On the development of competence in solving clinical problems;

Can it be taught? Or can it only be learned?

Stefan Ramaekers

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Over het leren oplossen van klinische problemen

(met een samenvatting in het Nederlands)

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"The problem with trying to define everything simply is that when everything interacts, nothing is simple"

Glenn Regehr [1]

1 Regehr, G. (2010). It's NOT rocket science: rethinking our metaphors for research in health professions education. *Medical Education, 44*, p. 36.

1. General introduction

Introduction

"Last month I was somewhat hesitant about the clerkships. Now I know: this is really it. I made the right choice [of study]*."*

"I had been waiting for this for so long, but now I am going through a depression of absolute ignorance."

For students, the transition from preclinical to clinical learning can be both exciting and worrying.[1,2] The change in role from learner to apprentice care provider not only marks a significant step in their development towards professional competence; it also brings with it greater responsibilities, work pressure and the complexities of real practice.[3] In itself, the preclinical-clinical transition already entails substantial changes with regard to the nature of daily activities and workload, learning environment, roles and responsibilities.[4] Combined with the need to deal with the ambiguities of clinical practice, with disease, suffering and death, as well as coming to realise one's own deficiencies in terms of knowledge and skills, a lack of clinical guidance and difficulties in interactions with staff, this may cause a 'shock of practice' .[3-5]

The importance of providing students with authentic experiences, reflecting real-world problems and ways of handling them, early on in their studies has been advocated by many scholars.[6-9] It is assumed that authentic experiences will engage students in processes that mirror the challenges of their future work,[10-12] thereby providing them with better opportunities to engage in meaningful learning and bridging the gap between education and professional practice. The main arguments which have been put forward for adopting authenticity in approaches to learning and education are drawn from empirical research and theories concerning the complexity of real-life professional problems,[13,14] the nature of expertise,[15,16] situated cognition and learning,[17,18] competence development [16,19] and motivation for learning.[10,20]

Real-life problems and issues are often much less well-defined, structured and convergent than theory suggests.[14] Solving them usually requires an approach which combines multiple perspectives, exploring conditions, constructing explanations and predicting effects while taking many different aspects into account. There may be uncertainty about the outcomes and constraints with regard to the time and resources which can be used to solve these problems, while the support offered by general theories or guidelines for practice is limited.[16,21-23] The ability to solve simple, well-structured problems does not readily transfer to complex real-life problems,[23,24] as ill-defined problems seem to require different skills to well-defined tasks.[25,26]

Reducing the complexity of real-life situations, problems and questions to a level that students can handle, learn and progress from is one of the key issues in education. Whereas their complexity is one of the reasons why the use of authentic problems for educational purposes has been advocated, numerous studies have reported on a variety of difficulties that students encounter when trying to solve such problems. These difficulties concern both the problem solving process itself[27-30] and the process of learning from it.[31-34]

How then can students best profit from the benefits of authenticity in learning situations, while avoiding cognitive overload as a result of a level of complexity that exceeds the students' capacities and hinders their learning?

General aims, relevance and research context

The research in this thesis concerns the use of real-life situations, tasks and problems in order to support the development of clinical problem solving competencies. In particular, it focuses on the adjustments which need to be made in educational settings in order to fine-tune tasks and the specific settings in which they are used, to the students' level of competence and the developmental changes that take place.

The general aim of this thesis is twofold: on the one hand, it involves the design of a course in veterinary medicine, which is effective in terms of providing students with training in clinical problem solving and helping them to progress during the so-called preclinical phase of their studies. On the other hand, this thesis aims to extend the existing knowledge of underlying instructional design principles, understanding why and how they work, in what contexts and under what conditions. This knowledge should make it possible to determine the applicability of these principles to other educational settings, to optimise existing instructional designs and to support teachers when designing and teaching similar courses.

Relevance for educational theory and practice

This research is embedded in the following theoretical themes: (a) development of clinical problem solving competence; (b) instructional formats and course design; (c) the complexity and authenticity of cases; and (d) scaffolding student learning. Rather than approaching these themes as separate issues, this research seeks to understand how they interact in practice, as aims or conditions in one coherent design.

This research draws upon previous studies of the development of competence in clinical problem solving, a theme that has been studied extensively.[35-38] The key points of the current knowledge of clinical problem solving competence are summarised in this introductory chapter; where needed, specific aspects of the individual studies will be expanded upon.

The interactions that are explored in this thesis concern the effects that particular features of specific cases and educational settings have on students' problem solving and learning processes. Understanding these interactions is essential if we are to be able to adjust these features to fit the changes that occur in the process of the development of competence. Empirical studies of case designs, authenticity and adjustments made in the process of competence development are scarce. Although the importance of high quality cases and adjustments to competence development has been substantiated by many researchers,[15] most publications remain prescriptive and do not provide clarification.

The relevance of this research for educational practice lies in understanding how particular features of a task or the setting in which this task has to be fulfilled affect students' problem solving and learning processes, and how these features can be adjusted to fit the students' competence development. This combination of design features, effects and explanations within particular conditions conforms to the general model (Figure 1) of a design principle.[39]

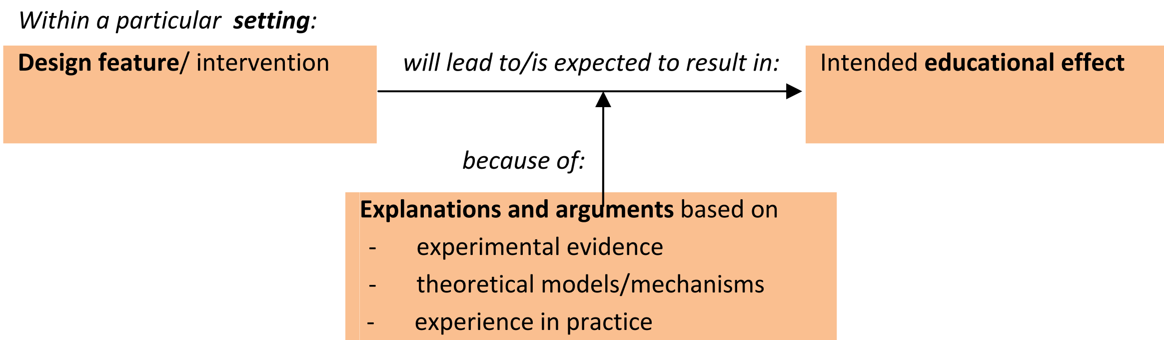

Figure 1. General model of a design principle.

An understanding of how, why and in what settings design principles have the intended effects, or interact when used in one design, provides teachers and designers with a firm grasp on the development and optimisation of similar educational designs in other settings. Similar designs that are expected to benefit from the findings of this research all share the aim of learning to solve (clinical) problems, the use of authentic tasks and the need to adapt the (cognitive) load to the students' level in the process of competence development.

Regarding clinical practice, the ability to solve clinical problems and to make the necessary decisions is nowadays recognised by many as a key competence which lies beyond the level of sufficient knowledge and simple logic.[40] Extending and optimising the opportunities for students to practise clinical problem solving during the preclinical phase can be beneficial for clinical practice in several ways.[1,41,42] In the short term, an effective training programme is expected to ease students' transition into clerkships, because some of the problems of transition can be reduced by improving the students' level of preparation.[3-5,42,43] In the long run, extensive practise in the preclinical phase could be instrumental for the development of a methodical approach, incorporating aspects of evidence-based practice, quality assurance, professional conduct, etc.

In short, by empirically studying the issue of creating authentic experiences and learning at a level which suits the students' potential and needs, we intend to provide teachers with insights that will be instrumental when developing courses and tasks and to estimate the effects of particular design features.

Educational setting / context of these studies

In the Netherlands, undergraduate training in veterinary medicine consists of a six-year programme. At the start of this research, the curriculum in veterinary medicine at Utrecht University was roughly divided into two phases; a four-year preclinical phase, covering most of the theoretical basics and skills training, followed by two years of clinical learning in clerkships and a research internship (Figure 2). In the past two decades, every five to six years, the curriculum has been revised in order to adjust the programme according to major developments in veterinary practice, research and higher education, and to address weaknesses which came to the fore in programme evaluations.

Preclinical phase				**Clinical phase**	
Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Biomedical and veterinary courses: - disciplinary and thematic - theory and skills training - electives				Clerkships Research internship	

Figure 2. Curriculum overview

Since the mid-1990s, the curriculum had incorporated a series of case demonstrations (in the third and fourth years) and a short course of 'advanced clinical diagnostics' (in parallel to the first clerkship), which was specifically aimed at bridging the gap between the preclinical phase (which has an emphasis on mastering biomedical theories) and clinical practice. However, the results of programme evaluations and reflections on the clerkships suggested that these components of the curriculum were insufficient to achieve a level of preparedness for clinical work that was in keeping with the ambitions and requirements of modern veterinary practice. Accordingly, it was decided that these programmes should be redesigned, as part of a large-scale curriculum review which started in 2001.

The course which resulted from this review, called the *clinical lessons*, forms the setting of this research. The *clinical lessons* aim to provide students with first experiences in solving authentic clinical problems, and to train them to reason and make decisions in clinical situations in accordance with the biomedical theories and the guidelines for practice which they have already studied. Furthermore, these lessons are intended to build on high levels of active student involvement and self-directed learning, and to enhance the students' awareness of standards of quality and professional conduct.

The initial course design resulted from a process of co-creation between the teaching staff and the author of this thesis. It was drafted based on views on the nature of clinical problems and situations, on reasoning with regard to clinical problems, and on the facilities and environments which are conducive to learning. These were grounded in prior experiences with clinical teaching formats and empirical results from studies about educational approaches such as case-based and problem-based learning. Achieving a high level of teacher agreement and support for the course design's implementation was regarded as an essential ingredient in the redesign process and this research on design issues.

Domain

The first studies concerning the ways in which physicians deal with the clinical problems they are confronted with, establish a diagnosis or determine which intervention is called for date back to the late 1950s.[44,45] Since then, four different perspectives on the essential elements of the problem solving process and generations of theories have been developed and refined.[35,46-48] From the very beginning, the issue of how students' training could benefit from knowledge about clinicians' powers of reasoning has fallen within the scope of this research.

Clinical reasoning, problem solving and decision making

Reflecting some of the differences in perspectives, the process of clinical reasoning has been formulated in many ways: clinical judgement; medical information processing; diagnostic reasoning; problem solving; medical decision making; heuristic reasoning; deciding under uncertainty; evidence-based practice, etc. As the word 'reasoning' refers to a broad range of higher-level cognitive processes, we will use the term *clinical problem solving* in this thesis, except when referring to a specific component of the process. We defined clinical problem solving operationally as: *the gathering, organising and interpreting of information about a clinical problem and its relevant context, in order to make professional judgments (e.g. differential diagnosis, prognosis) about the situation and decisions about what, within this context, should be done to solve the problem adequately or to prevent further problems from occurring (e.g. therapeutic or preventive interventions)*.

In the earliest models, systematically generating and testing hypotheses until explanations and solutions are found and possible alternatives are excluded was considered to be the essence of the clinical reasoning process. Hypotheses, generated early on in the reasoning process, help to predict what the findings ought to be, and the diagnostic process is basically a guided search for these findings and the process of comparing the actual findings with the predictions until a diagnosis is established.[46]

By contrasting the problem solving approaches and reasoning of experienced clinicians (experts) with those of students (novices), empirical studies have confirmed that experts are far more advanced than novices in areas such as the accuracy of their early hypotheses. However, successive empirical studies have also demonstrated that many of the differences between experts and novices cannot be explained using the notion of clinical problem solving as a general hypothetico-deductive process, strategy or skill.[46,49] Particularly in cases which they are familiar with, the approaches of experienced physicians rely largely on pattern recognition, inductive reasoning and experiences from approaches and decisions which have been successful in the past, rather than on systematic analysis, deductive reasoning or extensive testing of hypotheses.[48,50] Combined with repeated findings of low transfer from one solution to another,[46] these results have led to the conclusion that "*diagnostic accuracy seems not to depend as much on a particular (superior) strategy as on mastery of content*".[51]

In response to these findings, the focus of the research moved towards the role of knowledge in medical expertise, including how the knowledge of experts is structured and the development of these structures.[52,53] Script theory states that expertise in solving clinical problems relies on an extensive knowledge base, organised in schemas ('illness scripts') which suit the mixtures (patterns) of the information which is available in practice.[47,53,54] These scripts emerge from exposure to patient problems, and frequent practise is considered to be essential to synthesising and extending these illness scripts.[52,55] In the development of expertise, the underlying biomedical concepts and theories become encapsulated and are only reactivated when necessary.[56-59] Script formation is regarded as a way of coping with the cognitive load which is related to solving problems in knowledge-intensive domains.[15,55,60] Table 1 shows the main changes that characterise the development of competence in clinical problem solving.

Table 1. Development in problem solving competence (Boshuizen, 2003) [15]

Expert level	Knowledge structure	Learning	Problem solving	Control in clinical reasoning	Demand on cognitive capacity
Novice	Incomplete and loosely linked networks	Knowledge accretion, integration and validation	Long chains of detailed reasoning steps through networks	Active monitoring of each reasoning step	High
Intermediate	Closely linked networks	Encapsulation	Reasoning through encapsulated networks	Active monitoring of each reasoning step	Medium
Expert	Illness scripts	Illness script formation	Illness script activation and instantiation	Monitoring of level of script instantiation	Low
	Memory traces	Instantiated scripts	Automatic reminding	Checking relevance	Low

An awareness of the uncertainties and ambiguities that can be part of real-world problems has fuelled research about the ways in which clinical decisions are made under the condition of uncertainty. Decision analysis applies probability and utility theory quantitatively in order to support decision making in cases of, for example, uncertainty about the trade-off between the benefits and risks of a treatment, about the interpretation of diagnostic tests or a lack of information.[61,62] Using Bayes' theorem, the choices, outcomes and prior and posterior probabilities are weighted in order to develop models or guidelines which describe the decisions involved and the optimal (expert) approaches to a particular clinical problem.[51]

While the value of decision analysis, the development of guidelines or protocol, and using evidence-based practice to support clinical problem solving has been widely recognised, these aspects have also been criticised. This criticism may reveal some of the weaknesses or limitations of the current clinical problem solving models. Part of this body of criticism concerns the limited applicability of these methods to real-life clinical settings.[63-65] In addition, the problem solving models on which such methods and research studies are built are considered to be oversimplifications of actual practice, with a one-sided focus on causal (mainly pathophysiologic) mechanisms and explanations, and which assume problem solving to be an individual, rational and objective process.[48,63,66-68] Since the late 1990s, an increasing number of studies have aimed to improve our understanding of the contexts in which problem solving and decision making processes are embedded, focussing on influences such as patient preferences, organisational complexity, system-related errors, team dynamics in decision making, etc.[65,67,69-72]

Difficulties and bias in solving clinical problems

Currently, most researchers agree that clinical problems are highly content-specific and that the possibility of transferring one problem or solution to another is limited. Finding appropriate solutions depends to a large extent on a knowledge base which covers many different aspects of clinical problems and which is organised in structures adjusted to practice. Part of this knowledge is tacit and practice-bound, such as knowledge about local institutional facilities or policies that affect clinical decisions. Experienced physicians solve their problems in a variety of ways. Within their own areas of expertise, their strategies often rely on pattern recognition and previously successful approaches. In unfamiliar, rare or complex cases, extensive testing guided by the conscious deduction of hypothetical options or by confirmation of a working diagnosis by monitoring the effects of trial interventions may be used.

Clinical problems and solutions may be straightforward, but they can also be complex, particularly in situations featuring multiple dynamically changing conditions, extensive side-effects or interactions between therapeutic interventions, high risks or a significant impact on the patient's daily life and functioning.[73]

Circumstances which contribute to the complexity of the problem solving process itself include the fact that clinical decisions typically have to be made on the basis of limited, selectively-gathered information (avoiding too great a burden on the patient and unnecessary diagnostic costs), sometimes under the pressure of time (due to deterioration or other health risks) and taking into account considerable uncertainties. The reliability of the information gathered can be uncertain, the results of patient tests might be inconclusive, and a precise prognosis, with or without interventions, often cannot be made.[16,48,66,74] Furthermore, complex cases usually require chains of subsequent judgements and a substantial amount of context-bound knowledge, whereas theoretical guidance may be helpful to a much lesser degree.[16,69]

Table 2 provides an overview of the main cognitive challenges and typical biases or fallacies involved in clinical problem solving. The cognitive challenges are part of the problem solving and learning processes, even at the level of beginners. The occurrence of biases depends on the presence of the specific factors which can trigger the underlying mechanisms. These biases have been characterised as 'particular patterns of judgment deviation occurring in specific situations', associated with error and resulting from mechanisms such as cognitive dissonance, the routine execution of tasks and inferences made rapidly about situations under the pressure of time.[72,75] From a developmental perspective, biases are regarded as simple heuristic rules with an adaptive function, which is to reach reasonable conclusions or decisions within the limitations of the available time, knowledge and cognitive load.[76-78] In terms of the educational approach, cognitive challenges require frequent practise, and learning opportunities must be adapted to the students' level of development. These biases require the creation of an awareness of the typical flaws and predispositions that are related to clinical problem solving, in order to enable systematic reflection on outcomes and alternatives, and to facilitate the development of metacognitive control.

Learning and teaching clinical problem solving

The various forms of workplace learning, from clerkships to learning from experiences of work after graduation (and specialist training), offer invaluable opportunities to advance towards competence in clinical problem solving.[79] With regard to the preparation for the clerkships and providing students with training in particular aspects of clinical work (e.g. concurrent reasoning and communicating), instructional designs have been advocated which include the use of cases, clinical experiences and contact with patients in the preclinical phase.[1,5,42]

Table 2. Main cognitive challenges and typical biases in solving clinical problems.

Component of clinical problem solving	Cognitive challenges	Biases, fallacies	Description
Gathering information	- Selectively gathering the minimum amount of information which is required to achieve maximum certainty	Confirmation bias[80]	- Tendency to search for information in a way that confirms one's preconceptions
		Information bias[81]	- Tendency to gather information even when it cannot affect actions
Organising information	- Handling large amounts of information or performing tasks concurrently (while avoiding cognitive overload) - Assessing various relationships between findings in order to establish patterns which confirm/refute hypotheses	Failed heuristics[72]	- Inappropriate use of rules of thumb or (over)application under atypical circumstances
		Base rate neglect[82]	- Tendency to ignore the true rate of a condition and to pursue rare, more exotic diagnosis
Interpreting information	- Weighing up the reliability of information (sources) - Distinguishing findings within the variation ranges of 'normal' from 'abnormal' (pathologic) - Adjusting assessment procedures in accordance with intermediate findings	Framing/labelling effect	- Influences of a prior diagnosis made by others on the diagnosis and decisions about interventions
		Over- or underestimation of findings[72]	- Inadequate weighing of relevance or salience of findings, leading to the exclusion or confirmation of hypotheses
		Diagnostic overshadowing[83]	- Tendency, in the case of salient problems, not to attend to information about other problems
		Confirmation bias[80]	- Tendency to interpret information in a way that confirms one's preconceptions
Making judgments	- Drawing conclusions from extensive information (synthesis) - Making judgments despite a lack of information, ambiguity or uncertainty - Redefining the problem on the basis of findings	Premature closure[72]	- Tendency to stop considering alternatives once an initial diagnosis has been reached
		Representativeness heuristic[76]	- Tendency to make judgements influenced by the degree of representativeness of findings
		Availability heuristic[76]	- Tendency to consider diagnoses based on how easily they can be brought to mind/remembered
		Framing/order bias[84]	- Tendency to vary conclusions, depending on how information is presented or the order of presentation
Making Decisions	- Making appropriate inferences from the diagnosis, translating judgments into actions - Predicting consequences and estimating the effects and risks of the decisions made	Need for closure[85]	- Need to reach a definite conclusion or answer in important matters, in order to avoid feelings of confusion and uncertainty

Case-based and problem-based learning (CBL and PBL) are instructional approaches which have been developed with the need for adequate preparation for real-world problems and fostering (clinical) reasoning in mind.[86,87] Nowadays, many different variations of these learning approaches exist.[88] Their central features have been extensively studied and some of the underlying assumptions and expected educational outcomes have been empirically confirmed.[89,90] Meta-analyses of studies assessing the effects of PBL are conclusive with regard to students' problem solving abilities, skill development, long-term retention and student satisfaction.[91-93] Nevertheless, by the early 1990s it had become clear that there was no evidence to support the assumed enhancement of general, content-independent problem solving skills,[53] as the overall results concerning the acquisition of knowledge had been inconclusive.[91,94]

With regard to specific elements of instructional formats and their impact on learning processes, studies have repeatedly shown the importance of high-quality cases,[20,89,95,96] productive (small) group interaction[33,97,98] and appropriate facilitation by the tutor.[99,100] Highly structured or single-answer cases, a lack of motivation or 'belief' in this type of case discussions as an effective educational method, overly directive interference from tutors, poor group dynamics, etc. have been identified as hindrances to case discussions. These factors create discrepancies between theoretical, potential contributions to learning and the actual outcomes in practice.[101,102] They can thwart the students' attempts at elaboration, critical questioning and co-construction, thus affecting the depth of the discussion, leading to superficial, ritual and routine coverage of a case.[33,98,103-105] Some studies suggest a dominating influence of the quality of cases on outcomes, rather than the students' prior knowledge or the competences of the tutors.[20,89,96]

In contrast to the number of studies on specific features of PBL in entirely PBL-curricula, very few studies have been published about the use of a PBL approach in combination with other educational formats. Combining PBL with traditional instructional formats seems to provoke the same types of hindrances. In a study by Houlden *et al.*,[106] six problems in facilitating a hybrid PBL/traditional curriculum were reported: the use of 'mini-lecturing'; dysfunctional group dynamics; rushing through the cases with the sole aim of finding the 'right answer'; superficial analysis and studying limited aspects of the case; frustration with tutors who are not experts in the appropriate content and doubting PBL or expressing a preference for lectures.

Main argument and research questions

This research is based on the premise that effective training in clinical problem solving will contribute to the quality of (veterinary) medical practice. In order to incorporate this kind of training as an embedded component within the curriculum, a sufficient level of reciprocity between the theoretical and clinical parts of the curriculum needs to be achieved. With regard to the preclinical phase of the curriculum, training in clinical problem solving should provide students with extensive opportunities to practise with a variety of authentic problems and situations.

The *clinical lessons*, the object of this research, take place in the second half of the preclinical phase. These lessons are intended to ease the transition into the clinical phase by raising the students' level of competence in clinical problem solving at the start of their clerkships. In view of this function within the curriculum, the emphasis in this training programme is on:

- The appropriate use of knowledge and skills in case-specific situations, linking (general) biomedical and clinical theories to (specific) clinical problems and vice versa;
- Supporting the development of a realistic image of clinical practice, including its ambiguities and uncertainties and aspects of professionalism in handling these issues;
- The enhancement of clinical problem solving approaches and strategies, in particular pertaining to conscious procedural choices and making adjustments as a result of findings;
- Creating an awareness of the cognitive biases and flaws which can affect clinical problem solving, and stimulating (metacognitive) monitoring and reflection.

Considering the empirical findings about the instructional format in PBL and the proven threats to its effectiveness, it stands to reason that the choice of cases, achieving effective group dynamics and facilitation by the teachers can be potential hindrances in comparable formats and require, at the very least, a carefully chosen design. There are, nevertheless, some distinct differences between the instructional formats of the *clinical lessons* and PBL that are likely to affect work and learning processes, such as their place within the curriculum, the flow of case information and the roles of the teacher. The current theories do not offer sufficient insights to predict the impact of these differences in instructional design features on the students' learning and development of competence. With this research, we aim to remedy this

lack. The view that effective practice with real or high fidelity clinical cases should suit the level that the students can cope with and will learn most from will remain central to this research.
The main question which this research will address is: *how can authentic tasks, teacher support and the instructional design be best adjusted to students' development of competence in clinical problem solving?*

The term 'task' is used here in a broad sense; the task ingredients which are included in this research concern the case or problem to be solved, the instructional setting in which it has to be solved and the support that the students receive from their teachers during this process. Therefore, this research and its specific focus are directed towards:

1. *Optimal case design*: Which aspects of a case determine its authenticity and can be used to engage students in meaningful problem solving? Which features of the information determine the complexity of a case with regard to clinical problem solving? How can the authenticity and complexity of cases be adjusted to fit students' (changing) levels of competence in clinical problem solving?
2. *Optimal student support from teachers*: When using clinical problem solving in practice, how is self-directed learning best supported by the teacher? Which adjustments in student support during the course fit to the students' progress in development?
3. *Effectiveness of the instructional formats and course design*: How does the educational design of the *clinical lessons* contribute to the students' development of competence in terms of: (a) improved solutions to clinical problems; (b) improved approaches to problems and problem solving processes; and (c) perceived progress and the effectiveness of the programme?
4. *Assessment of progress*: How can progress in the development of problem solving competencies be established in a way which meets the criteria of: validity (representing real-life problems, situations and uncertainties from practice); reliability (consistently representing student performances) and sensitivity (detecting changes in competence within the frame of a one-year course)?

Methodology

The overall design of this study is drawn from the design-based research methodology, [107] using a mixed-methods approach[108,109] to address the multidimensional character of complex educational designs and outcomes in practice. Plomp and Nieveen[110] define this type of research as the "*systematic study of designing, developing and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them".*

A close fit to the research questions is an important prerequisite for the choice of methodology. Design-based research blends the processes of empirical research with the theory-driven innovation of learning programmes through the progressive refinement of an educational design and the theories it is based on (Figure 3). It is considered to be an important methodology for developing an understanding of how, why and when educational interventions, design features, programmes or innovations work in practice.[111,112]

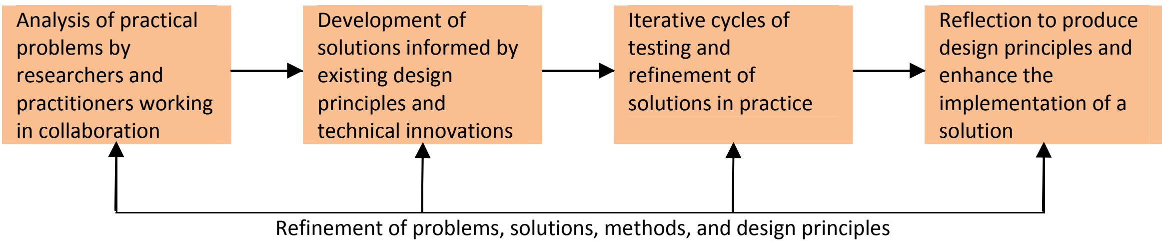

Figure 3. Basic structure of design research methodology [113]

Taking these characteristics into account, the design-based research methodology not only suits the research questions and the kind of answers we are aiming to find in this thesis, it also fits the setting and circumstances under which this research was conducted:

- In order to allow an exploration of the effects of various design features in a real world setting, most of the research was embedded in on-going coursework;
- The *clinical lessons* make up a complex course that extends across almost all of the last preclinical year. With a yearly average of 175 participating students, it requires over 1000 sessions and the involvement of about 80 clinical teachers;
- In spite of the process of collaborative course design and solid preparations for its implementation, there was relatively little experience readily available with regard to some aspects of the execution of the *clinical lessons* (particularly the tutorials);
- The development of the *clinical lessons* was part of a large-scale revision of the curriculum. This process of revision and implementation of the course could not

afford delays caused by a lack of research results about uncertainties in the course design.

