische, en niet-routinematige* problemen, ook uitgevoerd in een nieuwe context.
- Studenten zouden òf meer de praktijk in moeten gaan (bv. tijdens de bachelor fase op zijn minst een stage volgen), òf de praktijk zou meer in het onderwijs moeten worden geïntegreerd. Voorbeelden van onderwijs met een duidelijke praktijk component zijn '*duale leerwegen'* (leren en werken tegelijk) en '*action learning'* (leren via het uitvoeren van echte praktijkopdrachten).

Hoofdstuk 4 en 5: Cognitief onderzoek vertaald naar instructievoorschriften.

Hoofdstuk 4 beschrijft een (her-)ontwerp van een PGO-leeromgeving, ingegeven door (a) de conclusies van hoofdstuk 2 en 3 en (b) onderzoek uit eerdere studies over het stimuleren van expertise.
Op basis van dit empirisch onderzoek werden instructievoorschriften afgeleid en is de PGO-leeromgeving geoptimaliseerd op de volgende vijf instructie dimensies:

1. De taakdimensie: probleembeschrijvingen, casusinformatie en bijbehorende databronnen.
Betreffende de '*taakdimensie*' werd in de nieuwe leeromgeving de authenticiteit van de case studies verhoogd. Authentieke bedrijfsproblemen en bedrijfsinformatie (van echt bestaande bedrijven) werd gebruikt voor de verwerving, de toepassing, en de toetsing van kennis. De crux van de cases die we gebruikten, zat in de authentieke kenmerken: de situatiebeschrijving kende een ruwe opbouw en was niet voorgestructureerd met 'advance organizers' of samenvattingen die de essentie van een case al weergeven. De praktijksituaties bevatten juist veel data die studenten moesten interpreteren en omzetten naar informatie. De data die we aanboden waren soms redundant of tegenstrijdig, dan weer incompleet. Studenten dienden additionele informatie te zoeken, geheel volgens een echte bedrijfssetting. De achterliggende gedachte hierbij is dat, in tegenstelling tot voor onderwijsdoeleinden geschreven cases, een reële ongestructureerde casus 'authentieke' cognitieve acties vereist, zoals: selecteren, interpreteren, representeren, ordenen, infereren en synthetiseren. De (multimediale, veelal elektronische) casusinformatie bestond uit powerpointpresentaties van een bedrijf, jaarverslagen, databestanden, stukken uit rapporten, etc.

2. De collaboratieve dimensie: de wijze van interactie en samenwerking tussen studenten.
De 'collaboratieve (samenwerkings) dimensie werd aangepast, met als doel dichter te komen bij een teamwork situatie in professionele organisaties. Wekelijks hadden de studenten meerdere bijeenkomsten in kleine 'professionele' teams van drie à vier personen. Deze

kleine teams werkten aan de case-analyses, presentaties en discussievragen. De samenwerking tussen studenten uit de kleine teams werd ondersteund door elektronische communicatie (e-mail, chat, en discussielijsten).

In tegenstelling tot een reguliere PGO omgeving waar studenten twee maal per week onder begeleiding van een tutor samenkomen, hadden in de nieuwe leeromgeving de studenten slechts één *plenair*e bijeenkomst per week (met de tutor en met ongeveer veertien studenten). Deze bijeenkomst mèt tutor was gericht op *nabespreking* van leerdoelen en de besproken literatuur. De controle groepen in de traditionele PGO-setting hadden *twee* gebruikelijke (wekelijkse) onderwijsbijeenkomsten.

3. De tutor-student control-dimensie: de mate waarop de student invloed en controle heeft over leerpad, leertempo en moeilijkheidsgraad.
In vergelijking met een reguliere PGO omgeving, werkten de studenten in de kleine, zelfsturende teams onafhankelijker van hun begeleiders en verkregen daarmee meer controle over hun taken binnen het leerproces. De studenten verdeelden zelf binnen hun team de rollen (van notulist, voorzitter, etc.), ze bepaalden zelf tijd, duur en wijze van overleg. Zo waren er teams die veel via het web vergaderden, andere teams kwamen veel face to face bijeen. Al met al kregen de teams veel verantwoordelijkheid en werkten ze meer autonoom van de docent. Tegenover deze grotere vrijheid stonden echter strikte en duidelijke spelregels: zo dienden alle studentteams voor een bepaalde deadline een analyse van de casusproblemen op te leveren volgens duidelijke criteria. De tutor ontving deze analyse via e-mail, en gaf feedback, waarna alle teams inzage kregen in de casusanalyse van alle teams.

