Understanding managerial problem-solving, knowledge use and information processing: Investigating stages from school to the workplace

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Abstract

The present study explores stages in managerial problem-solving skills of participants beginning with formal education, and continuing through the professional workplace setting. We studied nine different levels of expertise: from novice student groups, to graduates and expert groups. Participants were asked to diagnose and solve business cases. The transcripts (handwritten 'case solutions') of all 115 participants were analyzed on managerial knowledge use and problem-solving accuracy. The results demonstrate the importance of acquiring 'dynamical' knowledge for accurate problem-solving. For students and junior experts, the results suggest a weak use (transfer) of knowledge and ineffective problem-solving approaches. In general, this study indicates that progress in expertise is not so straightforward (linear) as often assumed. Several implications for education are discussed.

Keywords: Expertise stages; Problem-solving skill acquisition; Managerial knowledge; Decision making; Problem-solving accuracy; Information-processing; Workplace transitions

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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 difficulties 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 does not 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, 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, that 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.

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.

1.1. Diagnostic accuracy

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, Shulman, & 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).

1.2. Solutions accuracy

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 (Éraut, 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?

1.3. 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).

1.4. 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).

1.5. 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).

2. Method

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 thirds male and one third female). All participants followed the same data collection procedure during the study. Each participant received a nominative compensation for participation.

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).

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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.

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).

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 & Erskine, 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, etcetera).

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).
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 s per word, i.e. 2.50 min 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.

2.5. Data-analysis

We compared the nine different expertise groups by using analysis of variance (ANOVA). 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 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.

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 2/3 or more) the model case solutions. We provided the label ‘partially accurate’ when the main idea of participants’ only partially (between 1/3 and 2/3) matched the case solutions. We labeled participants’ case diagnosis and case solution as ‘inaccurate’ when the participant’s answers did hardly or not (less than 1/3) 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).

2.6.1. 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.

2.6.2. 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’.

2.6.3. 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.

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. Results

In describing the data in Figs. 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.

3.1. Analysis 1: Accuracy of case-diagnosis in problem-solving

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

3.1.1. Inaccurate diagnoses

Fig. 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 inaccurate diagnoses was negatively related \([F(8, 93) = 3.29; \text{MS}_e = 0.25, p = .003]\), (measure of association \(r = -.280\)). Correspondingly, we found a low Effect Size (ES) of .25.
Fig. 1. The number of both accurate and inaccurate case diagnoses related to level of expertise. With kind permission of Springer Science and Business Media (Arts, Gijselaers, & Segers, 2004).

Fig. 2. The mean number of total provided case solutions provided by participants. With kind permission of Springer Science and Business Media.

Fig. 3. Accuracy of case solutions related to expertise level. With kind permission of Springer Science and Business Media.
3.1.2. Accurate diagnoses

We found significant differences between the groups concerning the number of accurate diagnoses \([F(8, 91) = 2.22; \text{MS}_e = 1.12, p = .033. \text{ES} = .69]\). 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.

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

3.2.1. 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 \([F(8, 105) = 15.76, \text{MS}_e = 9.60, p = .000, \text{ES} = .94]\).
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. Fig. 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.

3.2.2. ‘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. Fig. 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 Fig. 2 showed a decline in the number of solutions during the highest expertise stages, Fig. 3 shows a significant positive relationship between the nine levels of expertise and solution accuracy \([F(8, 91) = 7.73, \text{MS}_e = 16.91, p = .000, \text{ES} = .89]\), 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 (Fig. 3) while an analysis on the quantity of solutions provided suggests an inverted U-curve effect (Fig. 2). These data lead to the acceptance of hypothesis 2: Managerial experts will provide fewer but more accurate solutions than management students.

3.2.3. Accurate, partially accurate, and inaccurate case solutions

In Fig. 3, we have presented the aggregated score of (a) inaccurate solutions, (b) partially accurate solutions, and (c) accurate solutions, in Fig. 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 \([F(8, 91) = 5.51, \text{MS}_e = 2.96, p = .000, \text{ES} = .98]\), (b) the mean number of partially accurate solutions \([F(8, 91) = 6.92, \text{MS}_e = 4.63, p = .000, \text{ES} = .87]\), and (c) the number of inaccurate solutions \([F(8, 91) = 2.56, \text{MS}_e = 2.94, p = .015, \text{ES} = .72]\). Fig. 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.

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 inaccurate 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. 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).

3.3.1. Case facts

The level of expertise had a significant effect on the number of accurate case facts reproduced by participants in their case analysis [$F(8,105) = 2.99; \text{MS}_c = 12.70, \ p = .004, \ ES = .75$]. 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 intermediates. Nearly all case facts that experts reproduced were relevant case facts. For the relevant case facts a significant effect of level of expertise was found [$F(8,95) = 4.47, \text{MS}_c = 12.3, \ p = .00, \ ES = .81$]. 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 H3. Management students will retain (a) relatively more case information and (b) relatively more irrelevant case information than experts.

3.3.2. Managerial concepts

The level of expertise was also significantly related to the use of managerial concepts [\(F(8, 105) = 13.23; \text{MSE} = 14.28, p = .000, \text{ES} = .93\)]. 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. Fig. 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.

3.3.3. Inferences

The number of inferences produced was also significantly related to the level of expertise [\(F(8, 105) = 26.63, \text{MSE} = 69.92, p = .000, \text{ES} = .79\)]. 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, Fig. 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 (H4), but at the same time demonstrate more dynamical knowledge than beginners (H5).

To assess the role of knowledge in relation to diagnostic and problem-solving performance (H6), 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.

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.

3.4. 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. Fig. 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 the fewest time (about half of the time needed by intermediate students) to work on the problem. 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).

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.

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 et al., 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 (Fig. 2), while we concur with the MDL that accuracy of problem-solving progresses in a monotonic way (Fig. 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’.

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 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.

### 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.
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.

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.

Second, 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 irrelevant 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.

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

<table>
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<th>Beginners</th>
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<tr>
<td>Diagnostic accuracy</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Monotonic increasing</td>
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<tr>
<td>Problem-solving accuracy</td>
<td>Low</td>
<td>Medium</td>
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<td>Total number of case solutions provided</td>
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<td>Use of discipline knowledge during reasoning</td>
<td>Low</td>
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<td>Medium</td>
<td>Inverted U-curve</td>
</tr>
<tr>
<td>Use of dynamical knowledge</td>
<td>Low</td>
<td>Medium</td>
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<td>(selecting relevant information)</td>
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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.

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.

5.1. 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.

5.2. 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).

5.3. 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 of ‘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.

5.4. 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.
5.5. 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.

References