After implementation, three iterative cycles[114] were used to adjust specific design features and to study the effects of these adjustments, thereby improving our understanding of the effects of these features or interventions. Figure 4 shows the overall design of the study and the change in focus in each iteration.

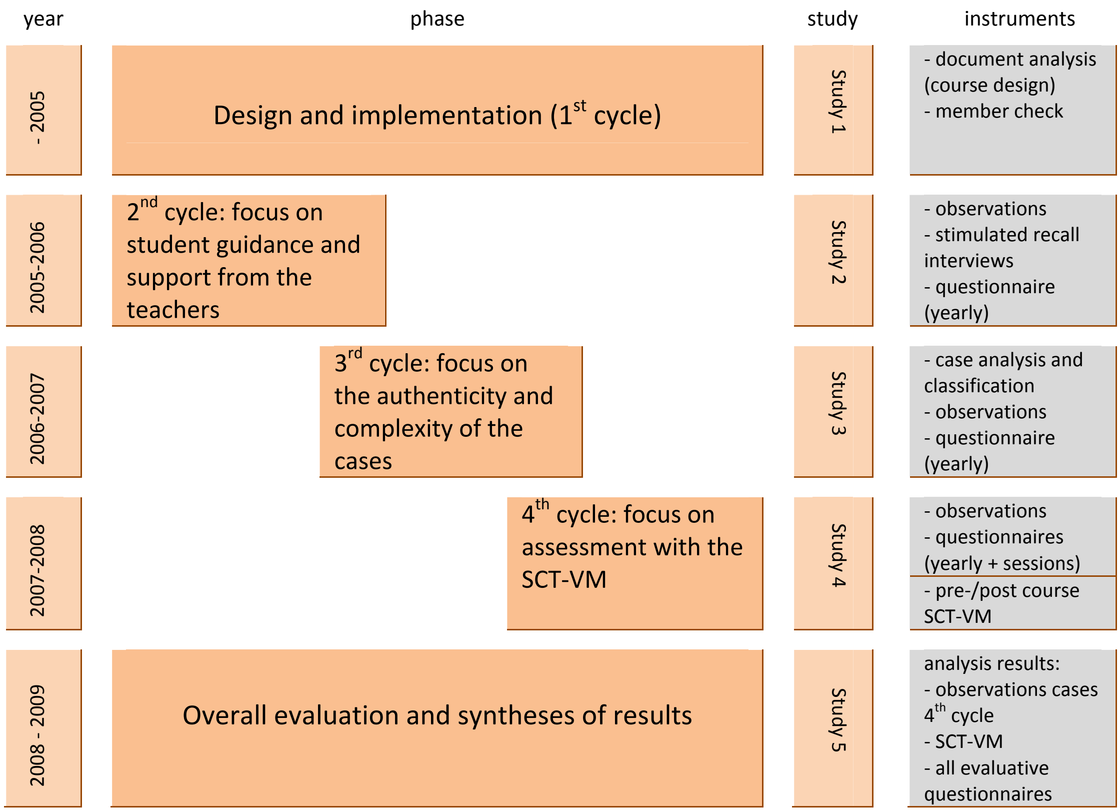

Figure 4. Overall design of the research

Overview of this thesis

The structure of this thesis was chosen in accordance with the overall design of the research.

Chapter 2 concerns the *key features of the design of the clinical lessons* and the rationale behind it. In a proof-of-concept study, we explored the extent to which the combination of design principles that makes up the course design facilitates the learning process and the fulfilment of the functions that are required in order to enhance the development of clinical problem solving competency. In addition to insights about the validity of the course design 'on paper', this study allowed us to identify latent weaknesses and ambiguities in the design.

Optimal *student support or guidance from the teacher* is the object of the study in **chapter 3**. The combination of the just-in-time provision of additional case information, scaffolding and the monitoring of performance creates interactions between the teachers' roles which can affect the students' reasoning and problem-solving processes. In this study, we established the effects of this combination of roles and optimal ways of fulfilling them.

In **chapter 4**, we focus on an optimal *case design*, specifically with regard to two key aspects of case quality: authenticity and complexity. We determined the optimal timing of case information in order to facilitate reasoning and problem solving processes, in a way which is similar to the use of these processes in clinical practice, as well as to support case preparation and reduce the case complexity to a level from which the students can learn the most. Understanding how the attributes of case information regulate the level of complexity is a prerequisite for adjusting cases to match the students' development and to make progress through the sequence of cases.

In order to establish *the extent of the students' progress* in terms of better clinical judgements and decisions, without interference during the *clinical lessons* from their peers and tutors, a script concordance test was developed, covering primary clinical care in veterinary medicine (SCT-VM). **Chapter 5** concerns the development of this test and its methodological qualities. A pressing issue for this test is whether it is possible to develop a test of decision making which incorporates the uncertainties and ambiguities of clinical practice (validity) and, at the same time, leaves no doubt about the consistency of the results (reliability) with regard to the students' performances.

In **chapter 6**, we will return to the course design as a whole. The aim of this study is to establish the *effectiveness of the design* in practice. Its effectiveness is defined in terms of changes in the students' approaches to clinical problems which indicate progress in their development of problem solving competence, improvements in the quality of their solutions to clinical problems as shown in the results of the SCT-VM, and its effectiveness as perceived by the students with regard to making and justifying clinical judgements and decisions.

In **chapter 7**, we will reflect on our findings and draw conclusions from the combined studies, specifically with regard to the theoretical explanations behind the effectiveness of particular design features, and generalisations which can be made with regard to design principles and conditions to be met in other contexts. The last part of this chapter reflects on the thesis as a whole and provides directions for educational practice, innovation in the curriculum and future research.

As this thesis is based on papers which were written to be read individually, some overlap and repetition across chapters is inevitable.

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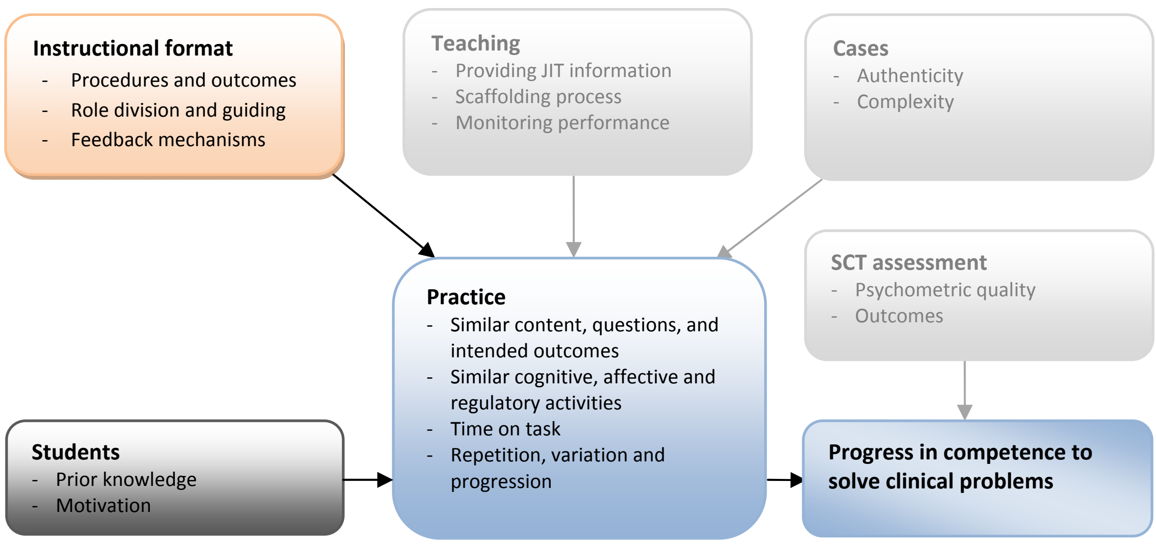
"… showed how insights from the laboratory are inherently limited in their ability to explain or predict learning in the classroom"

Philip Bell, 2004 [2]



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2. A proof-of-concept study of an instructional design for training competence in solving clinical problems [3]

Abstract

This paper examines the design of a course, which aims to ease the transition from preclinical learning into clinical work. This course is based on the premise that many of the difficulties which students experience in this transition result from a lack of experience in applying knowledge in real practice situations. It is focused on the development of competence in solving clinical problems, employs an instructional model with alternating clinical practicals, demonstrations and tutorials, and extends throughout the last preclinical year.

This study employed a 'proof-of-concept' approach to establish whether the core principles of a design are feasible with regard to achieving the intended results. With the learning functions as a frame of reference, retrospective analysis of the course's design features shows that this design matches the conditions from theories about the development of competence in solving clinical problems and instructional design. Three areas of uncertainties in the design are identified: the quality of the cases (information, openness), effective teaching (student and teacher roles) and adjustment to the development of competence (progress, coherence).

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3 This chapter has, in adapted form (US-EN), been accepted for publication:

Ramaekers SPJ, van Beukelen P, Kremer WDJ, van Keulen J, Pilot A. (2011) An Instructional Model for Training Competence in Solving Clinical Problems. *Journal of Veterinary Medical Education, 38* (in press).

Introduction

The transition from preclinical to clinical learning can be both exciting and worrying. For students, the change in role from learner into apprentice provider of care not only marks a significant step in their development towards professional competence, but also brings greater responsibilities, work pressure and dealing with the complexities of real practice. Various studies in human and veterinary medicine have addressed issues of student anxiety and transition periods have been identified as particularly stressful.[1-3] On the nature of transition problems and causal influences, different perspectives prevail. They range from student anxiety resulting from cognitive overload and inability to handle the demands of clinical practice[4-6] to stress which is attributed to processes of professional socialisation and interaction with clinical staff and clients.[4,7,8] Underneath may be experiences of knowledge shortcomings which are inherent in the changes in knowledge organisation in this phase of competence development[8-10] and a lack of workplace-related knowledge.[11]

Depending on the perspective on the sources and mechanisms behind transition problems, different solutions have been suggested. For difficulties rooted in processes of professional socialization and learning to handle challenging clinical experiences, measures are recommended which aim at raising the quality of student support and guidance during the clinical phase[1,12] and training of non-technical skills.[3,13] Major problems related to an inability to recall or apply prior knowledge in practical situations are supposedly avoided by improving the preparation of students in the preclinical phase. However, simply referring to cases and issues from practice is not enough. Even in problem-based learning settings, in which cases are used to link learning to real practice, the contrast between the preclinical and clinical phase still appears too sharp.[8] Therefore, an instructional model of alternating (theory-oriented) preclinical and clinical learning has been advocated, which includes more authentic clinical experiences and patient contacts in the preclinical phase.[14-16]

Alternating theoretical and clinical learning can be achieved in various ways. An increasing number of curricula integrates some form of early clinical exposure,[17] for example by incorporating in the first preclinical years 1-2 weeks in a clinical or primary care setting. This study concerns an alternative design which may meet some of the concerns about early clinical contacts. It consists of a course, taking place during the second half of the preclinical phase. The course aims to provide students with opportunity to practice with clinical cases and build their first clinical experiences. It has been developed as part of a curriculum reform in veterinary medicine at Utrecht University, which included measures to improve clinical supervision and student support during the clerkships as well.

Educational setting

The Utrecht curriculum in veterinary medicine consists of a four-year preclinical programme, covering most of the theoretical basis and skills training, followed by two years of clinical learning during clerkships. Every five to six years the curriculum has been revised to adjust the course to major developments in veterinary practice, research and higher education, and to address course weaknesses which come to the fore in evaluations.

Since the mid-nineties, the curriculum has incorporated a series of case demonstrations (in year 3-4) and a short course of 'advanced clinical diagnostics', parallel to the first clerkships, to bridge the gap between theory and clinical practice. Results from subsequent course evaluations and reflection on clerkships suggested, however, that these courses did not lead to the projected level of preparedness for clinical work. Accordingly, it was decided that the whole programme meant to optimise the transition into practice, should be reviewed. The effectiveness of the existing courses was supposedly limited because they:

- did not require enough active student involvement (large groups; teachers demonstrating their execution of patient assessment and decision-making),
- focused too much on acquiring new knowledge and advanced skills (assuming integration of previously gained knowledge and transfer to new situations taking place automatically),
- reinforced a narrow image of clinical practice (with insufficient attention given to learning to deal with the complexities and ambiguities of practice, and to an appropriate justification of professional opinions, choices and decisions).

These deficiencies were attributed in some part to the educational design itself, as well as resulting from an inconsistent execution of the course. Achieving a high level of teacher agreement and support to implementation were viewed as part of the redesign process.

Aims and objectives of the course

The intended outcome of the programme redesign was a course, the 'clinical lessons', which met the following aims and functions:

a. provide *ample opportunity to practise* applying knowledge and skills in the reasoning about and solving of realistic clinical problems,
b. focus on *reinforcement and integration of knowledge*, which was gained previously in separate disciplines and subjects,
c. emphasize explicit *justification of professional judgements, choices and decisions* and 'evidence-based' standards of work,
d. support the development of *a realistic image of clinical veterinary practice* (type and complexity of problems, ambiguities, workload, demands on veterinarians, etc.).

Some additional features of the educational and organisational setting were acknowledged as conditional. The course:

- provides exposure, in the preclinical phase, to authentic clinical problems and settings,
- builds on a high level of active student involvement and self-directed learning / work,
- incorporates an assessment programme which is aligned with the process of competence development,
- is arranged within the possibilities of the clinical conditions available (University Clinical Departments), an acceptable workload and patient well-being (about 175 students yearly).

Design of educational programmes and courses

Extensive educational programmes are usually built on a complex mixture of intertwined design features and instructional measures (e.g. Taylor[18]). They typically have to be designed against only a partial understanding of all the underlying variables and their interactions at the different layers of the system.[19] General insights from learning and teaching theories are inherently limited in their ability to predict the actual learning in a specific context and real-life setting.[20] Furthermore, implementing a novel instructional approach in practice and making it effective often demands adjustments and refinements to its original design as it unfolds in reality.[21] The whole process of course development and implementation is prone to slippage[22] and the relationship between learning theories, intended programme and the actual outcomes may become blurred. Van den Akker[23] refers to this when differentiating between the intended and the implemented curriculum (Figure 1).

Intended curriculum	
Ideal: rationale or basic philosophy underlying a curriculum	*Written:* Intentions as specified in curriculum documents and materials

Implemented curriculum		
Operational: Actual process of teaching and learning (also: curriculum-in-action)	*Perceived:* Curriculum as interpreted by its users (especially teachers)	*Experiential:* Learning experiences as perceived by learners

Attained curriculum	
Assessed: selection of curriculum content, which is included in the assessments (also: hidden curriculum)	*Learned:* Resulting learning outcomes of learners

Figure 1. Curriculum representations (modified, van den Akker[23])

Creating a conducive learning environment as well as gaining an understanding of learning and teaching in natural settings,[24] require the relationship between the course design and educational theories to be transparent. This enables the identification of the areas of focus for optimising the design, implementation considerations and research questions. The main issue this study will address concerns the extent to which the instructional design of this course is feasible with regard to achieving its aims and objectives. This requires an answer to the following questions:

a. What are the key features of the actual course design?
b. Which (learning) processes do the course objectives require? Which learning functions need to be fulfilled to facilitate these processes and meet the objectives?
c. How well do the key features match the required processes and functions? Which potential weaknesses or ambiguities in the course design are identified?

Methods

This study employed a 'proof-of-concept' approach, a methodology used in applied design research to establish whether the core principles of a design are probable and feasible, before the risks or investments connected to further testing are taken. Here, it was used in particular for retrospective assessment of the feasibility of the course design with regard to achieving the intended results, to identify issues which had to be addressed to safeguard that the execution of the course would be consistent with its design, and to provide direction for supporting and monitoring implementation.

Procedure

The procedure followed was derived from the 'case study' methodology as described in Creswell's typology of qualitative research designs,[25] and modified for proof-of-concept. It included the following steps:

1. The key features of the *course design* were extracted by the first researcher from a content analysis of course documents (descriptions, study materials, minutes of preparatory meetings). To establish the accuracy of the described design features, a member check[26] was used with the core teaching staff that had been involved in the course design, as informants. (n=12; agreement after adjustments)
2. Based on theories and empirical research findings about solving clinical problems and instructional design, the *learning functions* and *processes* were identified, which are required to accomplish this course's aims and objectives. Learning functions are the psychological functions that have to be fulfilled for high quality learning to take place.[27,28] In this study they are used as a frame of reference for assessment of the course design. The instructional design theories which were considered valid for this particular setting concern:
   - initial education at a level of higher education,
   - in a (veterinary-) medical domain,
   - geared towards the development of competence,
   - with a focus on higher order thinking: clinical reasoning and problem solving.
3. To assess the validity of the course design, its key features were matched to the learning functions. The degree to which learning functions are adequately covered determines the validity of the course design; deficiencies in the coverage (or conditional fulfilment of functions) shed light on the uncertainties in the design.
4. Finally, discrepancies between the course design features and learning functions, as well as uncertainties within the design, are identified as areas of focus in improving the design, supporting and monitoring implementation, and in course evaluation or further research about educational issues.

Results

a. Key features of the course design

The clinical lessons extend through the last preclinical year (Figure 3). The core of the clinical lessons consists of a mixture of three complementary teaching formats: clinical practicals, tutorials and demonstrations. Cases make up the heart of these formats and every week several cases are covered, both theoretically (paper-based cases) and practically (real patients). Hundreds of sessions take place annually; they require the involvement of dozens of teachers and patients.

Preclinical phase				clinical phase	
Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Biomedical & veterinary courses: - disciplinary and thematic - theoretical and skills training			**Clinical lessons** Electives	Clerkships Research internship	

Figure 3. Curriculum overview

In each of the three teaching formats, the emphasis is on analysis of the problem and context, gathering the information needed, establishing a differential diagnosis and choosing therapeutic or preventive interventions. The students are expected to direct the exploration of the clinical problem(s), establishing a 'solution' and discussions about the case. The teachers' primary tasks are to provide students with the required patient information and to scaffold or guide them in the process.

Content analysis of the course documents revealed, at a level of separate sessions or meetings and teaching formats, the following *key features of the design*:

1. (Authentic) cases are *the unit of work.*

The problems, issues and questions students are dealing with in the clinical lessons are expressed in a case format. Cases are not limited to only (veterinary) medical issues; they may contain other issues which affect the patient's circumstances or clinical decisions, e.g. preventive care, ethical considerations or public health risks. Although cases are preferably as authentic as possible, there may be some adjustments to match a case with the students' level of competency.

2. *Activities and sequence*: the process of problem-solving activities is based on the procedures underlying patient assessment and preventive screening.

Both with real patients and in the paper-based cases, the students follow a sequence of activities similar to the basic procedures in patient assessment and preventive veterinary care. Depending on the specific content of a case, the students may start, for example, with the checking of vital functions (first aid) or an anamnesis (owner), and end in establishing treatment or preventive modalities or evaluating the appropriateness of their interventions. Commonly, students afterwards write a brief report about their findings, conclusions and the rationale behind their advice and decisions. These reports may take various formats, e.g. a letter of referral, an insurance report, etc.

3. The required case-specific *information* is provided *just in time.*

Unlike many other case-based learning formats, the students do not receive all the required case information beforehand or at the start of a session. Instead, they receive most of the information, at their request, as they progress through the assessment and the case unfolds. To allow preparation before the tutorials actually take place, students receive beforehand a case description with initial information about the problem and its context.

4. *Role of students*: all formats require / build on a high level of self-directed learning and critical co-operation between peers.

If case information is available beforehand, students prepare for the meeting collaboratively. They determine which additional patient information will be needed, discuss strategic and/or procedural aspects of the case, and decide which topics they might want to review before a case discussion actually takes place. The actual case explorations are led by two students. The other students in the group observe the course of the case exploration, participate in interim time-out discussions and provide peer feedback at the end of the meeting.

5. *Role of teachers:* teachers combine the provision of information with scaffolding students in their problem-solving process, and assessing their performance.

Teachers, in the role of owner or caretaker of the patient, or as the referring veterinarian, provide students, on request, with the additional information they need to deal with the case. They provide students with just enough help to establish a methodical approach to unfamiliar cases, to relate specific clinical problems to biomedical theories, to recognize reasoning biases, and to deal with the uncertainties of real-life problems. At the same time, they assess the students' level of performance and monitor their development and progress

6. *Regulation*: between phases in the process and at the end of a case discussion, time is allocated specifically to *reflection* and *feedback.*

If needed, students can call for a 'time-out' to review their case approach and problem-solving strategy, to reflect on their findings so far, and to decide how to proceed. This allows them to assess their own actions, reasoning, judgements, choices and decisions, without too frequent interferences in the process (reflection-on-action). Their peers contribute to this by providing feedback, suggesting alternatives, etc. End of session reflection and feedback are supposed to contain feed forward for next cases and performances.

At the level of the course as a whole, the key features of its design are:

7. The course covers a *large variety* of animals and conditions, *representing* the situations and problems that veterinarians are confronted with in their practice.

The clinical lessons extend throughout the last preclinical year. There are 2-3 sessions weekly and in each of them 2 or 3 cases are covered, either theoretically (paper-based cases) or practically (real patients). In total, a student is presented with over 210 cases. The (paper-based) cases for the tutorials are chosen to cover the main groups of complaints, problems or requests for help in primary veterinary medical care. As the university clinics fulfil the function of a referral centre, a substantial part of their patients do not represent the kind of cases and conditions that are typical for primary veterinary care. This requires from their teachers a careful selection of cases for the practicals and demonstrations, and conscious choices in the patient information that students receive.

8. As the course progresses, cases are placed in a *sequence of progressive* complexity and scaffolding support is gradually reduced.

Parallel to the expected progress of the students with regard to their clinical experience and level of self-regulation, more complex cases will be presented and scaffolding support reduced. Case complexity relates to attributes such as the problem transparency and space, the number and dynamics of related issues, variety in potential solutions, availability and reliability of information, the extent of expert knowledge required, time pressure, etc.

9. The different work formats have *complementary strengths* with regard to achieving the course objectives.

Whereas the clinical practicals, with real patients, most closely resemble the activities and experience of clinical work, the paper-based cases in the tutorials allow extensive attention to the reasoning process, relating findings, generating hypothesis, discussing possible patterns, etc. The clinical demonstrations require, as well as conducting the patient assessment or executing interventions, elements of presentation and explicit justification. Furthermore, demonstrations can be used to illustrate conditions or case aspects which are less common.

10. Longitudinally repeated assessments are used to *monitor progress* and to establish the achieved level of competence in clinical problem-solving reliably.

The students' individual progress is monitored throughout the year. On average, the performance of each student is assessed 8-12 times a year. At the end of the year, there is a final written exam covering five cases.

b. Learning processes: competence in solving clinical problems

Clinical problem solving was defined as *the process of (selective) gathering, interpreting and organizing of information, in order to make and justify professional judgements and decisions about a patient's condition and situation, (veterinary) medical interventions and their expected effects on the patient*.

According to the first models of diagnostic reasoning, solutions to clinical problems are found by generating in the process relevant hypotheses, and using these to guide subsequent data collection and testing of hypotheses, until a plausible explanation or solution is found.[29] Successive research and evolving cognitive theories led to elaborated models of clinical decision making and medical expertise. In particular, the notion of clinical reasoning as a general problem solving process or skill was challenged by empirical findings and philosophical discourse.[30,31] Depending on the case particulars, as well as the extent of their clinical experience with similar cases, physicians solve clinical problems in a variety of ways. Within their own area of experience, their approaches largely depend on pattern recognition, inductive reasoning and retrieval of prior successful choices and decisions, rather than on systematic analysis, deductive reasoning or extensive testing of hypotheses.[32,33]

Nowadays, researchers largely agree that competence in clinical problem solving relies on an extensive knowledge base, organised in schemes which suit the mixtures (patterns) of available information in practice, and which are usually referred to as illness scripts.[30,34,35] These scripts emerge from exposure to patient problems, and frequent practice is considered essential to synthesize, develop and extend illness scripts.[9,36,37] In this process, the underlying biomedical concepts and theories become encapsulated and only reactivated if needed.[38]

Achieving competence in domains with high levels of context specificity requires practice in a large variety of situations.[39-42] Flexible use of knowledge or transfer is facilitated by anchoring learning in meaningful contexts, as well as revisiting content at different times in rearranged contexts, for different purposes and from different perspectives.[43]

Just as the differences between analytical and more intuitive approaches to clinical problems have fuelled discussions about the strengths and weaknesses of various diagnostic reasoning models,[32,44,45] so they have been at the heart of different educational designs. Traditionally, clinical learning programmes are directed at teaching a systematic analysis of signs, symptoms and enabling conditions and relating them to differential diagnostic possibilities. This seems sensible as regards the insufficiently developed knowledge structures of novices, and the risk of biases, resulting from non-analytic processing. Since the mid-nineties, nevertheless, it has been argued repeatedly that training programmes should aim at mastering multiple problem solving strategies and avoid exclusive reliance on an algorithmic, analytic approach.[35,46] Analytical and non-analytical approaches are no longer regarded as two opposite strategies from which physicians consciously select either one; instead, their approach can be characterized as a mixture with elements of both recognition and analysis.[33,35,45] And the benefits of facilitating other strategies have been confirmed empirically in studies comparing diagnostic accuracy in alternative instructional designs.[47,48]

In summary: current views about the development of competence in solving clinical problems and effective instructional designs express: a) the importance of learning around realistic examples, b) which accurately represent the range of ways in which conditions clinically present, c) in sufficient numbers and starting early in the curriculum, d) providing practice in both analytic (deduction) and non-analytic (recognition) problem solving processes, and e) supporting the linking of specific cases and contexts with general theories, comparison across cases and practice with error-checking strategies.