4. De procedurele dimensie: de opbouw en volgorde van de onderwijsactiviteiten.
Veel PGO-onderwijs begint met een zeer korte beschrijving van een casus waaruit studenten problemen en verklaringen moeten destilleren. Met weinig casusinformatie kan het echter soms lastig zijn om realistische verklaringen (hypotheses) te genereren. Daarnaast is in de (beroeps)praktijk doorgaans een ruimere bedrijfsinformatie beschikbaar. Om deze redenen kregen studenten in de nieuwe leersituatie *naast* de algemene casusbeschrijving ook direct bedrijfsinformatie uit een bedrijfscontext aangereikt. Dit vereist van studenten informatie structureren en prioriteren, kortom de authentieke cognitieve activiteiten die we beoogden op te roepen.

Een tweede punt dat werd uitbouwd aan de PGO-procedure betreft het einde van het leerproces. In veel casegebaseerd onderwijs stopt de onderwijsbijeenkomst als de doelstellingen eenmaal zijn beantwoord en de kennis is verworven of toegepast. Maar juist daar blijft een belangrijke kans voor transfer van kennis liggen. Daarom vroegen we studenten om elke week het geleerde te relateren aan een andere *context*. Dat mocht zijn aan een vorige bijeenkomst, een ander hoofdstuk uit het boek, of een nieuw bedrijf. Zo werd dus gedurende de gehele cursus de centrale bedrijfscontext iedere week vergeleken met een ander bedrijf om de transfer van kennis naar andere contexten te stimuleren. Op deze wijze wilden we het geleerde juist uit een specifieke context halen ('de-contextualiseren') en op een meer generaliseerbaar vlak brengen.

5. De toetsdimensie. Aangezien het leren in een curriculum voor een belangrijk deel wordt gestuurd door de wijze waarop getoetst wordt, werden de studenten ook op een met het leerproces vergelijkbare, dus via realistische bedrijscases getoetst. Hiermee was de eindtoets van de cursus congruent met de authentieke leeromgeving.

De veranderingen in de vijf instructiedimensies zijn geïmplementeerd in een Marketing cursus uit het bestaande curriculum van de faculteit Economische Wetenschappen en

Bedrijfskunde aan de Universiteit van Maastricht. Met deze vernieuwde marketing PGO cursus is een experiment uitgevoerd met studenten die deze cursus volgden (aan het einde van hun tweede studiejaar).

Onderzoek naar cognitieve effecten van de nieuwe leeromgeving.
Om de leeropbrengst van de vernieuwde leeromgeving te meten, is een onderzoeksdesign gemaakt waarbij de vernieuwde ('experimentele') leersetting werd vergeleken met twee onveranderde ('controle') settings. Het algehele doel van de effectstudies was te onderzoeken of de vernieuwde leeromgeving, in vergelijking met de bestaande leeromgeving, zou leiden tot beter kennisgebruik en tot betere probleemoplosvaardigheden.

Resultaten van de effectstudies
1. Uit de resultaten van de *reguliere* eindtoets van de cursus bleek dat de experimentele groep significante beter presteerde op de open vragen. Bij deze open vragen lag het accent op toepassen van kennis in een nieuwe context. Bij de multiple-choicevragen uit de reguliere toets (gericht op het reproduceren en herkennen van kennis) werd daarentegen geen verschil in leeropbrengst gevonden.

2. Aan het einde van de cursus hebben alle studenten *realistische bedrijfscases* uitgewerkt. Hieruit bleek dat de studenten in de vernieuwde setting significant betere *probleemoplossende vaardigheden* vertoonden.