Instructional design: learning functions

Instructional Design (ID) theories and models offer a framework for designing educational events in ways which enhance the possibilities of learning, encourage student engagement and facilitate in-depth understanding. The assumption underlying ID is that the prospects for learning are increased if only the instructional components are properly managed. Basically, ID models reflect translations of theories about memory, learning and development into instructional strategies, activities and effective arrangements. Despite differences in their theoretical points of departure, various ingredients of these models are shared by many and supported by empirical research findings.

In design sciences, the notion of 'function' is central[49] to derive from objectives, projected outcomes or processes, the actions, tools or features to be integrated in a design. By analogy, learning functions are the functions which have to be fulfilled by the students to achieve particular objectives through high quality learning.[27] Their fulfilment can be facilitated, supported (e.g. '*encourage comparison through the use of questions'*) and even substituted (e.g. '*providing students with an overview of the material to be studied'*) by the teacher and other learning resources.[27,50]

Processes and functions: the frame of reference

Figure 2 shows a synthesis of the learning functions which are considered relevant with regard to development of competence in learning to solve clinical problems, and models how they are related. Consistent with the differences in the perspectives of various ID theories, three levels of processes and learning functions are distinguished: functions at the level of the *work processes,*[51,52] at the level of *learning processes*[53] and, finally, at the level of *development processes.*[52,54,55] They are related, incremental and iterative processes, although taking place within different time frames:

- At the centre of the work processes are the activities which make up clinical problem- solving (from 'gathering information' up to 'making decisions') and its secondary processes, such as communication with the patient's caretaker, the actual execution of assessment tests, and monitoring patient wellbeing and safety. Depending on the extent of experience with similar cases, the distribution between the various activities and the balance between 'systematic-analysis' and 'pattern recognition' differs.

- The learning processes concern those functions, additional to the work processes, that support learning from experience and raise practice to a level of 'deliberate practice'. Some of these functions start even already before the actual practice takes place; others take place during or after practice.
- The developmental processes and functions relate to the accumulation and consolidation of learning experiences, in order to achieve competence. While fulfilment of functions at the level of work and learning processes is supposedly achieved in a single session, the fulfilment of the functions at developmental level is conditional for the design of the course as a whole.

At the level of work and learning processes, the following function categories are identified:

I. *Orientation* (a-c) on the problem, objectives or outcomes, and on the procedure, activities and means.

These functions direct attention and expectations (provide focus), support reactivation of prior knowledge and evoke motivation.[53,54,56] Their significance is not confined to the orientation phase; fulfilment of these functions remains relevant almost throughout the whole learning process.[52,56]

II. *Practice* (d-g) in applying knowledge and skills, and expressing and testing one's own understanding and problem solving approach.

Central to practice is applying knowledge and skills in all components of the work process (gathering, organising and interpreting information, etc.). The additional functions support relating case details to prior experiences and theories, and reinforce or deepen understanding by building 'mental' models and meaning.[27,52,54,55,57] Questioning one's own assumptions and explanations, as well as monitoring and adjusting the work process, facilitates the gaining of insight into one's own reasoning and decision making (meta-cognition), and potential biases or error.[33,35]

III. *Evaluation* (h-j) of outcomes and the process, as well as generalisations about the problem and solutions, and feed forward for similar problems.

The evaluative functions support appraisal of the chosen approach, facilitate development of sensitivity for bias and error, shed light on possible alternative approaches, and provide feed forward for dealing with (comparable) problems in future practice.[27,52,53]

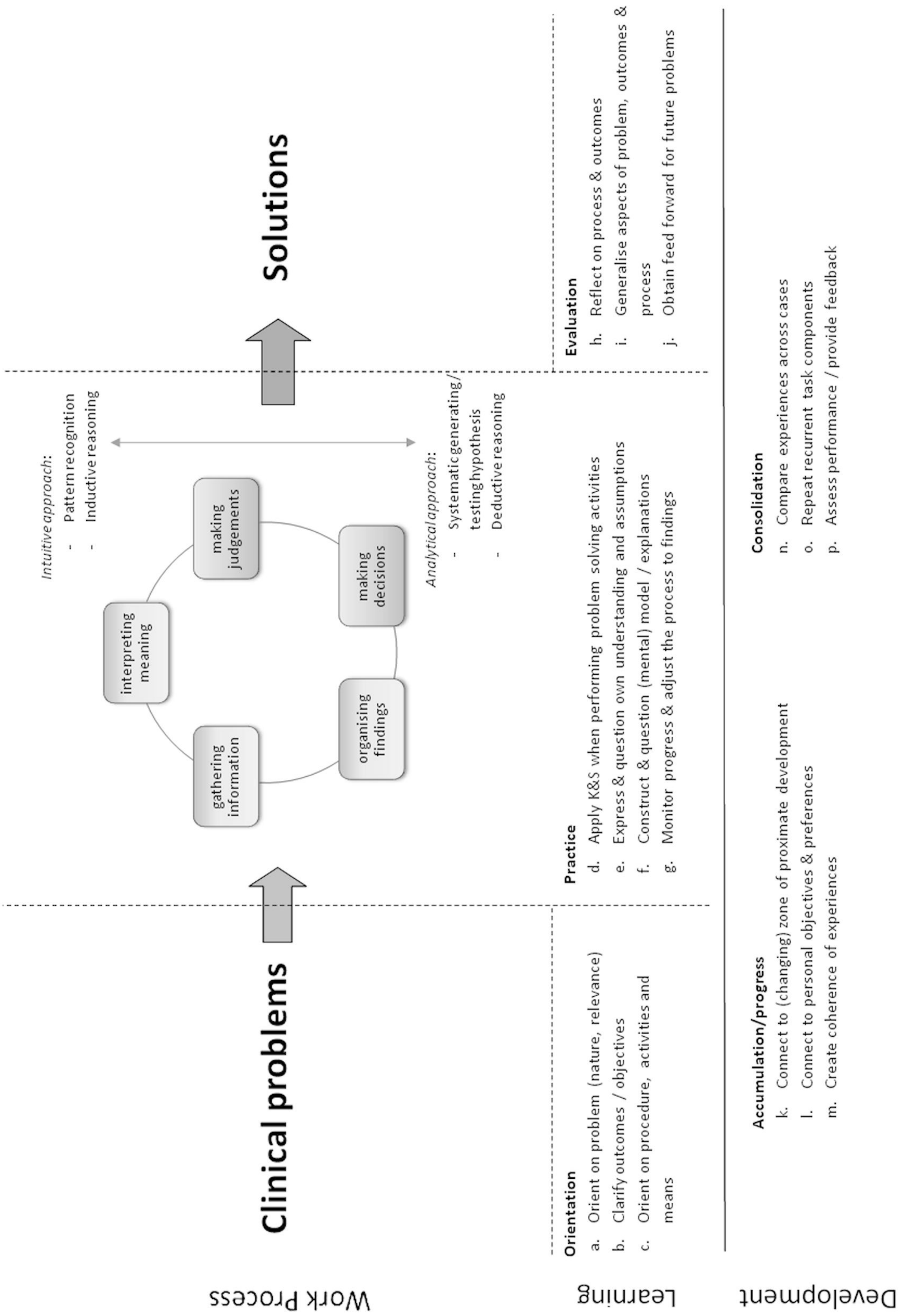

Figure 2. Processes and functions

At the level of developmental processes, the functions which are relevant to facilitate competence development are:

IV. *Accumulation / progress* (k-m) to connect to the level and motivation of the students and to create coherent experiences.

These functions concern adjustments of the content and complexity of a task to the student's level of competence and personal objectives, and the changes in competence and objectives as the student progresses during the course.[52-55] Supporting reinforcement of developing knowledge and skills through complementary experiences is part of these functions as well.

V. *Consolidation* (n-p) through combining and repeating experiences, assessment and feedback.

These functions support the consolidation of experience: acquiring routines in recurrent parts of the task, refinement of knowledge networks and development of illness scripts, and internalisation of standards of work quality.[27,53-56]

c. Assessing feasibility: design versus functions

The results of comparing the course's design features with the learning functions are summarised in Tables 1 and 2. The key question guiding this comparison is: *(how) does a particular feature of the course design facilitate fulfilling a specific learning function?* Because the roles of the students and their teachers (4 and 5) essentially concern the division of work in fulfilling the learning functions, they are not separately described in comparison to each specific learning function.

At both levels (course as a whole, separate sessions), functions are supported by one or more key features of the course. In particular, the functions related to practice are supported by several features. The ways in which a design feature facilitates fulfilment of a function vary:

- Most course features are merely conditional on fulfilling a function. For example, providing information beforehand which is sufficiently focused enables the students to direct their attention (limit their scope) in their preparation of the case discussion (3b).
- Some course features offer or require practice with an activity which corresponds (at least partly) to fulfilling a learning function, e.g. applying relevant knowledge and skills in all aspects of patient assessment (2d).

Table 1. Comparison course features – learning functions (at level of separate sessions)

Design features / Learning functions	1. (Authentic) cases are unit of work	2. Activities and sequence based on patient assessment procedure	3. Required information is provided just in time	6. Time allocated to (interim) reflection and feedback
I Orientation:				
a. Orient on the problem, nature and relevance (reactivate prior knowledge, evoke motivation)	· relevance of authentic problems is, in general, clear		· information provided beforehand clarifies nature (and relevance) of problem	
b. Clarify objectives / intended outcomes (focus / direct attention)	· general objectives are intrinsic element of case work · specific objectives unfold during case analysis		· information provided beforehand is sufficiently focused	
c. Orient on procedure, activities and means (raise expectations, choice of approach/procedure)	· authentic cases support realistic expectations and images of practice	· work procedure is intrinsic element of patient assessment	· information provided beforehand allows first choices in approach	
II Practice (problem solving):	Cases offer practice in:	Assessment procedure offers practice in:	JIT information:	Time-out offers opportunities:
d. Apply knowledge and skills (K&S) to accomplish task	· selecting and applying relevant K&S from various sub-domains	· applying relevant K&S in all aspects of problem solving process	· resembles realistic availability of information	· for reflection-on-action instead of reflection-in-action
e. Express and question own understanding and assumptions	· expression of understanding beyond a level of reproducing general theory	· explanation of understanding to others (patient, caretaker, referring colleague, etc.)	· requires expression of hypothesis / assumptions to guide decisions about the additional information needed	· to question / discuss thoughts, interpretations and assumptions explicitly
f. Construct and test task-specific model / explanations / meaning (relate, process critically, integrate)	· recognition of key features and patterns in findings · generating case-specific models and hypotheses	· relating findings from subsequent activities · using patterns / hypothesis to guide subsequent activities	· supports continuous refinement of case-specific models / explanations	· to focus on modelling, separate from execution of patient assessment
g. Monitor progress and adjust approach / procedure to findings (metacognition)	· adjusting processes and activities to findings	· concurrent execution of activities and monitoring results from choices (reflection-in-action)	· provides *immediate* feedback on actions	· for in-between reflection on progress, process and results
III Evaluation:				Final evaluation offers opportunity for:
h. Establish outcomes, reflect on process and how they relate	· case problems (+ effects of solutions) provide reference for review of outcomes	· coverage of necessary activities and sequence offer structure for review of process		· final reflection and feedback on results and (overall) process
i. Generalise case aspects, outcomes and process	· case format eases comparisons across cases			· comparison between cases and generalisations
j. Translate feedback into feed forward for similar tasks				· feedback, expression of learning gain and near-future objectives

Table 2. Comparison course features – learning functions (at course level)

Design features / Developmental functions	7. Sufficient number of cases, in a representative variety	8. Sequence of progression	9. Complementary formats	10. Longitudinal monitoring and assessment
IV Accumulation / progress:				
k. Connect to (changing) zone of proximate development		· cases arranged in order of gradual increase in complexity · gradual reduction of scaffolding interventions		· longitudinal monitoring provides direction for adjustments to level of students
l. Connect to personal learning needs and preferences	· a substantial number of cases offers variety in personal expectations and needs		· different formats offer variety in learning styles	
m. Create coherence of experiences		· gradual progress creates coherence of experiences	· separate formats have complementary strengths with regard to learning objectives	·continuity in teacher feedback supports coherence
V Consolidation:				
n. Combine experiences across tasks	· sufficient variety supports refinement and extension of schemata / scripts		· complementary formats enrich experiences across cases	
o. Repeat practice with recurrent (algorithmic) task components	· sufficient number of cases allows (within task) practice of routines			
p. Assess performance / obtain feedback repeatedly (internalisation)	· sufficient number and variety of cases is requirement for internalisation			· continuous assessment / reinforces internalisation of standards of quality in work

The assessment also revealed the following areas of uncertainty:

- *Orientation (case information)*: whereas cases deliberately start open-ended to allow exploration and case information to be provided in the process, it is uncertain whether the information students receive beforehand contains sufficient elements for orientation, to focus preparations and to make initial choices about the case approach.
- *Practice (peer involvement)*: several course features support the student's expression of understanding. Whether questioning their understanding and critical reflection are sufficiently facilitated by the involvement of their peers only during the interim time-outs is uncertain.
- *Practice (scaffolding multiple strategies)*: the design does not limit problem solving strategies to one (systematic-analytic, algorithmic) approach, independent of case content and the student's prior experiences. Nevertheless, the pedagogy of

scaffolding mixed approaches and facilitating the students' development of an array of problem solving strategies is not yet well-established.

- *Accumulation (case complexity)*: the course assumes an arrangement of cases in an order of progressive complexity, which in practice requires from teachers sufficient knowledge about how particular case attributes influence its complexity, and estimations of whether this case complexity falls within the students' zone of proximate development.
- *Consolidation (case variety)*: a sufficient number and variety of cases appears to be an important design feature, connected to fulfilling functions at course level. How many and how much variety may be considered satisfactory to support students at this level is unknown.

The use of learning functions as a frame of reference to establish validity builds on the assumption that students and their teachers manage to fulfil their roles adequately. This means that the validity of the course design also depends on the teachers' ability to combine different roles (5) and the students' self-directedness (4):

- *Teacher roles*: although the design assumes a high level of self-directed learning, the teachers have to combine, adaptively, different roles: providing additional case information at the students' request, scaffolding students in the process of clinical problem solving, and assessing their performance. During the process of course design the clinical teachers expressed their concern about the complexities of combining these roles effectively.
- *Student roles*: those students who have a leading role in the case discussions have sufficient opportunity to actively fulfil the learning functions. This is not so for their peers. In particular in the tutorials (paper-based cases), their active involvement is limited to the time-outs and the preparation and evaluation of the discussions.

Conclusions and discussion

Appropriateness of course objectives with regard to transition

The decision to focus on the development of competence in clinical reasoning and problem solving fits well into an analysis in which transition problems are attributed to a lack of experience in applying previously gained knowledge in practice. Solving clinical problems is recognised as a key-competence in providing (veterinary) medical care and may be one of the most demanding parts of clinical practice to learn. Beyond a mere application of (general) theoretical knowledge in a specific case, it requires, almost concurrently, selecting and handling the information needed, relating findings and recognising patterns, reasoning about problem aspects (testing hypotheses, weighing uncertainties, estimating probabilities, etc.), and making judgements and decisions. Experiences with realistic clinical settings and patients fuel the development of knowledge structures which suit the way knowledge is used in practice,[10,58] extend to procedural and workplace-related knowledge, e.g. Eraut,[11] and support the development of a realistic image of clinical practice.

Equally, the function of the *clinical lessons* does not extend beyond bridging the gap between the theoretical focus in the preclinical phase and learning in practice. Obviously, a lack of experience in applying knowledge in real-practice situations is a logical result of a clear distinction between the preclinical and clinical phase. And the importance of realistic experiences to facilitate this enrichment and changes in knowledge organisation merely emphasizes the relevance of learning in a clinical setting. Incorporating practice in clinical problem solving, patient contacts and clinical experiences in the preclinical phase, then, builds on the supposition that becoming acquainted with some aspects of clinical practice reduces the (cognitive) load on the students in the transition phase. Whether the experiences that students gain in this course are rich enough to ease this transition can be established after the course has been conducted and effects are studied in greater depth.

Validity of the programme design

The results from the comparison of the design features with the learning functions imply that this course design is feasible with regard to achieving its aims and objectives:

- it provides *opportunities to practise* by applying knowledge and skills in the reasoning about and solving of realistic clinical problems (by taking the clinical work process as the centre of the learning activities)
- it reinforces (*integration of*) *prior knowledge* which was learned in separate disciplines and subjects (by using cases and contexts, which require combinations and patterns of knowledge that exceed disciplinary boundaries)
- it offers opportunities for explicit *justification of professional judgements, choices and decisions* and ‘evidence based’ standards of work (by incorporating these

activities into the work process and additional facilitation of critical questioning and reflection)

- it supports the development of *a realistic image of clinical veterinary practice*, including its ambiguities, the responsibilities of the veterinarian, communication with the owner or caretaker (by using authentic problems and creating high-fidelity educational settings)
- and it is conducive to *development of competence* (by including activities which support consolidation and accumulation of experiences and using a variety of cases).

Matching the key features of the programme against the learning functions also revealed weaknesses or uncertainties at the design level, which may be addressed by additional support to implementation and execution of the programme, and require monitoring of effects and outcomes:

a. Instructive cases: the information provided beforehand, the openness of the case
b. Effective teaching: concurrent fulfilment of different teacher roles, active involvement of whole student group
c. Development of competence: progress in case complexity, support to multiple problem solving strategies, adjustment of scaffolding to changing level of competence.

Limitations of this study

In this study the (operational) feasibility of a programme design was assessed by analysing its key features in relation to theories about instructional design and competence development in solving clinical problems. In particular, by relating design elements (features, interventions, measurements, strategies, etc.) to the achievement of an intended outcome by means of fulfillment of learning functions, we employed a rationale corresponding to the format of design principles.[19] An educational design principle can be defined as a theoretically grounded construct, linking an instructive feature or intervention (process activity, means, environment, etc.) to the desired educational effects and the underlying explanations / mechanisms with regard to learning and instruction.

Instructive features and mechanisms may be formulated at different levels of specificity, e.g. '*education about …. creates an awareness of students that…*' versus '*in the first phase of learning sign language, parallel visual perception of shape, relative* *special location and movement of the hands raises the speed of …'*. Expressed in general terms, a design principle may not provide sufficient direction for further development of the programme, nor allow an understanding of its working mechanisms in practice. Formulated too specifically, design principles will not allow sufficient room for teachers and students to adjust their activities to their specific situation and context.

For this study, we aimed to assess the programme's validity by expressing design features at a level of activities, strategies or measures which can be taken by the teaching staff and perceptible learning functions. As a result, these design features still have a certain amount of bandwidth. For example, because there is no exact measure of case complexity, progress in the sequence of cases can only be interpreted from broader levels of complexity. In our view, this bandwidth is consistent with the heuristic nature of clinical problem solving processes, in particular when dealing with unfamiliar cases and uncertainties.

This proof-of-concept study is limited to the assessment of whether a particular design, or rather the construct on which the design is based, is feasible in view of achieving its aims and objectives. By that, it revealed in more detail how the various components of the programme are expected to contribute to its effectiveness, as well as potential interactions, weaknesses or uncertainties which should be taken into account in the further development and implementation. Obviously, the effectiveness of the programme will also depend on the way it is executed. A better understanding of its effectiveness, its impact on the transition to clinical practice, and why or how it works in terms of the contributions and interactions between the various programme ingredients,[59] is the objective of our subsequent studies.

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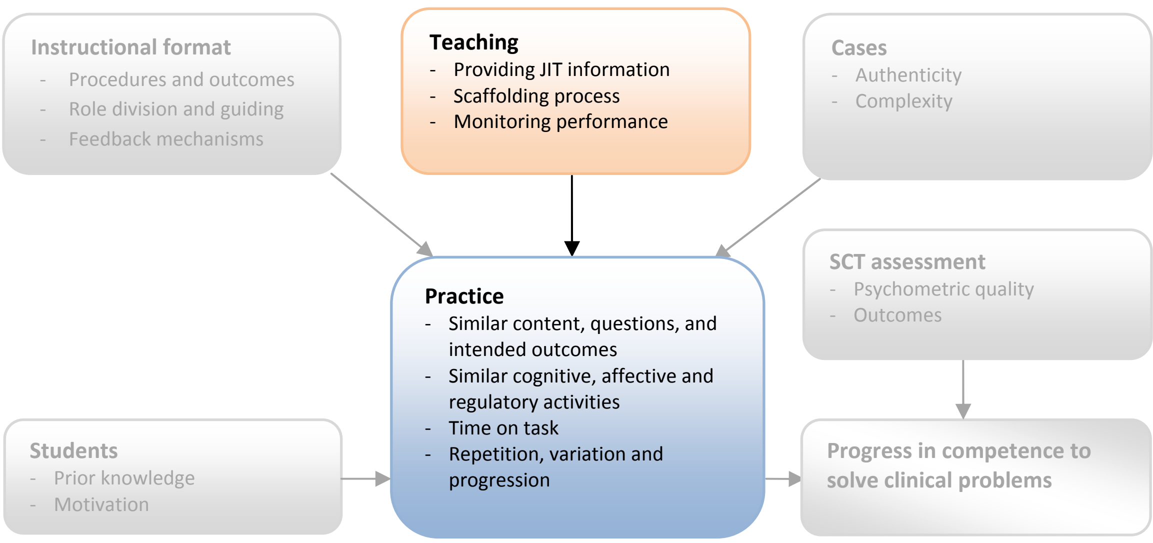
"In particular, it is clear that expert reasoning is not something that can be taught"

Vladimir Patel, 1994[4]



4 Patel, VL, Arocha, JF & Kaufman, DR (1994). Diagnostic reasoning and medical expertise. *The Psychology of learning and Motivation: Advances in Research and Theory, 31, p.* 242

3. Effective teaching in case-based education: patterns in teacher behaviour and their impact on the students' clinical problem solving and learning [5]

Abstract

Case-based learning formats, in which relevant case information is provided just in time, require teachers to combine their scaffolding role with an information-providing one. The objective of this study is to establish how this combination of roles affects teacher behaviour and that, in turn, mediates students' reasoning and problem solving. Data on actual behaviours, intentions, effects and appreciation were collected using observations of case discussions, interviews and a questionnaire in a mixed method, concurrent nested design.

Cross-case analysis of the observed discussions revealed two patterns of combining the provision of information with scaffolding. Although students commonly responded to scaffolding interventions as intended, the results from the observations and the questionnaire showed that a pattern with a high level of concurrent scaffolding and provision of information should be avoided.

5 This chapter has in adapted form (US-EN) been accepted for publication:

Ramaekers SPJ, van Keulen J, Kremer WDJ, Pilot A, van Beukelen P (2011). Effective teaching in case-based education: patterns in teacher behavior and their impact on the students' clinical problem solving and learning. *International Journal of Teaching and Learning in Higher Education*, 23 (in press).

Introduction

Since the emergence of approaches such as case-based and problem-based learning, the way cases are used and their functions in the learning process have extended beyond simple illustrative purposes or opportunities to practice the application of discrete skills.[1,2] Which case characteristics effectively contribute to higher-order learning and how students, in their learning from cases, are optimally supported by their teachers depends on the aims and specific type of case-based learning.[2,3] Research has identified three central conditions: high quality cases, a supportive instructional design and competent teachers.[4,5]

High quality cases are meaningful, reflect the issues, problems and circumstances that professionals are confronted with in reality,[6,7] provide similar information (and a similar sensory input) to the real situation[8,9] and require the same (mental) activities and processes.[10] They arouse curiosity, support the experience of a need-to-know[11] and call for higher-order thinking[12,13] by using prior knowledge and probing understanding.[14]

A *well-designed educational format* provides direction to learning activities, which is particularly valuable to support self-directed and group learning. It clarifies the purposes of learning activities,[15] offers guidance on effective task approaches, procedures (e.g. the 'seven step' method in problem-based learning) or templates[16] and creates transparency about the roles of participants and criteria for (self-)assessment.[17] Reflection and feedback are considered essential components of a format for supporting the translation of experiences into learning.[18,19]

The proficiency of competent teachers extends to the case content, ways to master this content and how to guide students in accordance with their needs. Although in many case-based learning formats teachers do not function as a main source of information, content expertise helps them recognise the particulars of the reasoning, assumptions and (mis)understandings of students as well as issues of focus in scaffolding them.[20] Understanding the ways a particular content can be mastered, as well as the typical difficulties that students might encounter and effective ways to help them overcome such hindrances, are beneficial for recognising the complexities of a case and deciding if, when and how to intervene in the process.[18,21] Appropriate teacher interventions raise case discussions to a higher level and stimulate students to engage in mastering this content.[6,22] In terms of learning, the students' learning activities and degree of support (scaffolding) they receive should match the achievement of constructive friction.[23]

One of the issues of interest in case-based learning is the optimal timing of information. In many case-based learning formats, students receive all necessary information before or at the beginning of a case session. To simulate the way information becomes available in authentic practices, cases can be designed to allow the just-in-time provision of information. This supposedly also reduces the cognitive load on students handling complex cases.[8,24]

The just-in-time provision of case information means teachers must fulfil several roles almost simultaneously: providing students with the case-specific information they require, scaffolding them in the process of problem analysis and solving and judging their performances and levels of competence. Fulfilling different roles at the same time can be demanding[25] and might lead to (unwanted) interactions between them.[26] This study concerns the ways teachers manage to fulfil these different roles and when students benefit most from this type of case-based learning design. It is guided by the following research questions:

1. *How does the requirement to combine an information-providing role and a scaffolding role in this case-based learning format affect teacher behaviour?*
2. *How does this teacher behaviour affect the students' reasoning and the problem solving process?*

Methods

To allow the exploration of the interactions between the educational setting, teacher interventions and students' performances in natural circumstances, this study was embedded in on-going coursework. It employed a mixture of methods (observations, interviews, questionnaires) applied in a 'concurrent nested design',[27] with the observations of case discussions as the predominant method. To establish the principles of effective teaching in this format, the findings on teacher behaviour, effects on the students' reasoning and perceived effectiveness were weighted against current notions about effective teaching.

Setting and educational design

The *clinical lessons* (veterinary medicine, Utrecht University) aim to provide students with their first experiences of solving realistic clinical problems and train them to reason and decide on clinical situations in accordance with previously studied biomedical theories and guidelines for practice. They are designed to ease the transfer from mastering preclinical subjects (years 1–3) to their application during the clerkships (years 5 and 6).

The *clinical lessons* take up a large part of the weekly coursework and extend almost throughout the fourth year. The core of the *clinical lessons* consists of three complementary teaching formats: clinical practicals, demonstrations and tutorials. The practicals and demonstrations involve real clinical patients, whereas the tutorials build on paper-based cases. In all formats, the students direct the exploration of the clinical problems and the case discussions to establish optimal 'solutions'. The teachers' primary roles are to provide students, just-in-time, with additional patient information, support or guide them in the process and assess their performances. Consistent with the notion of 'scaffolding',[6] this support is limited to the degree that students need to handle the complexities of cases at a level that would otherwise be beyond their capacities.

The *clinical lessons* are taught by a group of experienced veterinary practitioners belonging to the university clinical staff. Their teaching experience ranges from one to over 20 years. Because this particular format has been introduced only recently, teachers have been provided with initial training on conducting clinical tutorials. Student groups receive instruction and support during their first '*clinical lessons*' to become familiar with the format, their roles and mutual expectations.

This study focuses on the tutorials. In this format, the information-providing role of teachers is most pronounced. The design features of the tutorial format are:

a. Groups of 12 students prepare for the clinical tutorial collaboratively. They receive a case vignette beforehand with initial information about the problem and its context. On the basis of this vignette, they determine which additional patient information is needed, discuss strategic and procedural aspects of the case and decide which topics to review before the tutorial actually takes place;
b. Each tutorial covers two cases. On average, there is about 50 minutes per case to explore and discuss findings, choices and decisions. Starting from the results of their group's preparatory analysis, they further explore the case by following a similar procedure to that used for patient examination in reality. In the role of owner of the animal (patient) or as the referring veterinarian, their teacher provides them, on request, with the additional information they need to deal with the problem. Discussion on the case is led by the students;

c. During the case exploration, the students can take a 'time-out' from the patient examination process to review their approach and problem solving strategy, to reflect on their findings so far and to decide how to proceed. Their peers observe the case exploration, participate in the (time-out) discussions and provide feedback afterwards about the handling of the case;
d. The last part of tutorials is used for evaluative (self-)reflection and feedback from peers and the teacher. This covers the approach and results, as well as performances of the leading students. The student performances in the tutorials are graded individually 5–8 times a year.

Participants and data collection

During the academic years 2005–2008, 63 case discussions were observed and recorded on video- or audiotape to allow for an in-depth qualitative analysis. These observations related to 17 different student groups, 18 teachers and 44 cases. All student groups and teachers were observed at least twice. No particular student groups or teachers were specifically selected for this study. Within the on-going coursework, nevertheless, tutorials were preselected for observation to cover a sufficient variety of cases, student groups and teachers, as well as various moments throughout the year. Students and teachers provided informed consent to be audio or video recorded. The observing researcher (SR) did not actively participate in the case discussions.

In line with the concurrent nested design, interviews and a questionnaire were used to expand the understanding of observed behaviour by revealing teacher preferences and student appreciation for particular aspects of the tutorials:

- Altogether, 16 observed case discussions were followed by a semi-structured, stimulated recall interview with the teachers to reveal their views about occurrences within the observed case discussions and their rationale for interventions;
- During the last year a questionnaire was used to establish the students' appreciation of certain case characteristics, the instructional format and teacher performances, at a level of separate case discussions. Four students were asked to complete the questionnaire immediately after each case discussion. In total, 1814 completed questionnaires were returned, covering 627 (94.4%) of the sessions that took place. The full questionnaire is available from the first author.

Coding and analysis of observations

Video and audio recordings of the observed tutorials were analysed with ATLAS.ti. The unit of analysis was a single case discussion; the analysis procedure[28] was made up of the following steps:

1. Based on the research questions and underlying conceptual framework, a provisional list of codes was developed and applied to the first series (13) of observations to examine for fit and power.
2. As the analysis of case discussions progressed, the code list was restructured and extended to include events not covered in the original scheme. Furthermore, some descriptive codes concerning student and teacher behaviours were replaced by inferential codes reflecting reasoning and scaffolding patterns.
3. When the analysis of new case discussions revealed no more new events (saturation), the final code list was made up of four main categories of codes: problem solving phases, supportive learning phases, student behaviours and teacher behaviours.
4. Discourse analysis and cross-case comparison was used to shed light on patterns in the teachers' scaffolding behaviours and the students' reasoning, and on changes during the year.
5. Irregular occurrences and behaviours were reviewed to check our understanding of the case discussions and hypotheses about the teacher–student interactions, and to disclose hidden themes or phenomena.

Table 1 shows an overview of the coding scheme. The 'behaviour' categories are nested within the 'phases'. Phases cover larger segments of a case discussion and together they make up the whole case. Behaviours concern single utterances. The first main categories of teacher behaviour codes (T-ANSW, T-QUES and T-ADDS) express mostly teacher utterances in the role of 'information provider', whereas the codes T-PROC, T-GROU and T-EVAL concern the 'scaffolding' role. Students' utterances were coded interpretatively, [28] linking them to (cognitive) activities that make up 'clinical reasoning': the gathering, interpreting and organizing of information, establishing and testing hypothesis, drawing conclusions, making and justifying choices and decisions.

To determine the consistency of the coding, a randomly selected proportion (8%) of the recordings was coded independently by two clinical teachers and one research assistant. For the 'problem solving' and 'supportive learning' phases, the inter-rater agreement was very good (*K*=0.92), whereas for 'teacher behaviours' and 'students' reasoning', it was good (*K*=0.75).

Table 1 The coding scheme: main categories

Problem solving phases	Supportive learning phases
initial case information (C-INFO) checking vital functions (C-VITA) anamnesis (C-ANAM) initial problem description (C-PROB) general patient assessment (C-GENA) initial diagnostic hypothesis (C-INIT) specific patient assessment (C-SPEA) differential diagnosis (C-DDX) choice of treatment modalities (C-RX) execution of treatment (C-EXEC) review of effectiveness (C-EFF)	instruction beforehand (E-INFO) time-out (E-TO) evaluation (E-EVAL) teacher-guided discussion (E-COLL)

Teacher behaviours	Students' reasoning (behaviours)
providing answers (T-ANSW) asking questions (T-QUES) adding statements (T-ADDS) scaffolding the process (T-PROC) stimulating group interactions (T-GROU) guiding reflection and feedback (T-EVAL)	choice of strategy (R-STRAT) gathering information (R-GATH) organising information (R-ORG) interpreting information (R-INTP) making judgements (R-JUDG) making decisions (R-DECI) justifying judgements and decisions (R-JUST) other (R-OTHR)

Note: The behavioural main code categories are made up of 3–6 subcategories to allow differentiation. For example, the additional statements are divided into case-related, general theoretical and general practical statements.

Results

First, an overview will show how a case discussion was made up of the various problem solving and learning activities and the distribution of teacher and student behaviours. Next, the findings on behaviour, interactions and effects will be presented in the light of the two research questions.

Overview

The procedure that students followed to explore the case was essentially, as intended, similar to the structure and phases of a patient assessment. Figure 1 shows the sequence and relative duration of phases typical of the observed discussions. On average, nearly 70% of the time was spent on the case itself (problem solving phases);

the remaining 30% was used for discussing relevant background information and for reflection and feedback on the way the case had been handled and lessons to be learned (supportive learning phases).

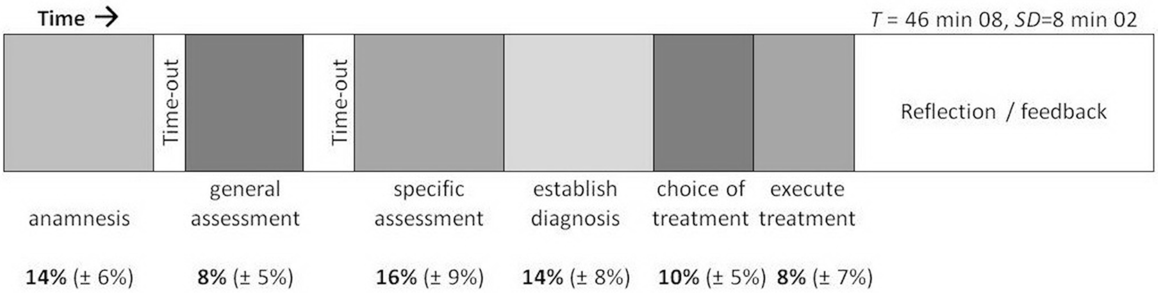


Figure 1. Typical sequence and relative duration of the various phases in the case discussions

Variations of the above, in particular the duration of phases, could be substantial. To some extent these variations can be attributed to differences between cases. For example, an acute posttraumatic case may require checking vital functions first. A second source of variation results from differences in the progress of students during the course. Whereas information gathering dominated the discussions at the beginning of the course, students gradually became more selective about the information they required and spent more time relating findings to each other and to their hypotheses, drawing conclusions and making decisions.

The proportional distribution of the behavioural categories reflects that usually a substantial part of the case discussion was used to gather all relevant information (Table 2a): students asking questions and performing tests to ascertain the information needed to understand the problem in its context and students testing their diagnostic hypotheses, possibilities and assumptions. The teachers (Table 2b) provided the requested information and, as necessary, intervened in the process and stimulated students to rethink their choices and conclusions, elaborate on particular issues or reflect on their approach and results.

The relatively large proportion of justifications by the students fits not only with the instruction to 'think aloud' but also resulted from frequent questions from teachers about related theoretical issues. Nearly 80% of these justifications were teacher-initiated. The coefficients of variance (defined by *SD/mean*) show the relative variation for each category. They indicate that teacher differences were largest in providing unrequested information (additional statements), group interventions and guiding reflection and feedback.

Table 2. Proportional distribution of the main categories of utterances. *M* and *SD* are expressed in the average percentage of utterances per case (2a. student reasoning, 2b. teacher behaviours)

Student reasoning	Utterances (in %) Mean	*SD*	Coeff. of variance
Choice of strategy	9.3	3.9	0.42
Gathering information	49.0	16.0	0.33
Organizing info.	6.9	3.0	0.43
Interpreting findings	7.7	3.6	0.47
Making judgments	5.0	2.5	0.50
Decision making	5.4	2.3	0.42
Justification	14.4	6.1	0.42
Other	2.3	2.0	

Teacher behaviours	Utterances (in %) Mean	*SD*	Coeff. of variance
Providing answers	49.1	15.8	0.32
Asking questions	14.3	6.4	0.45
Adding statements	12.8	10.4	0.81
Process interventions	10.7	5.7	0.54
Group interventions	2.8	2.9	1.04
Reflection / feedback	10.3	8.2	0.79

Appendix A contains three fragments from a case discussion transcript illustrating the nature of discussions and teacher–student interactions for the information-providing and scaffolding roles, as well as without any teacher interventions.

Teacher roles and behaviours

When focusing on teachers' role fulfilment and teacher–student interactions, the issue of matching the degree of scaffolding with a student's level of self-regulation came to the fore. A high level of self-regulation and a matching level of scaffolding were considered key features of the *clinical lessons*' design and their importance were recognised by teachers. In actual practice, however, some teachers frequently exerted influence on the direction of the problem solving process.

Sometimes the intentions of these interventions were explicit and clear; more often, teachers directed discussions in less obvious ways:

> *T: "Fine, good. I am glad, because my wife thought she [the patient] had a broken jaw. [...] Luckily, you did not find anything like that. I am glad because with a broken jaw this calf would have become worthless, wouldn't it?*
> *S: Well yes, um ..."* (case 080516LHD-3A)

Using their information-providing role to influence the course of the discussion was a scaffolding strategy the teachers commonly employed. For example, by referring to a sudden change in the patient's condition, unexpected complications or an uncooperative owner of the animal, they urged students to speed up their patient assessment, extend their search for possible causal factors and mechanisms or elaborate on the relevant theoretical issues.

In cross-case analysis of teacher behaviours, two patterns emerged. The main characteristics of both patterns are presented in Table 3. In the first (DS), the fulfilment of the scaffolding role was separated from information provision and delayed until between phases in the problem solving process. In the second pattern (CS), teacher roles were executed concurrently and corrections or directions were provided almost immediately in the process. In this pattern, little or no time was usually spent on reflection and feedback afterwards.

Table 3 Characteristics of the two teacher behavioural patterns

Pattern DS: delayed scaffolding, separated from provision of information	*Pattern CS*: immediate scaffolding, concurrent with provision of information
- the provision of information is limited to the information requested by the students - interim time-outs are used to scaffold reflection on findings (clarity) and choices about how to proceed (focus) - case discussion ends with an evaluative reflection on the content and process and the provision of feedback, containing feed forward for future case(s)	- replies to students' questions frequently contain additional information or counter questions, suggesting a direction about how to proceed or what should be covered by the patient assessment - teachers use questions and 'micro-lectures' to discuss relevant theoretical issues - the case discussion ends with an explanation of the optimal approach by the teacher. Little or no time is taken for reflection and feedback on the students' approach of the case

Reasons for interventions (interview results)

In recall, teachers expressed three grounds for their interventions in specific situations: doubts about the relevance of the particular information students had requested, disagreement with the students' choices or decisions in the case approach and a low work speed. Their intentions when scaffolding were explained in terms of 'control' ("*checking the students' knowledge*"), 'correction' ("*making sure that misunderstandings are corrected*"), stimulating students to 'think aloud' ("*share their thoughts*") and stimulating 'elaboration' ("*raising the discussion to a higher level*").

Effects on the students' reasoning

Observed effects on problem solving process

On the face of it, the students mostly responded to the teachers as expected: they used the additional case information and adjusted to changes in the case, reviewed or provided reasons for their choices, elaborated on relevant issues or reproduced the requested theoretical background. In discussions with minimal scaffolding, students themselves initiated a time-out whenever they wanted to reflect on the results of their approach and decide on how to proceed. In cases with a high level of concurrent scaffolding, major changes in the students' problem solving strategy and reasoning were teacher-initiated.

By and large, student responses did not openly reveal how they valued their teacher's interventions. In three of the observed cases, however, the discussion was visibly affected by a high level of concurrent scaffolding early in the process (pattern CS). In response to these interventions, the students' reasoning apparently lost direction and the discussion became almost completely teacher-led. A substantial part of the time (nearly 60%) had the character of a micro-lecture and focussed on theoretical backgrounds. When trying to return to the case, the students showed to be more focussed on what they assumed their teachers expected from them, than on the case itself: *"Well, I guess you would like to hear now a first problem description about this farm?"* (case 051011LHD-1A)

Afterwards, the students expressed their discomfort with the situation and disappointment.

Students' appreciation (questionnaire results)

To expand the understanding of the observed behavioural patterns and how these patterns affect the students' learning motivation, a questionnaire was used including a number of questions about the fulfilment of teacher roles, measured at the level of separate case discussions.

On a five-point scale ranging from 1 (disagree) to 5 (agree), the students' overall appreciation of the tutorials was high (authentic problems: M= 4.43 SD= 0.67; motivating issues: M= 4.21, SD= 0.73; opportunity to practice clinical reasoning: M= 4.19, SD= 0.70; perceived learning effect: M= 4.24 SD= 0.70) and significantly but only slightly less (ΔM= 0.12, ΔSE= 0.03) than for the clinical practicals with real patients. The students expressed that they considered teacher differences in their way of facilitating the tutorials as the main area of anxiety.

The 'perceived learning effect' had a positive significant correlation with the quality of the feedback, the amount of time spent on reflection, the transparency of teacher expectations and the clear switches between the different teacher roles (Table 4, Pearson's r). Its negative correlation with the frequency of scaffolding was also significant but weak. To compare the relative contribution of these variables to the 'perceived learning effect', multiple regressions were conducted using the forced entry method. The standardised beta coefficients showed the relative largest contribution of 'instructive feedback' (β= 0.43). The model, based on the teacher-related variables, explained 26% of the total variance (adjusted R^2= .26). The instructive aspects related to the case characteristics and the educational format were excluded from the model.

Table 4 Tabulated results from multiple regression

Perceived learning effect (n = 1814)	B	SE	β	Zero-order (= Pearson's r)
Constant	2,239	0,113		
Our discussion was frequently scaffolded by the teacher	–0,056	0,016	–,126 *	–,074 *
The switches between teacher roles were clear to me	0,116	0,017	,303 *	,153 *
The teacher's expectations about me were clear	0,089	0,017	,265 *	,122 *
The time spent on evaluative reflection was sufficient	0,116	0,020	,357 *	,142 *
The feedback I received was instructive	0,231	0,020	,431 *	,290 *

Note: R = .51, R^2 = .26, * p < .001

Discussion and conclusions

The observations revealed no serious drawbacks of the format of combining the provision of information with scaffolding. In general, teachers managed to fulfil both roles and, unlike other studies on facilitating case discussions,[29] they barely expressed dissatisfaction about inefficiencies, the lack of structure in student discussions, underutilisation of their expertise or uncertainty about when or how to intervene. The just-in-time provision of case information created an opportunity to engage students in a process of clinical problem solving in which the availability of information resembles authentic practice and students highly appreciated this.

With regard to the optimal teacher strategies for student support and the identified behavioural patterns, the findings were less unconditional:

- Various definitions and perspectives on scaffolding exist[22,30] but they commonly share two elements: the provision of *just enough* support to enable students to carry out a task and the *gradual fading* of this support. Theoretically, these elements link the effectiveness of teacher support to facilitating a high level of active engagement and self-directedness in thinking and learning activities, and to task fulfilment at a near next level that otherwise would be beyond a learner's current capacities. In practice, however, what is 'just enough' is difficult to establish and context-bound. Students adrift or a superficial level of discussion might be signs indicating a mismatch between the required and offered level of support, but these were also observed as temporary states in the problem solving process, which students themselves overcame.

- In the 'concurrent scaffolding' pattern (CS), role interactions were regularly observed. To some extent, these interactions fit in the concept of authentic cases. For example, including unexpected changes in the case is not only a way of directing the students' discussion to but also of creating opportunities to practice with handling authentic complications and incidents.[31] Nevertheless, by exaggerating case dynamics and using similar incidents or circumstances (e.g. an uncooperative patient caretaker) repeatedly to direct case discussions, teacher interventions became predictable, artificial and less appreciated. As one student expressed:

  "*You are just waiting for the moment something unexpected occurs. With this teacher, you don't know when it is going to happen, just you know that something will happen*." (case 070423P-4B)

Taken only from the observed behavioural responses, the students mostly seemed comfortable with the extent of the scaffolding and easily adjusted to the directions offered by their teachers. Under the surface of their immediate responses, however, the discourse in discussions sometimes showed clear differences between the two teaching patterns in favour of delayed scaffolding and feedback (pattern DS):

- From the way they were phrased immediate teacher interventions appeared to be triggered mostly by disagreement or doubts about the students' approach and an intention to check or correct the students' understanding of certain case aspects. Student responses to these interventions usually remained limited to brief answers. Interventions to encourage in-depth discussion, explicitly expressed in terms of 'think aloud' or 'elaborate', were scarce and used by those teachers who delayed most of their scaffolding and feedback.
- Small disturbances in the course of a discussion typically occurred in situations of immediate scaffolding about complex issues. This finding corresponds with studies concerning feedback when students have to deal with complex issues.[18] It has been suggested that such complex issues require greater degrees of processing and delayed interventions provide an opportunity to do so.
- The three irregular case discussions signified that early and continued interventions resulted in the students focussing on assumed teacher

expectations and on 'survival', a mode of student behaviour as described in Boekaerts' dual processing self-regulation model.[32]

The existence of differences in impact between the two scaffolding patterns is supported by the questionnaire results. Students attributed the effectiveness of their learning from the tutorials to features of teacher behaviour that are part of the pattern with delayed scaffolding, reflection and feedback. Differences between teachers, a lack of clarity about their intentions, expectations and role behaviours and their implicit ways of directing discussions were perceived by students as affecting negatively the reasoning process.

The aim of this study was to disclose how teachers combine the roles that are part of a case-based learning format with the just-in-time provision of information, and how this, in turn, influences students' reasoning and problem solving.

About the teachers' role fulfilment: the results from the observations and the questionnaire about separate case discussions support the conclusion that, in most cases, teachers can effectively combine the roles of providing information and scaffolding. When necessary, they provided students with guidance, questioned assumptions or interpretations and stimulated them to deepen their analysis, broaden their scope and relate specific case features to general theoretical notions. Nevertheless, including the just-in-time provision of case-specific information in this instructional format also created additional opportunities to influence the students' discussions, opportunities some teachers used to direct student discussions beyond the level of scaffolding.

In answer to the second research question: just-in-time provision of case information enabled students to practice solving clinical problems while obtaining patient information in a timescale that resembles authentic clinical practice. Although the students' direct behavioural responses to frequent interventions during case discussions were mostly characterized by adaptation, they consider the pattern of delayed scaffolding and feedback more beneficial for their learning. Possible explanations for their willingness to adapt to most ways of scaffolding might lie in an awareness of being assessed as well, positive experiences in most other case discussions or with other teachers facilitating the tutorials, or much appreciation for aspects such as the authenticity of the case, its clinical relevance and constructive cooperation with their peers.

The findings in this study emphasise that in this instructional format providing clarity on teacher roles and expectations, delayed scaffolding and facilitation of reflection and feedback are conditional for student learning and motivation. Furthermore, as students do not easily show when teacher interventions interfere with their problem solving process, effective teaching requires monitoring the student's behavioural responses and attending to signs of anxiety.

This study was primarily based on observations, with additional interviews and a questionnaire to confirm or extend the findings from the observations. This methodology, applied to a large number of cases in this study, yields an abundance of (qualitative) data and, therefore, requires rigorous data organisation, focus and bounding. The scope of this study was limited to the analysis of behaviours, interactions and effects from the perspective of role fulfilment. Furthermore, the cases were assumed to be of a constant quality, that is, to have more or less a similar impact on teacher behaviour and interactions. The third limitation of this study concerns the use of 'perceived learning' as the outcome measure. In doing so, the possibility, for example, that friction in the teacher–student interaction might also have beneficial effects on long-term learning outcomes is ignored. Further studies using outcome measures based on 'student performances' to reveal the effectiveness of teacher behaviour on competence development have been taken up and will be reported subsequently.

Appendix Sample case discussion (080507 Horse case 2B)

The case concerns a two-day-old foal, which initially seemed healthy but now does not want to drink and prefers lying down [SR].

t=03:24
S: you did not expect this foal to be born yet?
T: well, as a matter of fact we already expected him last week
S: the last days, did you notice the mare's nipples wax? Perhaps any secretion from the teats?
T: well, at some point her udder began to swell and already within hours a foal was born
S: no milk leaking before he was born?
T: not that I have noticed
S: not to your knowledge. Did you see her giving birth?
[...]

t=18:34
S1: I think this is.... um ...
S2: a positive undulation sign and constipation
S1: should we carry out some additional assessment tests?
S2: let's first establish a list of differential diagnostic possibilities, as there are a few things we need to keep in mind. For example a rupture of the bladder does not necessarily lead to apparent clinical signs
S1: and such rupture could exist besides meconium constipation
S2: yes, they could exist next to each other. At least it is not a case of lysis.... and sepsis seems unlikely, because he would have had fever.
[...]

t=30:54
T: So, what's next?
S1: It appears to be a persistent case of meconium constipation. We would like to use analgesics, as he is still not drinking and the problem has already existed for quite some time. Also, because the constipation persists, we propose purgative rinsing, more rigorously. For this, we would like to give him paraffin oil, using a stomach tube.
T: which analgesic did you have in mind?
S1: Flunixin. Only then, we would have to use a stomach pulser … should we add some other medication? To protect him from side effects?
S2: Well, it will be administered only once.
S1: Okay, just because Flunixin is only used once, we will not add any other drugs.
T: I sense, as the owner of this animal, some doubts about your choice of analgesic. What is it about?
[…]

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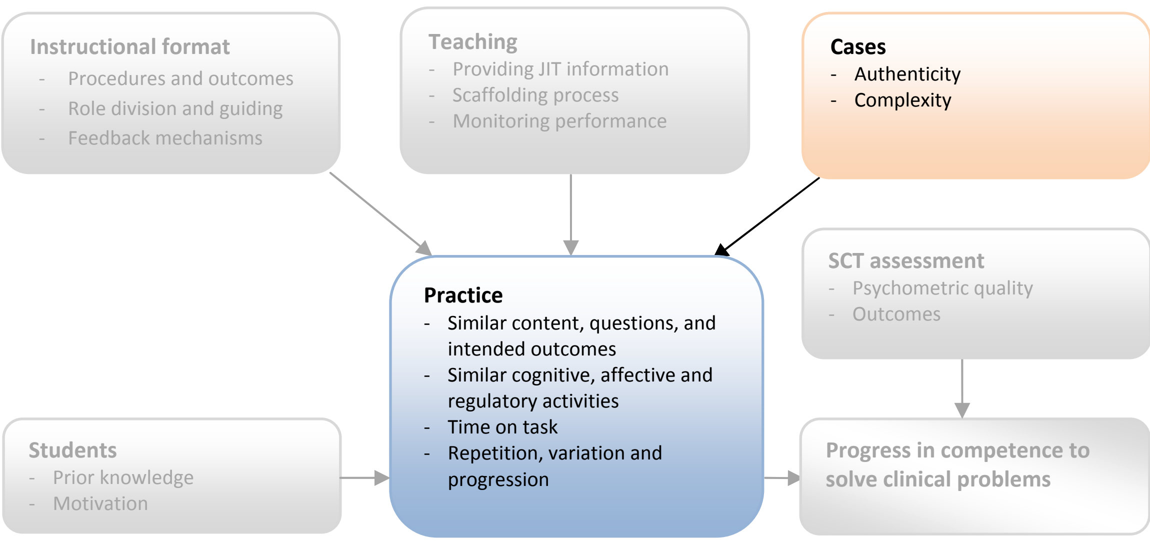
"Cases are the unit of clinical work, of consultation, of teaching…. and of clinical memory"

Ken Cox, 2001[6]



6 Cox, K. (2001). Stories as case knowledge: Case knowledge as stories. *Medical Education, 35*(9), p. 863.

4. Authenticity and complexity of cases; making two conditions meet [7]

Abstract

The effectiveness of case-based learning is largely determined by the quality of the cases that are used. Optimal cases engage students in activities, problems and experiences that reflect professional practices, at a level that they can handle and improve upon. This study focuses on the just-in-time provision of information in order to optimise case design with regard to levels of authenticity and complexity. First, cases were classified according to their specific characteristics. Next, discussions about cases with different characteristics were compared with regard to: the problem approach; reasoning activities; the content of the discussion and preparation time.

Overall, the cases engaged students in the kinds of reasoning activities that make up clinical problem solving, created similar cognitive challenges and encouraged a high level of time-on-task. Case information attributes such as the use of diffuse, multifaceted problems or a lack of contextual information and cues for solutions prompted changes in the students' approaches and the course of their discussions, indicating an increased level of complexity. In particular, the extent of the information provided beforehand was most likely to affect the students' levels of preparation, case approach and reasoning. It is recommended to strive in case vignettes for high functional fidelity rather than authenticity.