Over het geheel geven de resultaten uit (1.) en (2.) aan dat studenten in de experimentele conditie beter kennis kunnen toepassen en beter realistische problemen kunnen oplossen. 'Effect Size' (een andere maat om effecten te berekenen) bevestigde en versterkte de resultaten die eerder waren gevonden. We concludeerden dat de herontworpen PBL setting - in vergelijking met de reguliere PBL setting - significant bijdraagt tot beter leren en kennisgebruik van studenten. Er is echter geen verschil gevonden in hoeveelheid verworven kennis.

3. Tenslotte is een dieptestudie uitgevoerd naar de cognitieve effecten van de oorspronkelijke en de geoptimaliseerde PBL leeromgeving. Hierbij zijn, overeenkomstig hoofdstukken 2 en 3, als indicatoren van expertise gebruikt: (a) het niveau van kennisverwerving, (b) de kwaliteit van de probleemanalyse, (c) inductief redeneren (vooruit redeneren, van probleemanalyse naar oplossing), (d) diagnostische vaardigheid, en (e) accuraatheid in probleemoplossen. De resultaten van deze multidimensionele analyse gaven aan dat de studenten in de experimentele setting beter presteerden dan de studenten in de controle groepen op verschillende expertise aspecten tijdens het proces van probleemoplossen: de experimentele groep produceerde meer inferenties (afleidingen zoals conclusies en samenvattingen), meer inductieve redeneringen, en gaven ook meer diagnoses en probleem-oplosssingen van hogere kwaliteit.
Samengenomen indiceren de effectstudies dat de combinatie van alle veranderingen in het instructie ontwerp een positief effect heeft op de toepassing van management gerelateerde kennis en op de verbetering van probleem oplosvaardigheden.

*Discussie en implicaties***.**
Een algemene implicatie van de resultaten van de effectstudies is dat de herontworpen leeromgeving het potentieel biedt om de toepasbaarheid van kennis in praktische omgevingen te verbeteren. Een eindconclusie is dan ook dat een computerondersteunde leeromgeving met realistische, praktijkgerichte cases, in combinatie met het werken in kleine teams, probleemoplosvaardigheden en kennistransfer duidelijk kan bevorderen. Dit kan opleiders in marketing of verwante sociale studies aanmoedigen om bepaalde elementen uit de herontworpen PBL setting te gebruiken. De hoofdingrediënten waarop de herontworpen leeromgeving leunde waren kort samengevat dat studenten (a) in kleine, zelfsturende teamsettings werkten met een hoog gehalte aan student control over de situatie, (b) authentieke problemen en authentieke informatiebronnen gebruikten, en (c) werden ondersteund in hun probleemoplosbenadering.

Gegeven de positieve cognitieve leeropbrengsten van de herontworpen PBL setting kan de vraag worden gesteld: is het verstandig deze setting te implementeren in het gehele curriculum? Wij suggereren een graduele implementatie waarbij studenten in toenemende mate werken in kleine zelfsturende teams, geleidelijk meer controle verkrijgen over hun eigen leerproces en geleidelijk met meer authentieke taken worden geconfronteerd. Het opvoeren van meer authentieke elementen in leeromgevingen (meer teamwerk, meer authenticiteit in taken, meer controle over de leersituatie) is naar onze mening op zich geen garantie voor beter leren. Bij het gebruik van authentieke elementen (uit de praktijk) is het van belang te overdenken of studenten over voldoende cognitieve en metacognitieve vaardigheden beschikken. Wanneer de feedback van de tutoren zich niet alleen op de leerinhouden richt maar ook op de vereiste cognitieve en metacognitieve vaardigheden vereist voor succesvol probleemoplossen, is een graduele implementatie van authentieke elementen in de leeromgeving wellicht effectief. Op deze wijze kan de overgang (transitie) van onderwijs naar arbeidsmarkt gunstig worden bevorderd.

CURRICULUM VITAE

Jos Arts (Megen/Oss, 1964) graduated in 1991 at the Technical University of Twente (UT, Enschede), at the Faculty of 'Toegepaste Onderwijskunde' (specialization: 'computers and education').
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Since 2003 he has specialized in quality assurance and design of learning environments at the Technical University of Eindhoven (TUe), The Netherlands.

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