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7 This chapter has been submitted for publication:

Ramaekers SPJ, Pilot A, van Keulen J, van Beukelen P, Kremer WDJ. Authenticity and complexity of cases; making two conditions meet.

Introduction

What students learn in case-based learning depends to some extent on the quality of the cases that are used.[1] In problem based learning (PBL), the quality of the problems used has shown to exert a dominant influence on the processes conducive to learning.[2,3] In contrast to these findings which signify the importance of high-quality problems, studies investigating the effectiveness of cases at the level of their design features or case attributes, are sparse. Most previous studies have been prescriptive and have aimed to provide guidance for case design.[4,5] The case features which are considered to be effective in facilitating learning have usually been derived from learning theories rather than empirically grounded.[6] Different perspectives exist with regard to the educational quality of cases. 'Authenticity' denotes cases which are used for learning and resemble the content and issues of real-life situations and problems. 'Complexity' concerns the requirement that cases suit a level that students can handle and progress from. Authenticity and complexity are distinctive entities but they overlap to some degree.

Authenticity

The term 'authentic' commonly refers to something which is original, genuine or reliable rather than being a reproduction, artificial or misleading. Archbald and Newman[7] used the term first in the context of education in order to link learning and achievement to the construction of meaning, in-depth understanding, knowledge integration and performance that has a value beyond success in school. The main arguments for adopting authenticity in approaches to learning are drawn from research and theories concerning:

- *Real-life professional problems*. Many problems which professionals are confronted with are far more complex, poorly-structured and open-ended than the kind of problems commonly used in education.[1,8] The ability to solve the simple, well-structured problems does not readily transfer into complex, ill-structured ones.[8-10]
- *The nature of expertise.* Expert performance relies on a highly integrated base of various types of knowledge (declarative, procedural, strategic), part of which is tacit and context-bound.[11,12] Theory states that, if regularly exposed to real-life problems and circumstances, students will become engaged in cognitive processes

that reflect the challenges of their future work[13,14] and will integrate, reorganise and extend their knowledge on the basis of their own experiences;[15]

- *Competence development*. Competence is grounded on the integrated knowledge, skills and attitudes that are needed to deal with real-life complex problems.[16] Using realistic tasks for learning is assumed to support integration, to provide the opportunity to practise coordinating the constituent skills that make up complex performances and eventually to ease the transfer to real-life situations.[17]

Complexity

Authentic problems and situations may be too complex to be resolved by novice and intermediate learners and even affect their learning negatively.[18-20] Complexity concerns the extent to which a case consists of multiple problems and aspects affecting these problems, the interactions or mutual dependencies between these problems, and the dynamics of changes to the problem state.[10,21] Making sense of large numbers of variables and their relationships involves far more simultaneous cognitive operations than with small numbers under stable circumstances. According to cognitive load theory, working memory requirements are then assumed to increase at least proportionally. This hampers learning.[22,23]

Just as complex cases which lie far beyond students' prior knowledge and level of understanding may be unfavourable for learning and motivation,[24] so are excessively simple cases.[10,21] An optimal level of task difficulty should not only be tailored to the students' level of prior knowledge[25] but must also challenge their current understanding and require them to advance to a next level.[26,27] The theoretical optimum is described in terms of matching the students' zone of proximal development[28] or causing constructive friction.[29]

Designing high quality cases and focus of this study

The combined requirements that cases are supposed to meet define the teachers' selection and adjustments of cases. In particular to establish proportionate levels of authenticity and complexity, adjusted to the students' needs, case features must be chosen carefully. One strategy with which to avoid student learning being hindered could be to start with authentic but less complex tasks and gradually progress towards complex problems.[30] Alternatively, the contextual elements which complicate performance of the task as a whole could be simplified.[31] Cognitive load theory suggests a third strategy: just-in-time provision of the task information. This could avoid cognitive overload of working memory while working on a complex problem.[22] By providing, for example, information about the recurrent aspects of tasks beforehand, attention during task execution can be focussed on the case-specific aspects. The degree to which information has to be processed simultaneously and requires cognitive capacity is decisive in achieving the optimal timing of information delivery.[32]

Clinical problem solving is a core competence in medicine. In order to prepare students for the kinds of problems they will encounter in clinical practice, medical curricula nowadays offer students opportunities to practise their clinical reasoning and problem solving in realistic cases early on in their training. Incorporating just-in-time provision of information into the instructional design not only limits cognitive load on working memory when dealing with complex clinical problems, but also fits an authentic process of case exploration and analysis.

This study concerns the characteristics of cases that determine their fidelity with regard to clinical problem solving, create cognitive challenges similar to those in professional practice and engage students in meaningful problem solving at a level they can handle successfully. In particular, this study seeks to answer the question of optimal timing and the content of information: *Regarding just-in-time provision of case information, how are paper-based clinical cases best adjusted to facilitate an authentic problem solving process and to support task preparation?*

Methodology

In order to reveal the way in which particular attributes of case information affect students' reasoning and problem solving process in a natural educational setting, this study was embedded in the context of on-going coursework. Consequently, a procedure was used which addressed:

1. Identification, at case level, of the specific characteristics of the tutorial cases;
2. Assessment of the impact of case information attributes on the problem solving process and preparatory activities.

Educational setting

The '*clinical lessons*' in veterinary medicine (Utrecht University) make up a one-year course, which is designed to provide students with ample opportunity to practise clinical problem solving and to train them to make decisions in clinical situations in accordance with biomedical theories and guidelines for practice. These lessons take place in the preclinical year, before students enter their clerkships (years 5 and 6).

The core of the *clinical lessons* consists of three complementary teaching formats: clinical practicals; demonstrations and tutorials. Whereas the first two involve real patients, the tutorials build upon paper-based cases. In all of these formats, the students direct the problem solving process and additional discussions about the cases. The teachers provide the students, at their request, with additional patient information and guide them in the process if necessary. Throughout the process, the students are encouraged to think aloud.

This study concerns the tutorials. Within the tutorial format, the authenticity of the task is supposedly upheld through: (a) the content of the cases; (b) the activities and procedure in further exploration of the case; (c) the roles of the students and teachers; (d) the timing and content of the additional information; and (e) the projected outcomes and time pressure.

Materials

Cases for the *clinical lessons* were chosen to represent the variety of animals, clinical problems, conditions and issues that veterinarians commonly encounter in primary veterinary care. For the tutorials, nearly 50 case vignettes were prepared containing the initial case information that the students needed for their preparations. According to its design, the information included in a case vignette was intended to keep the cases open-ended in order to enable a realistic process of case exploration during the tutorial. The initial case information supposedly provided students with some direction for their preparations, but was not specific enough to exclude all other diagnostic options. The case vignettes were intended to allow four to six differential diagnostic possibilities. Extensive case vignettes may include complete patient records or farm management data. An example of one the shortest cases reads:

"Your voicemail contains a call from this morning about a wobbly horse".

In addition to the vignettes, guidelines for the teachers were available containing the case information they could need in the process of exploration and discussion by the students. Authentic resources (X-rays, patient files, etc.) were sometimes available; more often, they were not.

Case analysis: identification of case characteristics

a. First, a list of relevant case characteristics related to authenticity and complexity was derived from the literature. Each characteristic was described on a five-point Likert scale, ranging from agree/easy (1) to disagree/difficult (5). The overall level of difficulty of a single case was expressed in terms of a total case index.
b. Next, the information which the students received beforehand about the tutorial cases was analysed against the list of case characteristics. Each case was analysed by three clinical teachers, as well as three students who had successfully completed this programme. Both groups analysed the cases independently. The teachers appraised only the cases within their own specific area of expertise, while students examined the cases from their own study track (domestic animals, horses, farm animals). In total, 42 cases were analysed by 21 teachers and nine students.
c. The results of this analysis enabled the identification of 'extreme' cases with regard to the presence or absence of particular case characteristics (see Table 2), as well as a comparison of the level of difficulty across the cases.

Assessment of the impact on the problem solving process

a. In an instructional setting, the effectiveness of cases is indicated by the extent to which the nature and content of reasoning and problem solving activities are in accordance with the learning objectives and time-on-task.
b. During the academic years 2006-2008, a total of 42 case discussions were observed and recorded on video or audiotape, to facilitate a qualitative analysis of the type and content of student activities, and their time-on-task. These observations were related to 14 different student groups and 14 teachers. All of the student groups and teachers were observed at least twice. They gave their informed consent to be recorded for the purposes of this study. The observing researcher (SR) did not actively participate in the case discussions.
c. Recordings of the case explorations and discussions were analysed using a coding scheme that had been developed and refined on the basis of the observations during the year prior to this study.[33] Four main code categories were distinguished: problem solving phases; supportive learning phases; student reasoning behaviours and teacher behaviours. These phases cover larger (time) segments of a case discussion, while behaviours concern single utterances. The inter-rater agreement for the phases was high (*K*=0.91), while for behavioural

categories it was substantial (*K*=0.73). Student utterances were recoded interpretatively,[34] linking their expressions of reasoning to the (cognitive) activities that make up clinical problem solving. Clinical problem solving was operationally defined as the gathering, organising and interpreting of information about a clinical problem and its relevant context, in order to make professional judgments about the situation and decisions about what, within this context, should be done in order to solve the problem adequately or prevent further problems from occurring.

d. Finally, a cross-case comparison of the content and courses of discussions was used in order to reveal the impact of case information attributes on the students' reasoning and problem solving process. In particular, case descriptions with extreme scores for one of the information characteristics or the total index, as well as case discussions which had taken a different course, were checked in order to reveal potential variance.
e. Preparation time was registered immediately after each tutorial. Four students completed a short questionnaire about the case discussions and preparation time. In total, 1179 questionnaires were returned, covering 93.8% of all tutorial case discussions.

Results

Case characteristics

Overall, the teachers and students considered the cases for the tutorials to range from 'very easy' to 'moderately difficult'. Whereas the total case indexes theoretically reached from a minimum of 10 (easiest) to a maximum of 50 (most difficult), the actual range for this set of cases was 13 to 32. Comparing the teachers' and students' scores on separate cases, they agreed on many items and the total case indexes correlated significantly (r=0.405, n=42, p<.01). Nonetheless, the teachers typically appraised cases to be easier (M=20.8, SE=0.64) than the students (M=25.1, SE=0.64), and this difference was significant ($t(82)$=-4.77, p<.01).

Table 1 presents the teachers' and students' scores for the separate indexing items. The low scores for item four indicate that hardly any of the cases contained distracting or irrelevant information. The relatively high scores on the item *available case information* (3) are in line with the instructional format, based on the just-in-time provision of additional information during the case analysis and discussion.

Table 1. Average index item scores by the teachers and students (Sig. (2-tailed) *p<.05, ** p<.01)

N=42	Teachers		Students		
1= *Easy* (agree) ….. 5= *Difficult* (disagree)	*M*	*SD*	*M*	*SD*	*ΔM*
1. The problem is given and well-demarcated	2.02	1.09	2.86	1.03	-.83**
2. The case information contains cues for analysis and solutions	2.17	.73	2.90	1.06	-.74**
3. Most required case information is available	3.00	.86	3.26	.67	-.26
4. The case contains no distracting nor irrelevant information	1.26	.54	1.64	.82	-.38*
5. The problem analysis is supported by authentic materials and the case structure	2.31	.87	2.21	.98	.10
6. The case concerns a common clinical problem / situation	2.14	.78	1.83	.79	.31
7. The case is within range of the students' prior knowledge	2.38	.96	3.33	.65	-.95**
8. Every veterinary practitioner should be able to solve this problem	1.93	.78	2.26	.89	-.33
9. Directions to solutions are available in frequently used textbooks and journals	1.93	.84	2.43	.83	-.50**
10. The case can be analysed and solved within the time available	1.67	.79	2.57	.91	-.90**
Total case index	20.8	4.1	25.1	4.2	-4.33**

Time-on-task

During the tutorial, the students spent, on average, almost 96% of all of the available time on the task. Just over 60% of the time was used to explore and discuss the specific details of the case itself (problem solving phases), and the activities in these phases closely resembled authentic clinical practice. About 36% was used for discussions about relevant background theories, for reflection and feedback on how the case had been handled and for lessons learned from the case (supportive learning phases). The remaining 4% was spent off-task.

The proportional distribution between the problem solving and supportive learning phases varied substantially. In part, this variation could be attributed to differences between the actual content of the cases and the course of a discussion; to some extent, the time used for activities such as discussing relevant theories appeared also to be a matter of perceived need.

Regarding their preparations, the average time which the students stated that they had spent on their case preparation was 220 (± 90) minutes. The students who were actively involved in executing parts of the patient assessment took significantly more time (ΔM=132 min, p=0.000) than those who only participated in the discussions about hypotheses, strategy, findings and conclusions. Relating preparation time to low and high scores on the case information items (items 1 to 5) revealed that the students used significantly more preparation time in cases where extensive information was available beforehand (*r*=.576, *p*=0.000).

Nature and content of activities

Focussing on the nature and content of the students' reasoning and problem solving activities revealed an emphasis on gathering the information that they needed in order to analyse and understand the case. Figure 1 indicates the proportional distribution of the categories of reasoning behaviour. Some variation in this pattern resulted from changes in the students' reasoning activities, in relation to the progress that they made during the course. As they progressed through the year, the proportion of information-gathering activities diminished, while time spent relating and comparing findings to (diagnostic) hypotheses and making judgements and decisions gradually increased. Across-case analysis identified a few issues and doubts that were repeatedly discussed when deciding or reflecting on the case approach and problem solving strategy. In Figure 1, these issues (cognitive challenges) are presented, summarised and structured alongside the categories of student behaviour.

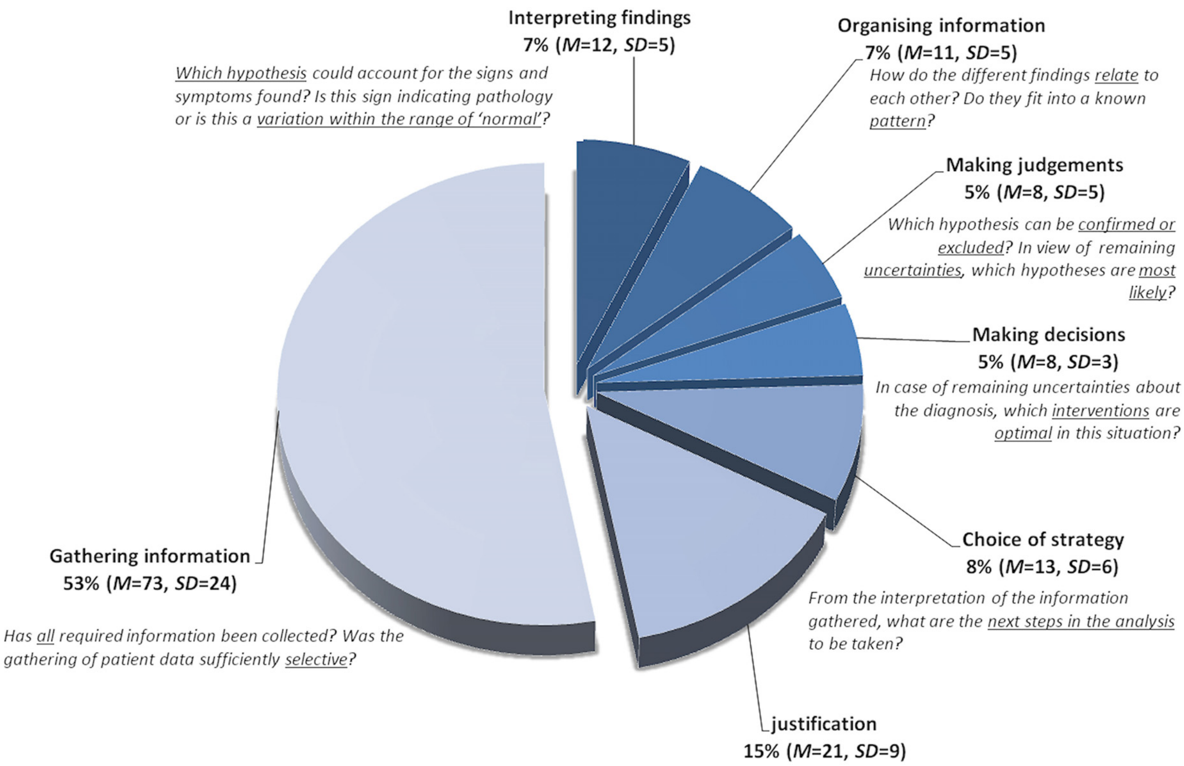

Figure 1. Proportional distribution of the students' reasoning behaviours and the cognitive challenges frequently expressed.

Teacher interventions which were aiming at supporting the students' case approach or strategy made up only 3.3% of all teacher activities. Mostly, interventions were directed towards justification of the students' decisions and linking specific case aspects to general theory (25.1%).

Observed effects of initial case information

The case discussions with high and low scores for a particular case information feature were compared in order to shed light on the impact of this feature on the problem solving process. Table 2 provides the main results.

In general, the case information attributes which raised the level of complexity (*lack of: problem demarcation, relevant information, key features, cues and structure*) often induced extensive data gathering, expressions of uncertainty and hesitation, prolonged discussions and an increase in the pressure to manage the case within the available time. In response to such situations, the students commonly resumed an algorithmic, step-by-step approach, attempting to cover all aspects and possibilities systematically.

Table 2. Impact of case information features on problem solving

Feature:	**1. Problem demarcation**		
Levels:	*Easy*: The problem is given and well-demarcated in the case vignette (n=8, *M*=1.4)	⟷	*Difficult*: The problem is vaguely described and made up of multiple (related) problems (n=6, *M*=3.8)
Effects:	- The differences between cases with and without a given problem proved to be limited. An apparent problem helped the students to focus their preparation. Nevertheless, even with a clear problem statement ("*my dog is not eating*") or request from the owner ("*some of the young pigs are coughing; what should I do?*"), the students still engaged in a process of exploring the problem, the possible causes and enabling conditions. - In this process of exploration and analysis, the problem representation changed regularly. For example: initially, the problem was a cow limping. Next, it was redefined as a claw problem. After further examination, the main problem was considered to be improper farm management ("*inappropriate feeding*"). - In cases with multiple related problems, the students tended to collect extensive patient data. Furthermore, collecting, interpreting and structuring the information appeared to be separate, sequential processes rather than concurrent activities. Time pressure became more apparent.		

Table 2 (Cont.). Impact of case information features on problem solving

Feature:	**2. Available information and 3. cues for solutions**
Levels:	*Easy*: Most relevant information is available. The vignette contains cues for analysis and solutions (n=9, *M*=1.4) ⟷ *Difficult*: The vignette contains very little relevant information (or key features). There are no cues in which direction to focus or how to approach the problem (n=11, *M*=4.0)
Effects:	- In cases with limited initial information, the students responded either with superficial preparations ("*too many different diagnostic possibilities and topics to prepare*") or with a comprehensive list of 'standard' questions and tests, covering most conditions. In the actual case discussions, the students' approach was algorithmic, and strongly guided by the list that had been prepared. - A lack of cues in the initial information about the direction of the solution did not noticeably affect the students' approach to the cases. The basic procedures of patient or health management assessment helped the students to maintain their grip on the process. Whenever they were uncertain about the approach, e.g. because of a lack of cues in the information, they usually reverted to the basic 'standard' procedure.
Feature:	**4. Distracting information and 5. Authentic case representation**
Levels:	*Easy*: The case contains few authentic materials. The available information is relevant and well-structured (n=29, *M*=1,0) ⟷ *Difficult*: The information includes authentic materials, however unstructured, partly irrelevant and lacking interpretation (n=4, *M*=3.8)
Effects:	- The small number of cases with authentic, unstructured and potentially distracting information was insufficient to establish observable effects. The students' reasoning did not reveal any instances of doubt or questioning the relevance or reliability of the information provided. Well-structured cases supported the initial procedural choices. - Some vignettes lacked contextual information which, in real-life practice, would be known, e.g. the patient history, details about farm management, etc. To make up for this, the students started by gathering the missing information or extended their anamnesis to cover all of the relevant contextual information.

Discussion and conclusions

In this study, the focus was on the timing of case information delivery, in order to balance case complexity by facilitating the students' preparation as well as maintaining an authentic reasoning and problem solving process. Just-in-time provision of information has been put forward as a way to enable students to practise completing complex tasks and managing a flow of information which resembles authentic practice, without creating an overload on working memory.

The tutorial cases appear to be valid with regard to learning to solve clinical problems. They represent the kind of clinical problems and complexities that veterinarians are confronted with in practice. An analysis of the information provided in the case vignettes revealed at case level which case attributes had been included that affected their authenticity and complexity. Teachers and students essentially agreed on how they valued most case features. The total indexes signified that these cases ranged from ‘easy’ to ‘moderately difficult’.

The results regarding the nature and content of the activities in the tutorials, as well as the time-on-task, support the conclusion that these cases were conducive to the intended learning processes and outcomes. The time-on-task during the case discussions proved to be rather high, particularly when compared with other tutorials in the same degree course.[35] Regarding the specific activities and content of the case discussions, about two-thirds of this time was actually used for problem-solving activities similar to those used in real practice. The case discussion during the other one-third was also functional with regard to learning, as it involved linking case-specific aspects to general theoretical insights. The recurrent issues that were revealed in the cross-case comparison of content also corresponded to the kinds of challenges which appear regarding problem-solving approaches and strategies in real practice.

On the whole, this selection of cases with these information attributes proved to be effective in engaging students in the kind of reasoning activities that make up clinical problem solving, created similar cognitive challenges and encouraged a high level of time-on-task. Furthermore, the students were not disproportionately hindered by the complexities embedded in the cases.

Within this set of cases, different vignettes and case attributes did not contribute consistently to facilitating preparation and the problem-solving process:

1. The results from the observations confirmed that cases with many features at the high end of the complexity scale affected the problem-solving process accordingly. In these cases, the students’ approach showed signs of hesitation and a loss of speed, and they reverted to a general, systematic, step-by-step strategy, using most of the time to gather information;
2. Of all of the information attributes studied, the ‘extent of case information’ had the most distinct effect on both the extent of the students’ preparation and the course of the problem-solving process:
    - Insufficient information prevented the students from focussing their preparation and led to more superficial, non-specific preparation and approach to the case. This was also reflected in the finding that the students used more preparation time if the vignette included more information;

- Extensive gathering of information during the tutorial reduced the time available for an in-depth discussion about the interpretation of the findings, underlying causal models and the relationship between the findings and hypotheses;

3. Changes in the extent and structure of the information' available affected both the preparation and discussion in a similar way. Changes in the 'problem demarcation' and 'cues for analysis' did not clearly influence the case discussion. Therefore, in order to reduce case complexity during the problem-solving process, changing the extent and structure of the information in the case vignette appears to be the most effective course of action.

In many of the tutorial cases, the information students received beforehand was concise, to-the-point, reasonably well-structured, limited in terms of authentic materials and contained hardly any distracting or irrelevant information. The assumption underlying a preference for these information attributes was that extensive information would lead to more closed cases, thus tempting students to seek a single right answer and to prepare for only the most likely condition. In addition, extensive information and a thorough preparatory case analysis were assumed to reduce the authenticity of the problem-solving process and affect the students' reasoning during the tutorial. Despite the overall positive outcomes of the tutorial cases, the combination of the information attributes shown to be suboptimal in some cases. Short case vignettes did elicit superficial case preparation, and the assumptions of a too-narrow scope of the students' preparation and an unauthentic problem-solving process were not confirmed in cases with extensive information.

Regarding just-in-time provision of case information, how are paper-based clinical cases best adjusted to facilitate an authentic problem solving process and support task preparation?

- The complexity of real-life cases which require numerous aspects to be handled concurrently can be reduced if students prepare for some of the more complicated features of the case and are provided with relevant information before the tutorial. Furthermore, the provision of additional case information at the student's request creates a flow of information resembling authentic problem-solving processes.

- Particularly in cases of ‘extensive’ and ‘unstructured’ information, the problem-solving process found during the tutorial can be enhanced through adequate preparation.
- In order to support case-specific preparation, the vignettes should include sufficient information to enable an analysis of the relevant case features and allow the students to focus on preparatory activities.
- The extent of the information about the case and its context is essentially an optimisation problem. Overload as well as insufficient information can be avoided by aiming for a level of ‘functional fidelity’, which encompasses including in the vignette only the authentic contextual information which has a bearing on the considerations, clinical judgements and decisions to be made. The vignette should include at least all of the information which is available in real-life practice when a veterinarian is confronted with a similar case.

This study was conducted in a natural educational setting. In this setting, a range of cases was used, which were chosen to represent clinical practice rather than creating a sample with a large variety of case information attributes. Furthermore, deficiencies in the case vignettes were sometimes compensated for by the teacher, for example by providing the students with additional information without being asked. Similarly, poorly-structured or distracting information and unexpected changes to the cases could be introduced by the teacher during the case discussion. As a result, the findings in the observed case discussions were possibly less clear-cut than would have been the case in highly complex clinical problems without corrective interventions. While such corrections do not support students’ preparations, they do, however, offer opportunities to fine-tune case complexity so that students can progress in terms of their level of competence.

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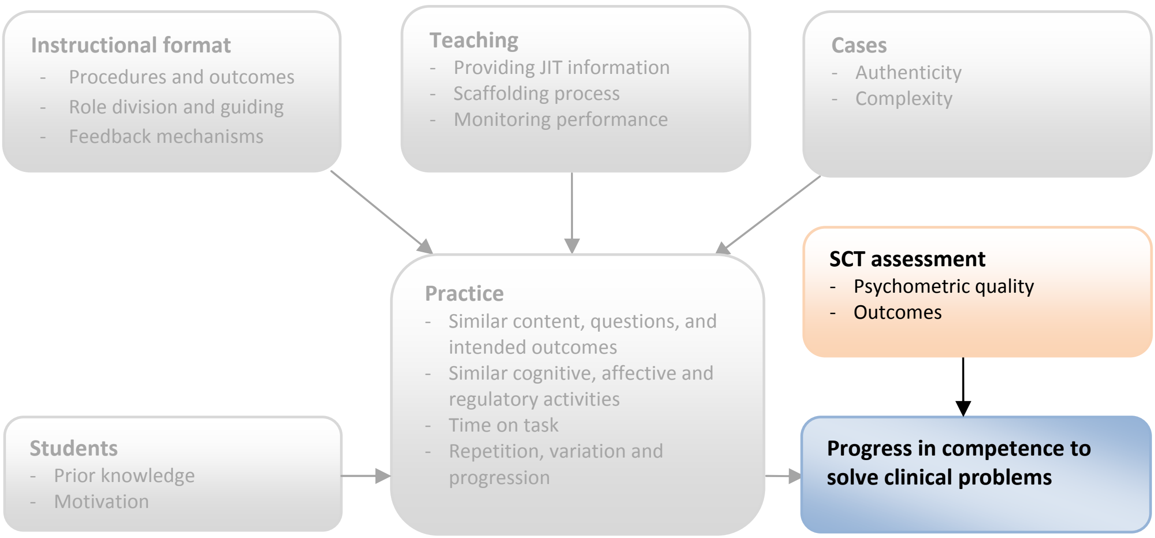
"In real-world practice, problems do not present themselves to the practitioner as givens. He must make sense of an uncertain situation that initially makes no sense"

Donald Schön, 1983[8]



8 D.A. Schön (1983) *The Reflective Practitioner: How professionals think in action*. London: Temple Smith, p. 40

5. Assessment of competence in clinical reasoning and decision making under uncertainty: the Script Concordance Test method [9]

Abstract

Real-life, complex problems often require that decisions are made despite limited information or insufficient time to explore all relevant aspects. Incorporating authentic uncertainties into an assessment, however, poses problems in establishing results and analysing its methodological qualities. This study aims at the development of a test on clinical decision making in veterinary medicine, and establishing its reliability and validity. The test is based on the Script Concordance Test format and covers a large sample of authentic cases and uncertainties. The answer key was compiled with reference to the professional judgements and decisions of a panel of experienced practitioners. From a substantive appraisal of the cases and items, analysis of the test results, and the responses from the experienced practitioners, it is concluded that this test validly represents the problems, decisions and uncertainties of clinical practice. In spite of the hindrances caused by the uncertainties included in the test, the reliability and validity of the test and its results could be evaluated and proved to meet measurement criteria.

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[9] This chapter was published as:

Ramaekers SPJ, Kremer WDJ, Pilot A, van Beukelen P, van Keulen J. (2010). Assessment of competence in clinical reasoning and decision making under uncertainty: the Script Concordance Test method. *Assessment & Evaluation in Higher Education,* 35(6), 661-73.

Introduction

Dealing with ill-defined problems and having to make decisions in uncertain situations, on the basis of limited information or under time pressure, is for many professionals a part of everyday practice.[1,2] To determine whether students are adequately prepared for this, assessment of their problem solving and decision making capacities should include problems and circumstances which pose similar cognitive challenges.

Although authentic assignments and problems are considered particularly valuable for the validity of an assessment (e.g. Linn *et al.*[3]), including real-life, open-ended problems and issues in an assessment, with uncertainties and possibly several solutions, creates various difficulties in establishing and analysing results. For example, how are good and poor student performances to be reliably distinguished when questions and answers contain ambiguities?

This study concerns the design of a test to measure progress in the development of competence in problem solving and decision making in situations of uncertainty, and evaluation of its measurement properties. The test was developed for a course in clinical problem solving in veterinary medicine. Its design is based on the Script Concordance Test (SCT) format, developed by Charlin and others[4] to assess problem solving and decision making skills in realistic situations.

Theoretical foundations

The nature of clinical problem solving and decision making

The SCT format is grounded in theory and empirical research on clinical reasoning, problem solving and the organisation of knowledge. How doctors analyse clinical problems, establish a diagnosis and decide about treatments, has been studied since the late fifties. Initially, systematically testing hypotheses until explanations were found was considered the essence of the problem solving process. As some differences and similarities between experts and novices could not be explained by means of a superior reasoning process, research changed its focus towards the structure of expert knowledge.[5]

The illness script theory assumes that experienced clinicians have their knowledge organised in coherent networks, 'scripts', covering numerous aspects of diseases, meaningful for practice. These scripts emerge through clinical experience and become, over the years, refined and rich in detail about particular patients, diseases, associated situations and enabling conditions.[6,7] In this process, the knowledge of underlying biomedical principles and mechanisms, and the causal reasoning at the base of judgements and decisions, become embedded (encapsulated) into clinical concepts, but are still accessible if needed.[8] Comparing new cases with previous experiences and pattern recognition increasingly dominates the problem solving process as expertise advances.[9]

Recognition of the complexity of real-world problems and human limitations in dealing simultaneously with too many different issues, has fuelled research into the way decisions are made under uncertainty. Based on quantitative models and weighting of pre- and post-test probabilities, standards have been developed which describe an optimal (expert) approach to a particular clinical problem. Their value as methods for retrospective analysis of the decisions made, including reasoning fallacies and sources of bias, has been widely recognised.[10] Criticism has been made of the limited applicability of these methods in a real-life clinical setting.[11,12]

Currently, most researchers agree that clinical problems are highly context-specific and that transfer from one problem solution to another is limited.[13] Finding appropriate solutions depends mainly on a knowledge base covering many different aspects of clinical problems and organised in structures, adjusted to practice.[14] Experienced clinicians may solve their problems in a variety of ways; even in similar situations, they do not necessarily follow the same line of thought to achieve similar outcomes.[15,16] Their strategies largely depend on pattern recognition and previous successful choices; they rarely use conscious reasoning, deduction or extensive testing.[16,17]

Circumstances which contribute to uncertainty are that decisions sometimes have to be made under time pressure or on the basis of very limited information. The reliability of information may be uncertain, results of patient tests may be inconclusive and a prognosis may not be predicted precisely.[1,17]

Rationale of the SCT format

The SCT format is designed to develop assessments of problem solving competence in a way that fits current notions about clinical problem solving and decision making. SCTs supposedly measure correct interpretations of available data,[18] the extent and richness of mental ‘scripts’,[19] and competence in testing hypothesis and decision making under uncertainty.[20] The problems that participants are presented with are chosen to match the issues, circumstances and cognitive challenges of real practice. Consequently, the design of SCTs fits into views on assessment (and learning) which emphasise the importance of a high level of authenticity for the validity of the assessment. [21,22]

To incorporate real-life issues and problems, beyond the level of 'single right answer' questions, the appropriateness of solutions in an SCT is based on the professional judgements of a group of experts (reference panel). Several answers may be considered appropriate. The decisions of the participants are compared with those of the reference panel; the degree of agreement between the participant and the experts determines how answers are valued and indicates the participants' level of competence.

With the SCT format, tests have been constructed in various domains within medicine (e.g. Meterissian *et al*.[23]) and characteristics which have been studied are the timing of the assessment and the effects of different formats,[24] optimisations of the scoring methods[25] and the composition of the reference panel.[26,27] Results were compared between different levels of clinical experience, and also across different cultures and learning environments.[18] Furthermore, results on SCTs have been related to other indicators of clinical competence.[28]

As regards the assessment of clinical competence in the transition phase from preclinical learning into internship, previous studies have shown that, despite an increase of clinical experiences, the performances on conventional tests do not show improvement.[29,30] This phenomenon is referred to as the 'intermediate dip'. Two explanations have been suggested: a temporary lack of knowledge organisation owing to insufficient integration of practical experiences with theoretical knowledge, and shortcomings of conventional tests to measure problem solving competence validly.[31] The absence of this intermediate dip in the SCT, when we compare the results at different levels of experience, is considered an indication that supports the validity of the SCT with regard to clinical decision making.[4]

Focus of this study

Previous studies of the SCT typically concerned a limited domain (a medical specialisation or a group of related conditions), participants with clinical experience and a comparison of scores between participants with different levels of experience. In this study, the SCT is applied on a broad domain (primary veterinary care), participants are undergraduates without substantial clinical experience and the scores of the same students on the same test, before and after a one-year course in clinical problem solving, are compared. Against this background, the main issues this study addresses, concern:

a. The development of an SCT, and its corresponding answer key, to be used at undergraduate level to assess progress in problem solving competence.
b. Evaluation of the (internal-consistency) reliability of test results. Although ambiguity in the problems and answers of the test is conditional, this should not lead to doubt about the consistency of the measured results with regard to the students' performances. Furthermore, does repeated admission of the same test affect the reliability of participant results?
c. Evaluation of the (content) validity of the test. Do the cases and test items adequately represent the larger domain of the conditions, clinical decisions and uncertainties in primary veterinary care?
d. Evaluation of the test sensitivity. Can the test detect changes in competence within the frame of a one-year course in solving clinical problems?

Methodology

Materials

Table 1. Case vignette with two items

<table>
<tr><td colspan="3">'Carl', a six-year-old male Rottweiler dog, is presented to you. For three days, he has not eaten and vomits 5 to 8 times per day. According to his owner, he is usually a gobbler and never picky in what is served. He has not stopped drinking. Carl is kept as a family pet and allowed to walk about freely in and around the house, as long as he stays on the premises. First impression: an agitated dog with some signs of discomfort. There is no visible loss of weight. Pulse rate: 140/ min (equal, regular); respiratory rate: 28 / min (costo-abdominal); temp. 39°C; skin turgor: average-poor.</td></tr>
<tr><td>Suppose you consider this a case of:
b. stimulation of central receptors (due to poisoning)</td><td>and then you find that:
despite fierce attempts, he hardly produces any vomit</td><td>then this diagnostic hypothesis becomes:
-2 -1 0 +1 +2</td></tr>
<tr><td colspan="3">-2 = very unlikely -1 = less likely 0 = not more nor less likely +1 = more likely; +2 = very likely.</td></tr>
</table>

<table>
<tr><td>Suppose you consider for further assessment / treatment:
d. abdominal X-ray</td><td>and the assessment of the patient revealed:
yellow mucosa + extended CRT (capillary refill time)</td><td>then this approach becomes:
-2 -1 0 +1 +2</td></tr>
<tr><td colspan="3">--2 = contraindicated -1 = not advisable 0 = not less nor more significant +1 = advisable +2 = indicated.</td></tr>
</table>

In an SCT, problems and situations are described in short case vignettes. A vignette contains the main features of a case's first presentation and relevant aspects of its history which would be known in reality. Each case comes with four test items, formulated as a hypothesis or suggestion for action (Table 1).

Besides this hypothesis or proposed action, a test item holds additional information about the case. Participants are asked to assess the effect of the additional information on the plausibility of the hypothesis or the appropriateness of the proposed action. This entails carefully combining and weighing all available information.

Test development procedure

Development of the SCT included the following steps:

1. The assessment matrix was based on epidemiological data concerning the clinical problems that frequently occur in primary veterinary care, to achieve a representative sample of cases.
   Clinical teachers, representing the main subdomains in veterinary medicine, provided the information needed to turn these clinical problems into realistic cases. Test items were chosen to reflect authentic biomedical and veterinary issues, including dilemmas related to owner preferences, ethical issues or time pressure.
2. To disclose whether the students' unfamiliarity with the SCT-format of items, or the 'indifferent' answer category would affect their reasoning and choices, three trial sessions were conducted with fourth-year students from the previous cohort, following the 'think-aloud' procedure. These trials confirmed engagement of the students in the intended cognitive processes. Changes in the format or phrasing of cases were not indicated; the trials did, however, reveal the necessity for high-quality test instructions.
3. The final version of the SCT-VM was composed, covering 30 cases and 120 test items to create a sample large enough for the content to be tested. Previous studies[32] indicated that an SCT covering a medical subdomain needs about 50 to 60 test items to achieve a reliability (Cronbach's α) of 0.80 or more.
4. To establish the answer key, the test was completed by the reference panel. Based on previous studies,[26] a minimum of ten experts per subdomain (animal species) was regarded as sufficient. Inclusion criteria for the reference panel were: veterinary practitioner, non-teaching, with at least ten years of clinical experience

in primary veterinary care, acknowledged and recommended by colleagues (from university clinical staff). Thirty-five practitioners were invited to participate; 28 agreed and completed the test. For each expert, only the answers which concerned cases in their particular areas of expertise are included in the answer key.

5. In addition to the test itself, a short questionnaire was developed for participant feedback, in particular about the SCT format of test items and the representativeness of the cases.

Context and participants

This SCT in veterinary medicine (SCT-VM) was developed as an instrument to establish the progress students make in a course on clinical problem solving, including practice with real patients, and covering most of the last (fourth) pre-clinical year before the clerkships (Utrecht University). The test is conducted twice, near the beginning and at the end of the course.

Students participate on a voluntary basis. Test results are neither part of the course assessment programme nor revealed to the teaching staff. The students receive individual feedback about their scores, and guidance in the interpretation of results.
Of all students on the course, 168 (97.7%) participated in the test; 148 of them in both the pre- and the post-test. To avoid student performances being affected by unfamiliarity with this type of case description, the pre-test took place after the students had some opportunity to become accustomed to case vignettes in clinical tutorials (max. seven).

Data analysis

1. Development of the answer key:
   a. The *degree of concurrence between members of the reference panel* was analysed to identify the items that should be reviewed and, if necessary, excluded from the answer key. Large variability in answers may result from measurement error, e.g. in the construction or phrasing of an item. Total concurrence indicates that the item does not involve an aspect of uncertainty.
   b. The *optimal scoring model.* The usual SCT scoring model is based on a score of one for the experts' modal answer, whereas the alternative answers receive a score corresponding to the proportion of panel members who choose the same alternative. Given some apparent patterns in the answers of the

reference panel, alternative scoring models with a potentially better fit were studied to disclose their effects on the students' scores.

2. Evaluation of reliability and validity:
   a. With the provisional answer key and scoring model, the estimated *internal-consistency reliability* and item-total correlations were calculated. Commonly used measures such as the Discrimination Index or distractor analysis were not used for item analysis, as they assume a single right answer. The individual scores of the panel members were checked to uncover deviant response patterns.
   b. If indicated (large variability in expert answers, low item-total correlation), items were reviewed independently by two senior veterinarians to reassess their *validity.*[33]
   c. With the final answer key, the scores of participants were established and internal consistencies re-estimated.
   d. Generalisability theory provides methods to disentangle the contributions of multiple factors (e.g. the number of items) and their interactions with the reliability of results.[34] To determine the reproducibility of test results and the effects of repeated use of the test, a G-study (variance component analysis) was conducted, based on a two-facet fully-crossed design with the items, participants, and the two occasions as facets. A D-study projected the effects of changes in one of the facets with regard to optimisation of reliability.
3. Evaluation of *test sensitivity*:
   Finally, results of the pre- and post-test were compared, to disclose whether the test measured a significant change in competence.

Results

Test development: answer key and scoring model

With the panel members' responses, a provisional answer key was composed based on 12 experts in companion animals, 12 in farm animals and 11 in horses. This answer key showed a degree of concurrence between two-thirds of all experts on one alternative in 22 test items, and on two adjacent alternatives (e.g. 'very unlikely' and 'less likely') in 71 of the test items. In 17 items the distribution of answers of the reference panel called for a review. Figure 1 illustrates different degrees of item concurrence.

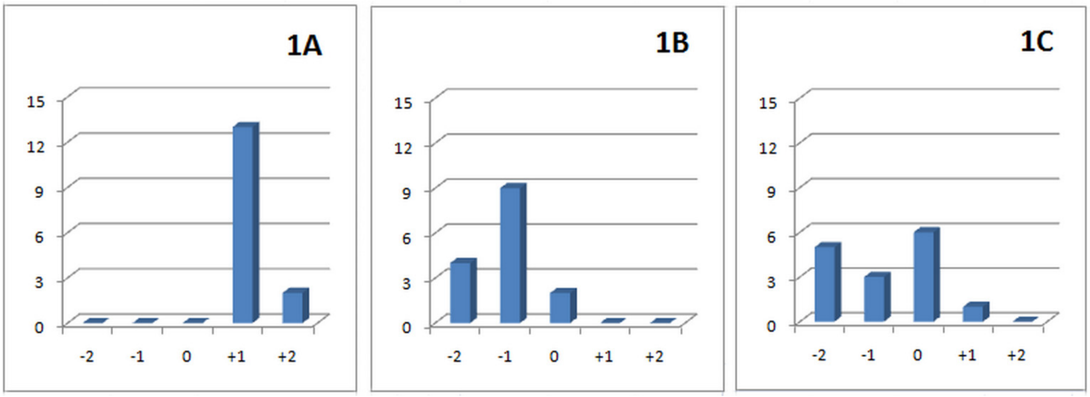

Figure 1.Variable degrees of concordance (expert responses): a. Large majority in one alternative, b. Majority in two adjacent alternatives, c. Other patterns

Close examination of the distribution in the experts' responses led to two hypotheses (a three-point answer scale provides sufficient differentiation; a modus score of one point is an overestimation), tested with four alternative scoring models. The effects of the alternative models on the averages and ranges of the reference panel and the students in the pre-test are presented in Figure 2. Correlations between results in models 2, 3 and 5 with those of the SCT aggregate scoring model (model 1) are strong (r=0.98 resp. 0.89 and 0.96; p<.01; n=164). For model 4 this correlation is moderate to strong (0.66).

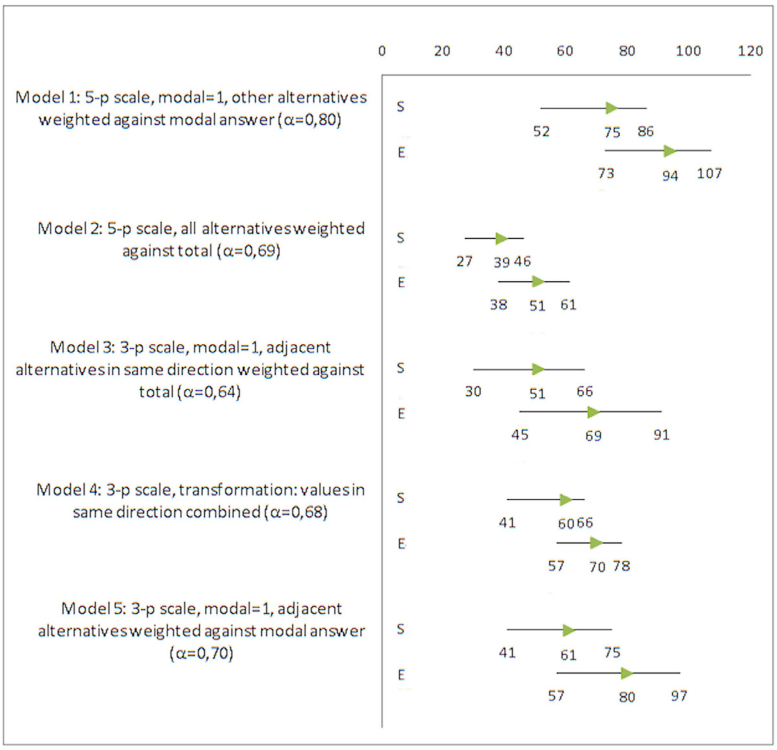

Figure 2.Effects of alternative scoring models on the pre-test results of students (S) and the expert panel (E): lowest score – mean – highest score

Both types of adjustments in the scoring model resemble higher levels of concurrence between the experts and lead to a reduction of the scale range. The lower reliabilities (Cronbach's α) in these models might result from the information loss owing to non-valued responses. As the SCT-VM is intended to monitor competence development, reducing the scale range (differences between students) was avoided. Further analysis is based on model 1.

Reliability and content validity

The review of the 17 items with a limited concurrence between panel members did not uncover apparent errors in the case or item construction, affecting validity. None of these items were removed in the final answer key.

The internal consistency (alpha) of the pre-test and post-test is respectively 0.80 and 0.79. Item-total statistics show that removal would not increase alpha by more than 0.004 for any of the items. One practitioner, with over 40% outlier answers and a low personal score (<*M*-2*SD*), was excluded from the reference panel.

Table 2. G-study: variance component analysis and generalisability

GENERALISABILITY
Design type: two-facet fully-crossed design (P * F1 * F2)

Number of participants: 160
Number of items: 120
Number of occasions: 2

Source	***df***	***ss***	***ms***	***Variance***	***Proportion***
Participants (P)	159	156.641	.985	.0004	2,5%
Items (F1)	119	666.981	5.605	.016	11,6%
Occasions (F2)	1	12.484	12.484	.001	0,5%
P*F1	18921	2749.176	.145	.027	19,2%
P*F2	159	12.522	.079	.000	0%
F1*F2	119	38.523	.324	.001	1,0%
P*F1*F2	18921	1728.250	.091	.091	65,1%

Error Variances:	Relative	Absolute
	.001	.001
G-coefficients:	*G*	*Phi*
	.854	.769

The results from the G-study about the generalisability of participant results and the relative contribution of different sources of variance are shown in Table 2. The G-coefficient indicates that 85.4% of the result-to-result variation is owed to real differences between the participants. The additional D-study established that a minimal 80 items would have been sufficient to obtain a reliability (G-coefficient) greater than 0.8; and if this test had been used only once, then 130 items would have been needed to achieve the same reliability.

Sensitivity to changes in competence

The students' scores improved from the pre-test (*M*=74.9, *SD*=5.5) to the post-test (*M*=79.6; *SD*=4.9). The improvement is significant (*t*=12.753, *df*=147, *p*<.00025). Furthermore, their individual scores on the pre- and post-test correlate positively (*r*=0.653, *N*=148, *p*<.001) and the effect size is large (Cohen's *d*=0.89).

Participant feedback on using the test

The results from the questionnaire (Figure 3) show that the students and experts more or less agreed on the authenticity of the cases (4.2 ± 2.0 on a five-point Likert scale) and on the perceived difficulty of the SCT-format (3.8 ± 1.0). Students considered the cases more complex; they also perceived the test as knowledge-intensive, rather than reasoning-intensive. Monitoring progress in clinical reasoning is considered very useful (4.6) by the students.

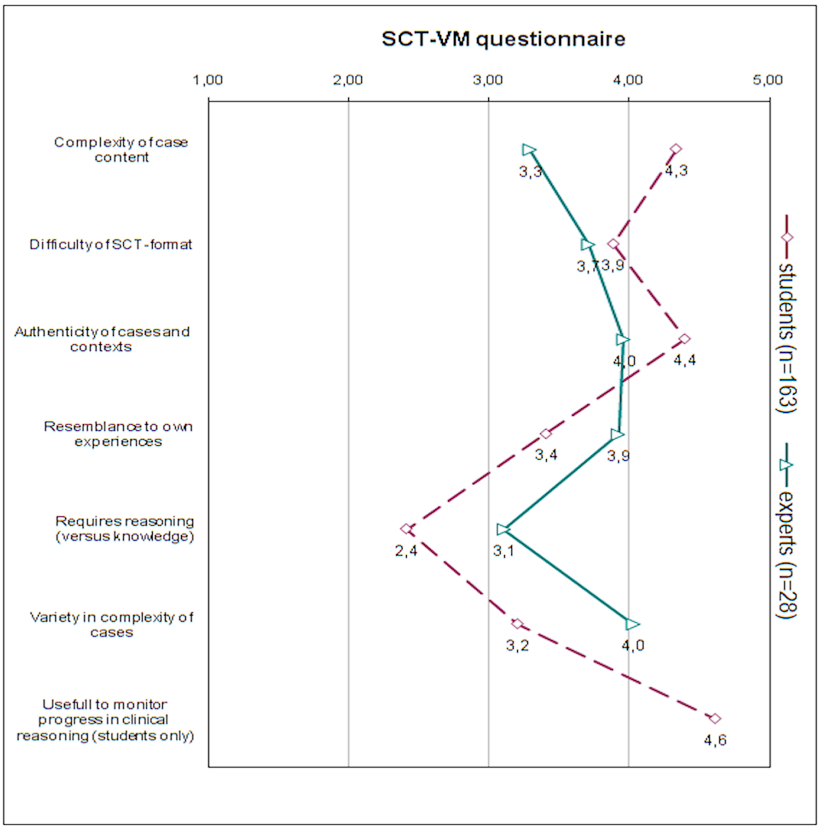

Figure 3. Results from the questionnaire

Discussion

Reliability

The reliability criterion concerns the consistency of the measurements and results across the items within the test. A potential threat to the reliability of the SCT-VM results from including uncertainties in the test. They should reflect realistic uncertainties, and the variability in responses which they cause should be distinguished from error in item construction or inconsistencies in the answer key. Ultimately, there should be no doubt as to whether test scores reflect the students' actual performances.

To achieve a high level of consistency of measurement, reliability issues have been reviewed repeatedly during test development up to the final evaluation:

- During the development of the SCT-VM and in the analysis of results, items with low concurrence between experts were reviewed to identify answer variability *owing to construction error*. No items were removed. One of the panel members, however, was excluded as this member's answers were beyond a reasonable level of distribution. Testing the effects of alternative scoring models confirmed the *fit of the classic SCT-model* with the data in the SCT-VM.
- The test results of the SCT-VM are based on a *substantial number* of cases and items and its *internal consistency* in both administrations is satisfactory (>0.79). The G-study, which combines different types of reliability analysis in one model, shows a *high generalisability* of results (0.85) and that repeated use did not affect test results. To assess progress with a pre- and post-test, a total of 80 items would have been satisfactory, aiming at G>0.80.

Validity

Appraisal of validity requires a substantive analysis of the instrument, relating test results to the content, processes and conditions of the competences to be measured.[33] A clear difference between written test formats and clinical problem solving in practice, which may affect the reasoning processes, is the actual presence of a patient. Such presence requires attending to issues of comfort and safety, and to communication with the owner, concurrently with the problem solving process. Moreover, in an SCT the hypotheses are already suggested, whereas in real practice, clinicians generate their own hypotheses.

Within these limitations, however, the findings in this study support in several ways the validity of the SCT-VM for assessing clinical problem solving and decision making:

- The SCT-VM contains a *large sample* of cases and items, based on epidemiological data, *representative* of the problems and conditions that veterinarians in primary care frequently encounter. Within this number of cases and items, *the different areas* of clinical judgements and decisions are covered. The authenticity of the problems and circumstances in the cases was confirmed by the experts from the reference panel and by the reviewers of items.
- The SCT-VM requires *cognitive activities similar* to those in practice: interpreting the information and weighing its reliability, reasoning about and recognising possible patterns, appraising the probability of hypotheses and alternatives, estimating the outcomes or effectiveness of interventions. The results of these activities are stated in terms of *judgements* or *decisions*. The think-aloud in the trial sessions and the students' feedback confirm engagement in the same activities and processes.
- The judgements and decisions of the *experienced practitioners* make up the reference against which student answers are compared. This allows real-life problems and dilemmas, beyond the level of 'single right answer' issues, to be included in the test.
- *Coverage of the domain* of primary veterinary care was achieved by a reference panel with sufficient expertise from each subdomain. If the distribution of expert answers was beyond the expected range of differences, the case content was re-examined to disclose artificial uncertainties (e.g. lacking information which would be available in practice) or construction errors affecting test results.

Conclusion

In the light of the findings in this study, we conclude that the SCT-VM meets the described objectives and conditions. Hindrances related to the breadth of the domain to be covered, as well as the limited clinical experiences of the students, could be avoided. The results from using the same test twice made it clear that an SCT can be used as an instrument to monitor progress in problem solving and decision making competence.

The SCT-VM in this study was used formatively. In the case of an assessment with a summative function, students might have been more hesitant to participate in a test with ambiguities in the cases, questions and answers. How that would have influenced their choices in these cases is open to speculation.

The main limitations of an SCT concern aspects of concurrent patient handling, communicating and problem solving, and a lack of necessity to generate one's own hypotheses. An assessment with real or simulation patients has better opportunities to include these aspects as well. Nevertheless, the SCT format has some important usability advantages; it is based on a large number of cases, can be administered comparatively easily and processed uniformly to a large numbers of students, without creating a burden on real patients. These strengths, in our opinion, offset the limitations of the SCT. We recommend that the SCT format be used more widely in actual educational practices, so that its features and applicability in other domains and its use for summative purposes may be further investigated.

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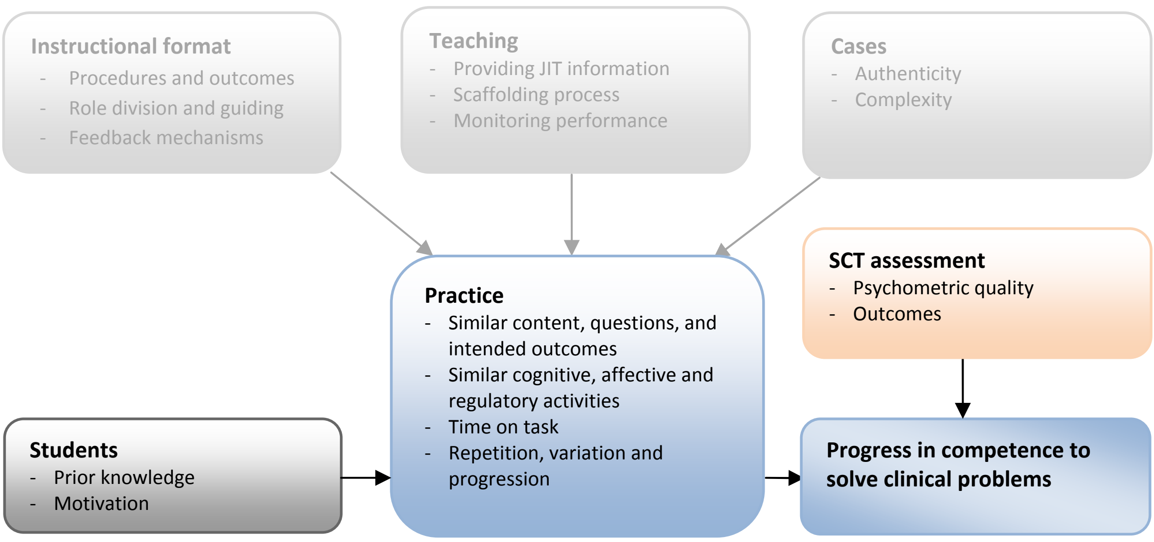
"It is important that researchers and educators understand the critical issues behind the various program effectiveness reviews so that they can intelligently interpret their conclusions"

Robert Slavin, 2008[10]



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6. Effectiveness of a programme design for the development of competence in solving clinical problems [11]

Abstract

This paper addresses the effectiveness of a training programme designed to enhance the development of competence in clinical problem solving for students with a sound theoretical base in biomedical and clinical sciences. The programme is built on the use of authentic problems and situations, a high level of student self-directedness, and provision of ample opportunity to experience handling clinical issues with paper-based as well as real-life clinical situations. This study examined the extent to which this programme design was effective in achieving its objectives. It employed methodological triangulation of results from questionnaires, performance observations and assessment tests. These results showed that the design was perceived as effective, leading to improved performances in the process of solving clinical problems as well as to better solutions in the assessment of problem solving competence.

[11] This chapter has, in adapted form, been accepted for publication:

Ramaekers SPJ, van Keulen J, van Beukelen P, Kremer WDJ, Pilot A. (2011). Effectiveness of a programme design for the development of competence in solving clinical problems. *Medical Teacher, 23* (in press).

Introduction

The ability to solve clinical problems and make the required decisions is nowadays recognised by many as key competence in clinical practice.[1] For a long time, clinical problem solving had been regarded as a rational process of merely applying logic to medicine.[2,3] Due to a growing understanding of the complexity of problem solving processes and the many sources and opportunities for making erroneous decisions, training programmes and assessments explicitly containing aspects of clinical reasoning and decision making have become part of medical curricula.

In the preclinical phase, case-based and problem-based learning are commonly used as instructional designs to support the development of clinical problem solving competence. Whereas the strengths of these learning approaches have been recognised[4] and debated,[5] alternative designs to optimise learning opportunities have been explored.[6,7] This study concerns the design of a programme that combines a case-based instructional format with opportunities to practise and experience real-life clinical situations. It builds on theories about authentic learning[8,9] and instructional design,[10,11] employing a mixture of paper-based cases (tutorials) with real patients (clinical practicals) to engage students with a sound knowledge of basic and clinical sciences in solving high-fidelity clinical problems. The programme is intended to reinforce links between theory and practice and to ease the transfer from learning preclinical subjects to their application during clerkships.

A preceding proof-of-concept study established that the instructional design, on which the programme is based, was valid with regard to facilitating the processes and learning functions that are essential for development of competence in clinical problem solving,[12] In this study, the question was whether the programme proved to be as effective in practice as might be expected from the theoretical arguments on which the design was based. Discrepancies between what was actually attained from a training programme and its original design may result from conceptual shortcomings underlying that design[11,13], as well as from practical considerations.[14,15]

The purpose of this study was to establish the extent to which the design was effective in enhancing the development of competence in solving clinical problems. To achieve this, the issue of effectiveness was approached in three complementary ways:

a. Did the students *perceive the programme as effective* with regard to raising their level of competence in solving clinical problems?

b. Did the programme lead to *changes in the students' approach to clinical problems* that are consistent with progress in the development of problem solving competence?
c. Did the programme lead to an improved performance in terms of *an improved quality of solutions to clinical problems*?

Methods

This study drew on a mixture of qualitative and quantitative methods and used 'methodological triangulation' complementary[16] to address the multidimensional character of educational outcomes and effectiveness. Each of the used methods had its own perspective on dimensions of effectiveness with regard to competence in clinical problem solving. Table 1 shows the conceptual relationship between the data collected.[17]

Table 1. Data structure in triangulation.

Level	Processes	Instrument / method	Categories of variables	Outcomes
Case level	Problem solving process Learning process	Observations (B) throughout the course	Components of clinical problem solving	Changes in approach to clinical problems
		Questionnaire (A2) at the end of case discussion	Qualities of cases, teacher performance and work format	Perceived effectiveness of single case discussion related to learning
Course level	Development process	Script Concordance Test (C)	Different problems, levels of complexity and different types of judgements and decisions	Improved accuracy of solutions to clinical problems
		Questionnaire (A1) at the end of the course	Opportunities to practise and support learning and development processes	Perceived effectiveness of course as a whole related to competence development

Educational context and design

In 2004, the curriculum components for training clinical problem solving in veterinary medicine (Utrecht University) were re-designed as part of a large-scale curriculum revision. Key features of the new programme, '*clinical lessons*', relate to the use of authentic cases and problems, engagement in learning processes derived from the work processes in clinical practice, a high level of student self-directedness, and exposure to a large variety of cases, both real patients and paper-based.[12]

The programme extends through to the last (4th) year before clinical clerkship and takes up a substantial part of the weekly coursework. The core of the *clinical lessons* consists of three complementary educational formats: clinical practicals, demonstrations and tutorials. Whereas the first two involve real clinical patients, the latter build on paper-based cases. In all formats, the students direct the exploration of clinical problems and discussions to establish optimal 'solutions'. The teachers' primary roles are to support and guide students in the process, provide them with additional patient information at their request, and assess performances and progress.

In line with the methodology of design-based research, a specific component of the programme has been adjusted every year and the effects of this adjustment have been studied. In 2005 to 2006, adjustments were geared towards optimisation of teaching, particularly regarding student guidance.[18] In 2006 to 2007, the cases for tutorials and progress in case complexity were reviewed to achieve optimisation. This study focuses on the academic year 2007 to 2008, the first year after both student guidance and cases had been optimised.

Data collection

a. Questionnaires: perceived effectiveness of the programme

The perceived effectiveness of the programme with regard to clinical problem solving competence was established in two ways:

a1. Course level: the students' appreciation of the course as a whole, its design and effectiveness were evaluated at the end of year. This questionnaire consisted of 26 items structured around the instructional design, opportunities to practise and perceived effectiveness of the course. 129 questionnaires were returned, covering 75.8% of all participating students.

a2. Case level: a questionnaire with 15 items about the 'case attributes', 'teacher performance' and 'general qualities of the work format' (including its educational effectiveness) was completed immediately after each clinical lesson by four students, two leading the case exploration and two observing. 1814 completed questionnaires were returned, covering 627 (94.4%) of the sessions that took place.

The items in the first questionnaire were derived from the literature about case-based learning formats and instructional design while the second questionnaire was based on the results of evaluations and observations during the two years prior to this study. In both questionnaires, students were asked to indicate their degree of agreement on a five-point Likert scale (1=completely disagree, 5= completely agree) for each item. The full questionnaires are available from the first author.

b. Observations: problem solving process

A total of 14 *clinical lessons* at the beginning and end of the course were observed and recorded on audio tape to allow for an in-depth qualitative analysis. These observations related to 14 different cases, 6 student groups and 6 teachers. Each student group and teacher was observed at least twice. They gave informed consent to be recorded on audio tape. The observing researcher [SR] did not actively participate in any case discussion.

Recordings of the *clinical lessons* were analysed, with a single case discussion as the unit of analysis. The coding scheme was developed and refined on the basis of the conceptual framework underlying this instructional design and the behaviours actually observed.[18] Four main code categories were distinguished (Table 2A, 2B): problem solving phases, supportive learning phases, student reasoning behaviours and teacher behaviours. The 'behaviour' categories were nested within the 'phases'. Behaviours concern single utterances while phases cover larger segments of a case discussion. The inter-rater agreements for the 'problem solving' and 'supportive learning' phases were high (*K*=0.92) while those for 'teacher behaviours' and 'students' reasoning behaviours' were substantial (*K*=0.75).

Student utterances were coded interpretatively,[19] linking their behaviour to the (cognitive) activities that make up 'clinical problem solving': the gathering, interpreting and organising of information, establishing and testing hypothesis, drawing conclusions, making and justifying decisions and choices. Next, qualitative analysis of the specific content of the discussion and cross-case comparisons were used to shed light on changes in the students' reasoning during the year.

Table 2a. The coding scheme - main categories phases.

Problem solving phases	Supportive learning phases
initial case information (C-INFO) checking vital functions (C-VITA) anamnesis (C-ANAM) initial problem description (C-PROB) general patient assessment (C-GENA) initial diagnostic hypothesis (C-INIT) specific patient assessment (C-SPEA) differential diagnosis (C-DDX) choice of treatment modalities (C-RX) execution of treatment (C-EXEC) review of effectiveness (C-EFF)	instruction beforehand (E-INFO) time-out (E-TO) evaluation (E-EVAL) teacher-guided discussion (E-COLL)

Table 2B. The coding scheme - main categories (behaviours.

Teacher behaviours	Students' reasoning (behaviours)
providing answers (T-ANSW) asking questions (T-QUES) additional statements (T-ADDS) scaffolding the process (T-PROC) stimulating group interactions (T-GROU) guiding reflection and feedback (T-EVAL)	choice of strategy (R-STRAT) gathering information (R-GATH) organising information (R-ORG) interpreting information (R-INTP) making judgements (R-JUDG) making decisions (R-DECI) justifying judgements and decisions (R-JUST) other (R-OTHR)

Empirical research and theories about competence development in clinical problem solving have shown a number of possible changes that can indicate progress. The student performances in the case discussions were checked against these indicators in this study:

(1) An increased speed and fluency when concurrently taking patient history or executing tests, processing case information, reasoning and making decisions, elaborating on findings or justifying choices.[20,21]

(2) A transitory increase in explicit application of biomedical theories and integrating knowledge from different domains when analysing and explaining the specific case problems.[22-25]

(3) A widening scope and awareness of relevant contextual features, including underlying functional and structural components, enabling conditions and case dynamics. This awareness supports an increased accuracy of problem analysis and decisions.[26,27]

(4) Improvements with regard to early diagnostic hypotheses, the use of obtained information to guide the assessment of these hypotheses and meta-cognitive monitoring of the progress made.[28]

Together, these changes result in (5) an ability to handle more complex cases successfully, (6) reduced dependence on teacher guidance, and (7) mastering a variety of problem solving approaches, including non-analytic processing.[29]

c. Assessment: quality of problem solutions

To establish, independent of teacher guidance and interventions, to what extent the students at the end of the course had improved in solving clinical cases they were confronted with, a *Script Concordance Test* (SCT) was developed, which specifically focused on clinical reasoning and decision making in realistic cases in veterinary medicine (SCT-VM). This test was administered twice, near the beginning and at the end of the course, to reveal the progress made during this course. Students participated voluntarily; test results were neither part of the course assessment programme nor revealed to the teaching staff. The students received individual feedback about their own scores and guidance in the interpretation of results.

The SCT-VM consisted of 30 cases and 120 items representing a variety of conditions that are common in primary veterinary care and different types of clinical judgements and decisions. Items in an SCT contain a hypothesis or a proposal for action as well as additional case information (Figure 1). The participants were asked to consider whether the suggested hypothesis or action was supported by all available case information or not. As the cases were intended to represent authentic problems, they included the kind of uncertainties that are common in clinical practice. The answer key of an SCT was, therefore, established by a reference panel of experts. The degree to which answers from participants concurred with those of the experts determined the score of the participants and indicated their level of competence.

For the second time in one month, you are called out to a nine years old mare with symptoms of recurring colic. At the first consultation, it appeared that this was caused by an impaction of the left ventral colon, which was treated with an analgesic and mineral oil/liquid paraffin. After two days the constipation appeared to resolve; nevertheless the horse continued to have symptoms of mild diarrhoea and reduced appetite. From yesterday it seems that the horse has symptoms of colic again (pawing at the ground, flank watching, intermittently lying down / standing up).

During your examination you find, among other things, some abdominal distension and you hear spontaneous gut sounds. Rectal examination reveals no abnormalities. General examination reveals that the horse is restless, there is some sweating, pulse rate 52 /minute, temperature is 38.2°, there is yellow discolouration of the conjunctiva and sclera, and a poor coat.

Suppose, you consider the following diagnostic hypothesis:	and in your assessment you find:	this hypothesis becomes:
-. strangulating obstruction of the colon	apart from a few days of fasting following the first treatment of the colic, there have been no recent changes in the diet	-2 -1 0 +1 +2

-2 = very unlikely -1 = less likely 0 = neither more nor less probable +1 = more likely +2 = (almost) certain

Suppose, you consider the following treatment approach:	and in your patient assessment you find:	than this approach becomes:
- paracentesis	- the colic increases during riding	-2 -1 0 +1 +2

-2 = (absolutely) contra-indicated -1 = not advisable 0 = not less nor more useful +1 = advisable +2 = (absolutely) indicated.

Figure 1. Example case in the SCT.

The answer key was based on the responses of 27 experts. Of all students on the course, 168 (97.7%) participated in one of the test admissions and 148 (86.0%) in both. Details about the methodological qualities of this test have been reported earlier.[30]

Methodological triangulation

Triangulation was geared towards combining complementary data to achieve a comprehensive view on the effectiveness of the course design. All the data involved the cohort of students participating in the *clinical lessons* for one year, with the same cases (tutorials and demonstrations) and teachers executing the programme. Although various data were available at the level of individual students (e.g., scores on the SCT-VM), findings from the observations and some results from the questionnaires were probably influenced by group dynamics. Therefore, the student cohort was taken as the unit of analysis for triangulation.

As for the triangulation procedure, the data from each method were first analysed separately from the other methods.[31] Next, findings were combined at the conceptual level to elaborate on separate results and establish the extent to which results converged or diverged.

Results

a. Perceived effectiveness of the programme

<u>a1. Course level:</u>

At the course level, student appreciation ranged from 4.39 (*valuable opportunity to practise with solving clinical problems*) to 2.94 (*clarity about the expected depth of preparation*), with an average of 3.75. Ten items from this questionnaire concerned the students' appreciation of the learning opportunities and the perceived effects of the programme. Eight of them scored above 4.0 (Table 3).

About the conditions possibly affecting their learning opportunities (not included in Table 3), the students were least satisfied with the *time available for preparation* (3.02 ± 0.94), *clarity about the expected depth of case preparation* (2.94 ± 0.99), the *aptness of their prior knowledge* (3.27 ± 0.84) and the *transparency of assessment criteria* (3.26 ± 1.05). In addition to this, a number of students expressed that the differences between teachers sometimes created uncertainty that had a negative effect on case discussions and learning.

Table 3. Results questionnaire at the course level (1=disagree, 5=agree).

N=129		
Opportunities (α=.67)	***M***	***SD***
The *clinical lessons* offered a valuable opportunity to:		
- practise with solving clinical problems	4.39	0.64
- learn from instructive cases and patients	4.25	0.61
- extend and deepen my knowledge base	4.30	0.63
- practise with performing relevant clinical skills	3.83	0.85

Effects (α=.82)	***M***	***SD***
The *clinical lessons* have increased my:		
- ability to deal effectively with clinical problems	4.13	0.68
- ability to justify my clinical decisions	4.07	0.62
- awareness of my own competence level with regard to professional conduct	3.39	0.96
- motivation for this degree study	4.29	0.71
- understanding of how various subjects within this degree study relate to each other	4.04	0.70
- readiness for clinical clerkship	4.09	0.67

a2. Case level:

At the level of separate cases, student appreciation ranged from 4.45 (*authentic clinical problems and circumstances*) to 3.11 (*frequent teacher interventions*), with an overall mean of 3.87. During the year, these scores did not change significantly, except the one for '*clarity about teacher expectations*'. As the students progressed, this clarity increased significantly from 3.00 to 3.89 (Spearman's r_s = .106, p <.001).

The programme features that were most valued by the students were: *authenticity of the case* (4.45 ± 0.65), *practise with clinical problem solving* (4.25 ± 0.69), *teacher guidance* (4.16 ± 0.71), *attention given to evaluation / reflection* (4.28 ± 0.83) and *transparency of changes in teacher role* (4.12 ± 0.88). Overall, case discussions were considered *highly instructive* (4.29 ± 0.67) and *inspiring for their study* (4.25 ± 0.72).

b. Changes in the students' approach to clinical problems

Although student performances at the beginning and end of the course had some common characteristics, various differences were identified that exemplified the progress in solving clinical problems at this stage of student development:

(1) Speed of work and fluency. It took the students about 4 to 6 weeks to master applying the procedures of patient assessment and farm health management screening at a level that supported their problem solving process. Parallel to the development of elementary routines in performing recurrent parts of the assessment (anamnesis, observation, basic examination of organ systems and vital functions), their speed and fluency of work increased. Questions and considerations were more to-the-point and students became less hesitant about the choices to be made. Furthermore, emphasis gradually changed from taking history (relevant questions) and communication (clarity and building rapport) to interpreting and relating findings, drawing conclusions and deciding how to proceed.

(2) Explicit use of theory. Throughout the course, the students reproduced vast amounts of factual knowledge relevant to the cases. During the first few months, however, the mechanisms underlying case problems and findings were only discussed in depth when probed by the teachers. Rather than 'building' a comprehensive case-specific model relating problems and findings to theories and hypotheses, the students persisted in a stepwise process of elimination, centred around one diagnostic hypothesis at a time. It was near the end of the course that different lines of thoughts were handled simultaneously and new information was weighted against several hypotheses.

(3) Scope. The range of potential relevant aspects that the students included in their case analyses increased during the course. In the first series of cases, student attention was typically focused on issues related to the pathophysiological process. Gradually, aspects such as enabling conditions, prevention and animal health management, costs of additional tests, owner expectations, public health and ethical issues were included as well. Similarly, a gradual change in focus took place from identification and concentration on one organ system to awareness of potential effects on other organ systems and systemic diseases.

(4) *Early hypotheses, metacognitive monitoring and procedural adjustments*. The students' first hypotheses were often mere lists of differential diagnostic possibilities linked to particular symptoms and not suppositions based on case-specific combinations of signs and symptoms. During the year, this did not change very much. Likewise, restricting the gathering of information to what was necessary remained an issue of discussion throughout the year. The possibility of taking 'time-out' for reflection on the progress made and how to proceed was highly appreciated and frequently used by the students.

(5) Quality of solutions. To what extent the quality of the solutions improved owing to student progress could not be observed independent from other influences. The interactions with peers and support and guidance by the teacher commonly influenced problem solutions. Yet, during the last weeks of the course, the students managed successfully to practise with selected, complex cases covering many different aspects simultaneously.

(6) Dependence on guidance and support. When considering teacher support only quantitatively, hardly any reduction was observed during the year. Nevertheless, the nature and focus of this guidance changed in due time from pointed questioning about theoretical background and strategy towards facilitating in-depth discussion about relevant issues and elaboration on clinical practices.

(7) Variety in problem approaches. Despite the observed changes in scope and fluency in handling basic examination procedures, a clear development towards more variety in approaches to problems was not observed. Their strategic choices were actually often influenced by their teachers' interventions. A majority of the teachers stressed a systematic-analytic, almost algorithmic, approach. Others reinforced a more heuristic approach and the need to selectively gather information that is required to achieve the level of certainty considered necessary.

c. Improved performance in solutions to clinical problems

Progress with regard to the quality of solutions to clinical problems, established independently from the discourse of case discussions and guidance from teachers or peers, was made clear with the SCT-VM. The students' overall scores on the SCT-VM improved from the pre-course test (M=74.9, SD=5.5) to the post-course test (M=79.6; SD=4.9). This improvement was significant (t=12.753, df=147, p<.00025) and individual student scores in the pre- and post-test correlated positively (r=0.653, N=148, p<.001). The effect size was large (Cohen's d=.89). Figure 2 shows a scatter plot based on both scores, indicating the student's progress. As represented by the regression line, the students with the lowest scores on the pre-test made the largest relative improvement.

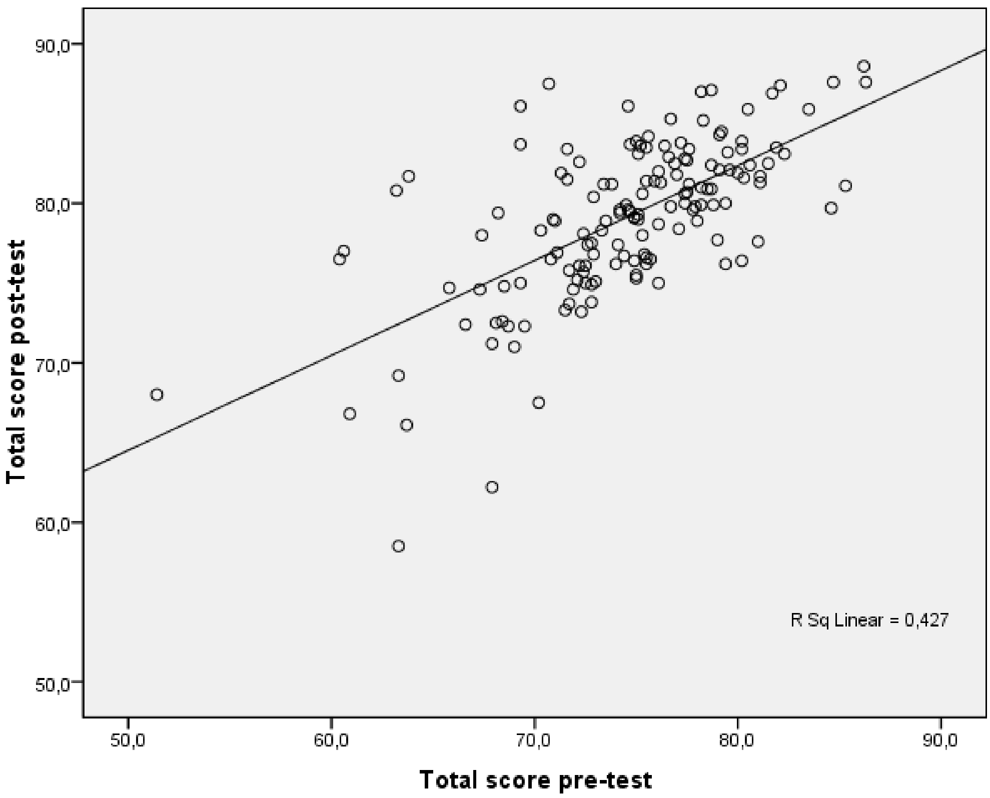

Figure 2. Scatter plot showing student progress in the SCT.

Discussion and conclusion

On all three dimensions of effectiveness, the results were consistent and indicated that the programme led to the projected growth of student competence in solving clinical problems.

a. *Perceived effectiveness with regard to competence in solving clinical problems*

The students perceived the *clinical lessons* as effective for their ability to solve clinical problems and their readiness for clerkships, as well as for their study motivation and understanding relationships between subjects. The opportunities in this course to practise with clinical problem solving and practical skills on instructive, real and paper-based clinical cases were highly appreciated. Further analysis of these results [18] indicated that the students attributed the effectiveness of case discussions largely to the quality of teacher guidance, the cases themselves, reflection at the end of each case and the feedback they received.

b. Changes in the students' approach to clinical problems

Previous studies have highlighted potential discrepancies between student self-efficacy (or confidence) and performance in real-practice situations.[32] In this study, the progress perceived by students in handling problem solving processes was confirmed by the observed changes during the year. Most evident were the increased fluency and speed of work, advances in the ability to handle processes and activities systematically, and a widening scope of relevant case aspects. The observed changes with regard to applying knowledge at a conceptual level and to procedural adjustments based on the interpretation of findings remained limited. This might be related to limitations on what can be achieved within the time frame of this course and in this phase of student development.

In this learning process, cases were solved by students interacting with their peers and a teacher. Hence, the quality of solutions cannot be taken as an independent measure of student learning outcomes. Nevertheless, by the end of the course, students were able to solve more complicated cases within the same amount of time and with a similar amount of interaction, and this indicates progress.

c. Improved quality of solutions to clinical problems

Whereas the findings from the observations mostly reflect student progress in handling the problem solving process, the results from the SCT-VM express their competence development in terms of improved professional judgements and decisions. The strength of these results indicates that the progress the students made in this course was substantial. In his synthesis of over 800 meta-analyses relating to educational achievement, Hattie[33] referred to an effect size of d=0.4 as the so-called hinge point. He considered this as a minimum; desired effects are those above this point that are attributable to specific interventions or methods. The performance improvements (d=0.89) that were established with the SCT-VM were clearly above this standard.

In conclusion, the programme has been shown to be effective in the enhancement of student competence in solving clinical problems and has received much appreciation. None of the findings in this study revealed specific limitations with regard to the use of these design features and underlying principles in comparable educational settings. Still, the effectiveness of the instructional format centred on work processes in practice and just-in-time provision of the required information may be dominated by the extent of the students' prior knowledge, particularly when such a format is applied in knowledge-intensive domains. A second premise concerns the teacher's ability to handle these instructional formats effectively. This requires managing the following different roles and activities almost concurrently: providing information, scaffolding the process, monitoring performance and stimulating group interaction if necessary, taking care of patient well-being and safety issues. Such a combination of roles and activities is difficult to manage, and the teachers in this course were sometimes not successful in achieving it. Teacher training and support of the implementation process can remedy this.

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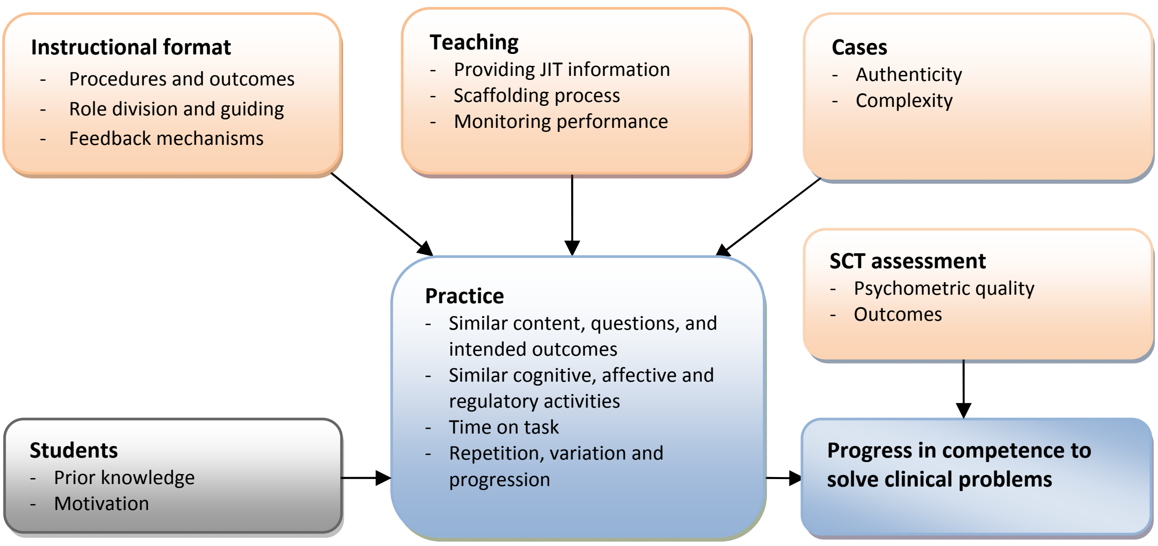
"There is a tension between the desire for locally usable knowledge on the one hand, and scientifically sound, generalizable knowledge on the other"

William Sandoval, 2004[12]

[12] Sandoval, WA, & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. *Educational Psychologist, 39*(4), p. 199.

7. General discussion



The research presented in this thesis was triggered by a number of closely linked aims and issues. A central aim was the development of a programme in clinical problem solving that would help students to bridge the gap between (veterinary-)medical theory and clinical practice. The underlying problem was how to create an educational setting and facilitate student activities that closely resemble authentic practice and, at the same time, suit developmental changes in the students' level of competence. Existing theories, research findings and instructional models were valuable in designing this programme. Nevertheless, we included programme features that were seen as improvements to existing models and suitable for the context for which this programme was meant, such as a mixture of paper-based and real patients, instructional formats based on authentic work processes and just-in-time provision of case information.

Whether these features in practice yield the hypothesised improvements and how interactions between the various design features affect the effectiveness of the programme as a whole could not be satisfactorily established on the basis of existing theories. To explore if, how or why these features worked in a real educational setting, we adopted in most studies a multi-method approach, typically dominated by analysis and observations of the executed programme. In this final chapter, we present the main results about the research as a whole. We reflect upon the meaning of our results with regard to the theoretical approach we chose, the methodology used and the limitations this places on our findings. Finally, we provide suggestions for educational practice and further research.

Overview of the main findings

The main research question guiding the studies in this thesis was: *how can authentic tasks, teacher support and instructional design be best adjusted to students' development of competence in clinical problem solving?*

Studies were carried out on the instructional format and setting in which the students practise clinical problem solving, the quality of the cases or problems to be solved, the support that students in the process receive from their teachers and the assessment of progress in the development of problem solving competence.

Instructional design

A programme that aims at higher-order skills such as problem solving, that provides students with ample opportunity to practise in various instructional formats and that includes real patients and teachers with different areas of clinical expertise requires a complex mixture of intertwined design features. In a proof-of-concept study (**Chapter 2**) we first assessed to what extent the programme design was consistent with current theories about the development of clinical problem solving competence and instructional design.

The core of the programme was built on ten key features guiding choices with regard to task formats, work procedures, division of roles, assessment and progress. Some features concern the design of separate sessions; others involve the course as a whole. Processes and student activities were addressed at three levels: (problem solving) reasoning, learning and development. The analysis of the actual design features against and the learning processes and learning functions to be fulfilled revealed that the programme design was feasible with regard to achieving its aims and objectives:

- Providing *opportunities to practise* by applying knowledge and skills in reasoning about and solving realistic clinical problems
- Reinforcing (*integration of*) *prior knowledge* learned in separate disciplines and subjects
- Requiring explicit *justification of professional judgements, choices and decisions* and 'evidence based' standards of work
- Supporting the development of *a realistic image of clinical veterinary practice*, including its ambiguities, standards of professional conduct and responsibilities of veterinarians
- Supporting consolidation and accumulation of experiences, applied in a large variety of cases, which is conducive to *development of competence.*

The proof-of-concept study not only revealed more specifically how the various programme components were expected to contribute to its effectiveness, but also pointed to potential weaknesses or uncertainties in the programme design and its theoretical foundations:

a. Quality of the cases: *the information provided beforehand* and *the openness of the cases*
b. Effective teaching: *concurrent fulfilment of the various teacher roles* and *active involvement of the whole student group*

c. Competence development: *progress in case complexity, adjustment of scaffolding to the changing level of competence,* and *support for multiple problem solving strategies*.

The subsequent studies were directed towards these uncertainties and established to what extent the actual outcomes were consistent with expectations and the intended curriculum.[1]

The quality of the cases

In line with prior studies and notions about the use of cases in education,[2] we defined the quality of cases against the dimensions authenticity and complexity. Authenticity was taken to be the extent to which an instructional task engages students in the same processes, activities and experiences they will encounter when handling a similar task in real practice. Complexity concerns the extent to which a task consists of multiple problems and different aspects affecting these problems, their mutual dependencies or interactions, and the dynamics of changes in the problem state.[2,3]

Just-in-time provision of case information has been included in the instructional design, in order to facilitate clinical problem solving and reasoning processes which (a) closely resemble authentic veterinary practices and (b) are adjusted to a level of complexity which the students can handle. According to cognitive load theory just-in-time provision of information is instrumental in enabling students to practise complex tasks, without creating an overload on working memory. Whether this applies in complex clinical problems, and which provision of information is optimal were investigated in the study described in **Chapter 4**: *regarding just-in-time provision of case information, how are paper-based clinical cases best adjusted to facilitate an authentic problem solving process and support task preparation?*

The results from observations of the executed programme revealed that:

- Overall, the tutorial case design with basic case information provided beforehand and additional information provided at the students' request facilitated a problem solving process with a flow of information, reasoning activities and cognitive challenges that resemble authentic clinical practice. Time on task during these tutorials was high.
- The course of discussions in cases with different information features was influenced by the case complexity. Of the case information attributes that were studied (problem demarcation, availability of relevant information, cues for

solutions, distracters, authentic information structure), the extent of the information in the case vignette proved to have the greatest impact on the course of the discussion.
- Case complexity can be reduced by giving students the opportunity to prepare the case discussion. To achieve this, the case vignette should include sufficient information to allow for a more detailed analysis of the case and focus on preparatory activities. Functional fidelity[4] implies that overload as well as scarcity of the information available beforehand is avoided.
- The teachers' role of providing additional case information also creates opportunities to intervene in the process and adjust the case complexity to the students' level of performance. Deficiencies in the information included in the case vignettes were sometimes compensated for by the teacher during the tutorials, for example by providing the students with additional information without being asked. Likewise, if they expected that students could handle this, teachers sometimes introduced during the case discussion some ill-structured or distracting information or unexpected developments within the clinical case, in order to heighten the case complexity.

Effective teaching

A consequence of building instructional formats on the work processes in practice and, in particular, of including just-in-time provision of case information is that teachers have to fulfil several roles more or less simultaneously: providing students with the case-specific information they require, scaffolding the problem solving process and monitoring performances and progress in competence. Combining different roles at the same time can be demanding[5,6] and lead to (unwanted) interactions between them.[7] Therefore, the second study (**Chapter 3**) was guided by the questions: *how does the requirement to combine an information-providing role and a scaffolding role in this case-based learning format affect teacher behaviour? how does this teacher behaviour affect the students' reasoning and the problem solving process?*

The findings from this study, based on observations complemented with stimulated recall interviews and evaluative questionnaires, lead to the conclusion that:
- In most cases, teachers effectively combined their roles of providing information and scaffolding. This enabled students to practice solving clinical problems while

obtaining patient information in a timescale that resembles authentic clinical practice.

- When necessary, teachers provided students with guidance, questioned assumptions or interpretations and stimulated them to deepen their analysis, broaden their scope and relate specific case features to general theoretical notions.
- Including a just-in-time provision of case-specific information in the instructional format created additional opportunities to influence the students' discussions, opportunities some teachers used to steer discussions in a particular direction. Cross-case analysis of the observed discussions revealed two patterns in how teachers combined the provision of information with scaffolding (Table 1).

Table 1 Characteristics of the two teacher behavioural patterns

Pattern DS: delayed scaffolding, separated from provision of information	*Pattern CS*: immediate scaffolding, concurrent with provision of information
- the provision of information is limited to the information requested by the students - interim time-outs are used to scaffold reflection on findings (clarity) and choices about how to proceed (focus) - case discussion ends with an evaluative reflection on the content and process and the provision of feedback, containing feed forward for future case(s)	- replies to students' questions frequently contain additional information or counter questions, suggesting a direction about how to proceed or what should be covered by the patient assessment - teachers use questions and 'micro-lectures' to discuss relevant theoretical issues - the case discussion ends with an explanation of the optimal approach by the teacher. Little or no time is taken for reflection and feedback on the students' approach of the case

As regards students' responses to their teachers' particular ways of combining roles, this study revealed that:

- usually students adapted their specific case approach and activities to the scaffolding used by their teacher.
- analysis of the cases with an irregular course of discussion and the student questionnaires emphasise that providing clarity on (a) teacher expectations and (b) role behaviour, as well as (c) the pattern with delayed scaffolding and facilitation of reflection and feedback, were perceived by the students as most effective for learning.

Development of competence in clinical problem solving

The 'clinical Lessons' were designed for students in the last year of the preclinical phase. At the start of the programme the students have already covered a substantial part of the theoretical basics in veterinary medicine but have very limited clinical experience. They are aware that they will enter clinical practice within the near future and are keen to become optimally prepared.

Across the empirical studies in this thesis, the changes during the course year that indicate development of competence (**Chapter 6**) showed a relatively stable pattern:

- Throughout the year, the students reproduced vast amounts of factual knowledge relevant to the cases. Their prior knowledge and case preparation proved sufficient for them to engage in the constructive exploration and discussion of a case; explicit incidents in terms of lacking knowledge usually concerned situational or practice-bound knowledge.
- Changes with regard to applying knowledge at a conceptual level and to procedural adjustments based on the interpretation of findings appeared towards the end of the course; students became able to handle different lines of thoughts simultaneously and new information was weighted against several hypotheses.
- Clear changes during the course year indicating progress in the development of competence in clinical problem solving concerned in particular: (a) increased fluency and speed of work, (b) greater ability to handle processes and activities systematically and (c) wider scope of relevant case aspects which were included in the problem solving process.
- Despite the observed changes in scope and students' fluency in handling basic examination procedures, a clear development towards more variety in the students' approaches to clinical problems was not found. We formulated the hypothesis that the students' strategic choices were often dominated by their teachers' interventions.
- In each of the years under study, student performances showed a marked change after the first four to six weeks. Whereas strategy and procedural issues in those first weeks commonly included extensive discussions and deliberate action, thereafter the basic question of how to proceed became visibly less dominant. The six-week threshold not only appeared to be a turning-point with regard to applying the basic procedures of patient assessment or farm health management screening, but at that point the students' perception of the problem and case

information changed as well. Case vignettes which had been assessed earlier as 'providing sufficient information' were after this point evaluated by the students as 'lacking enough detailed information to prepare'.

- In successive years, the students repeatedly expressed that they perceived satisfactory progress in handling of clinical problems. With regard to teacher support, however, hardly any quantitative reduction was observed during a course year. The nature and focus of this guidance changed during the course from pointed questioning about theoretical background and strategy towards in-depth discussion about relevant issues and elaboration of clinical practices.

The progress students made during this course in terms of the improved quality of their problem solutions could not be established on the basis of the case discussions. The interactions with peers and the support or guidance of their teachers did not allow for valid determination of an individual's contribution to the final outcomes of the discussion. Therefore, the fourth study (**Chapter 5**) focused on the development of a test to measure individual progress in the development of competence in problem solving and decision making. Its design was based on the Script Concordance Test (SCT) format, which was developed to assess clinical problem solving in realistic situations of uncertainty. Inclusion of uncertainties in test situations threatens the methodological qualities of a test. Furthermore, the SCT format has never been validated for participants without clinical experience. The study focused on the question: *how can progress in the development of problem solving competence be established in a way which meets the criteria of validity (representing real-practice problems, situations and uncertainties), reliability (consistently representing student performances) and sensitivity (detecting changes in competence within the frame of a one-year course)?*

An SCT in veterinary medicine (SCT-VM) was developed, covering a large sample of authentic cases and uncertainties. The answer key was based on the professional judgements and decisions of a panel of experienced practitioners. The test was administered twice, at the beginning and at the end of the course. From the psychometric analysis of test results and responses from the expert panel, it was concluded that this SCT-VM met the standards of quality regarding the validity, reliability and sensitivity of the test. Furthermore, the results showed that the potential weaknesses of this test, related to the breadth of the domain to be covered and to the limited clinical experiences of the students, could be avoided.

Comparison of students' scores on the SCT-VM showed both at group and at individual level a significant improvement from the pre-course test results to the post-course test and the effect size was large.

Theoretical frame of reference in retrospect

The studies in this thesis drew upon a number of theories and theoretical principles. In this paragraph we reflect on the meaning of our main findings in the light of this theoretical frame of reference.

Authenticity

The notion of authenticity has been central in the design of the *clinical lessons* and studies in this thesis. Since the start of this research project, 'authenticity' has entered the educational discourse on higher education but its meaning to teaching and learning at this level still lacks clarity and coherence. Three distinct perspectives can be identified: the authenticity of learning situations and experiences,[8,9] authenticity related to (support of) student engagement and self-directedness,[10] and authenticity with regard to teacher behaviour and identity.[11]

The way in which authenticity has been conceptualised in this thesis fits particularly well with the first perspective. In essence, authenticity in this perspective touches the issue of the validity of learning situations and experiences: does practice with these particular problems and in this educational setting engage students in the same situations, processes and (cognitive) activities that make up the problems, issues and work setting encountered by professionals?

Whereas the argument of validity suggests aiming at the highest possible degree of authenticity, an absolute level of authenticity in an educational setting is not possible or necessary or even desirable.[12-15] This raises the question of which task features are essential in facilitating student activities and work processes that mirror real-life situations whilst avoiding hindrances to learning.[9,16,17]

In a review of the literature, Gulikers[17] identified five features ('dimensions') of assessment tasks that determine their level of authenticity: (1) the specific content of the task, (2) the physical context, (3) the social context, (4) the assessment form and (5) assessment criteria. She argued that for reasons of alignment between instruction and assessment, these dimensions are also applicable to authentic instruction.

Our findings partly match the dimensions that Gulikers identified. Our results confirmed that the instructional formats of the *clinical lessons* as a whole led to the intended engagement of students in the activities that make up ‘clinical problem solving’. More specifically, the analysis of irregular courses of discussion and the sources of inauthentic behaviour revealed which design features determine the level of fidelity of a problem solving task in particular:[18]

(a) the specific *content and representation* (type and extent of information) of the *case*,
(b) the *work procedures and the activities* students engage in,
(c) the *roles and responsibilities* of everyone involved in the task
(d) the *work setting* (facilities, pressure on time, organisational complexity, etc.)
(e) the nature and content of the projected *outcomes*.

Applied to (clinical) problem solving, the design features identified in our studies proved to be more specific and a better fit to the data than Gulikers’s dimensions of authenticity.

Just-in-time information

We applied the principle of just-in-time information to create an authentic flow of case information, while managing the cognitive load of the task. As regards just-in-time provision of information, cognitive load theory distinguishes between supportive and procedural information.[19] Theoretically, supportive information (theories, models and concepts) is best provided before task practice and procedural information during practice. This was confirmed by Kester,[20] but results across studies were not unambiguous. In complex problem tasks, the reverse format (procedural before and supportive information during practice) yielded similar results. A possible explanation may be that in these complex tasks procedural information is highly interactive with the problem solving process and requires cognitive capacity. In clinical problem solving, this seems feasible: procedural choices depend to a large extent on the hypotheses and findings during the patient assessment. Procedural fine-tuning itself is part of working towards the solution. Differently from Kester’s findings, in our study the students’ explicit search for procedural guidance from their teachers during task performance was low. The extent of the additional information concerning procedural issues which the teachers provided without being asked was low as well.

The theoretically suggested optimal timing reflects a traditional perspective on education: start with understanding and then practice. At a level of repeated practice in solving complex problems, the distinction between task-specific, procedural and supportive information appears not to be functional. Our data suggest that in complex problem solving tasks distinction in the timing of information should rather be based on information characteristics such as the problem demarcation, information ambiguity, information structure, etc. These features affect task complexity and cognitive requirements and can be fine-tuned by teachers providing certain information just in time (before and during task execution).

Scaffolding

At the time the *clinical lessons* were designed, teachers agreed to aim for a high level of active student engagement and self-directedness, scaffolded by themselves. In practice, for a number of teachers limiting interventions to the intended scaffolding level proved far more difficult than assumed. In general, discrepancies between teacher intentions, cognitions, concerns and their actual behaviour are not unusual, and these differences have been a focus of teacher research in the last decade.[21]
In the study on how teachers combine different roles, we found that the teachers' decisions to intervene were often influenced by concerns other than supporting the self-directedness of the students. The intentions the teachers brought to the fore in stimulated recall indicate that their concerns are about checking knowledge and understanding, increasing the speed of work, and correcting mistakes. In addition to this, teacher interventions were directed towards (subtle) adjustments of the case complexity to the students' level of performance.

Attaining the intended level and content of teacher interventions proved demanding. Their role in providing additional information created extra opportunities for teachers to influence the case discussion. Scaffolding, embedded in the provision of information, sometimes successfully raised case complexity and stimulated elaboration of theoretical understanding or a critical reflection on assumptions or interpretations. Nevertheless, when teachers exaggerated case dynamics or used similar incidents repeatedly to influence the case discussion, these interventions became predictable, artificial and less appreciated by the students. Overall, our results indicate a preference for the delayed and limited scaffolding interventions, and facilitation of reflection and (peer) feedback.

Carefully monitoring student responses to teacher interferences with the problem solving process is an important strategy teachers can use to fine-tune their scaffolding. In all cases in which students felt overwhelmed by or even helpless in the face of teacher interventions, there were notable signs of discomfort, insecurity or blocking. Given the delicate balance between effective fine-tuning case complexity to the students' level and (delayed and limited) scaffolding of student performance, sufficient attention should be given to appropriate preparation and means of support for teachers.

Competence development

Most researchers agree on the main changes that characterise the development of competence in clinical problem solving and the fundamental mechanisms underlying these changes. In particular, the processes of restructuring and extending the knowledge base, through one's own experiences with patients and clinical situations, appear to dominate development at the time of transition to clerkships and beyond. The rationale behind the *clinical lessons* was to provide sufficient opportunity to practise applying knowledge in reasoning about clinical problems and to create a realistic image about clinical practice and patients, and thereby contribute to elementary development of 'illness scripts'. In particular the four design features at course level were intended to support the development of competence:

- covering a *large variety* of *representative* situations and problems
- cases ordered in a *sequence of progressive* complexity, with gradual reduction of scaffolding
- work *formats complementary* with regard to the learning objectives
- longitudinal *monitoring of progress* and repeated assessment.

Of these, the progressive increase of complexity in combination with reduced scaffolding was not realised. Still, the executed programme was made up of a large number of cases, both paper-based and real patients, covering a wide variety of conditions that lie behind the problems and questions veterinarians with which commonly deal. Throughout the year students received feedback on their performances about eight to fourteen times, including feed-forward for application in subsequent cases.

The progress students made in their development of competence was established by means of multiple measures. Advancement in professional judgements and decision making in cases containing realistic uncertainties was established by means of the SCT-VM. Increasing scores in this test point to progress in script development. The observations during the year revealed several changes in the problem solving process, in particular with regard to students' approach to cases, their range of potentially relevant aspects, and their fluency and speed of work. Beside these changes, the students also expressed their perception of progress.

Compared with the changes Boshuizen and others[22] have described about competence development in the phase of transition into clinical practice and in relation to 'knowledge encapsulation' theory, our findings display similarities but also some differences:

- Similar to the changes described, were the gradually widening scope on relevant case aspects and an increase in the number of auxiliary lines of reasoning. The practicals showed similarities with respect to the difficulties the students encountered in concurrently communicating with the patient's owner, executing the assessment, reasoning about interpretation of findings or establishing the next procedural steps, etc.
- Our data did not confirm clear changes in the use of biomedical theories and concepts as described by Boshuizen. A feasible explanation might be that in this educational setting the students have been more influenced by their teachers insisting that the students provide justifications or explanations using detailed knowledge. An alternative explanation is that the students at this stage of their development, just before transition to clerkships, had not yet advanced enough to go through those changes.

Our findings suggest that the development process is non-linear; different components of this competence did not progress at the same speed. The marked change after four to six weeks in the students' ability to handle the standard work procedure indicates this non-linearity.

Instructional design

Instructional design (ID) theory was used to build the frame of reference that was needed to assess the design of the *clinical lessons*. We modelled learning phases and functions by linking processes relevant for competence development in solving clinical problems at three levels: reasoning, learning and development. This model not only provided a structure for the many issues that need to be addressed in course design; it was also valuable in linking different ID theories which each covered only part of an educational design, and for identification of potential weaknesses or conflicting components in the design.

The frame of reference itself can be viewed as an ID model which is generic for educational situations that are built on authentic work processes, at a level where students already have sufficient prior knowledge. It links the work processes to activities which are conducive for learning (e.g. reflection).

The contributions of our findings to ID theory lie in a further specification of design principles, in their empirical underpinning and in understanding how design features can interact. The diverse findings from our studies can be expressed in the format of a design principle, for example:

- To create valid practice in clinical problem solving [*effect*] it is important to incorporate a functional level of fidelity of the case content, work procedures, roles of everyone involved, available facilities and the kind of outcomes required [*feature*]. A high level of fidelity in these specific task features creates the realistic flow and content of information which, in turn, facilitates practice with the components that make up clinical problem solving: the gathering, interpreting and organising of information, making professional judgements and decisions [*mechanism*].
- To support students optimally in solving clinical problems with a level of complexity just beyond their capacities [*effect*], the teachers' aid should be limited to the minimum required and when students do not advance any more [*intervention*], because this stimulates students to elaborate on the issue at hand, use their prior knowledge maximally and check their understanding through application to a case and discussion with peers [*mechanism*].

The instructional design of the *clinical lessons* shares many characteristics with a combination of clinical learning and problem-based learning (PBL). Three differences between these instructional formats affect the dynamics of sessions:

- The *clinical lessons* take place in the last year of the preclinical phase. The level of their prior knowledge allowed students to benefit optimally from using high-fidelity, authentic learning situations. Even though cases are intended as examples and primarily provide an opportunity to practise, solving the case proved to be far more of a driving force, according to the students, than identifying the knowledge they still lacked and needed to acquire.
- As a consequence of the instructional format with just-in-time provision of additional case information, the role of the teacher in the tutorials of the *clinical lessons* is plainly more prominent than in PBL.[23,24] They can for example change or adjust details of the case during the process, thereby directly affecting the students' case exploration and discussion. Evaluative results confirmed that the students recognise their teachers' influence on the course of the case discussions and what they learned.[24]

- Whereas in PBL student collaboration is considered essential,[25] the simulated case explorations that are part of the tutorials of the *clinical lessons* emphasise an individual approach/process. Active involvement of peers is confined to the discussions in between phases of the simulated patient assessment. Particularly at the beginning of the course students need to be stimulated to participate actively.

Assessment

The SCT assessment format (**Chapter 5**) we used to establish the progress that students made in this course is grounded on theoretical notions about the nature of authentic clinical problems, illness script development and test validity and reliability. The SCT format was relatively new. Differently from previous studies, we applied the format in a broad domain (primary veterinary care) with participants at undergraduate level and repeated administration of the test on the same participants.

Our findings with regard to the domain to be represented and the repeated administration primarily have value for the methodology of the SCT. The use of this type of test at preclinical level, in which participants have hardly any clinical experience, is at odds with the assumption that the processes of illness script formation and encapsulation depend on the exposure to many and varied real patient problems.[26] Given the progress that the students made, however, as indicated by the results for the pre-course and post-course tests, it is likely that students' development of illness scripts benefited from the combination of paper-based and real cases in the *clinical lessons*.

A clear difference between the SCT test format and clinical performance in practice concerns the actual presence of the patient. Performing patient assessment in real practice also requires attention to aspects of patient handling, comfort and safety, as well as communication with the owner, concurrently with the problem solving process. A second difference affecting the validity of the SCT is that in practice the hypotheses concerning the patient's condition and causal mechanisms or enabling conditions are not given but generated by the clinician him/herself. Recognising these limitations of the SCT we still considered that the strengths of this format outweighed its limitations. The SCT covers a large number of cases, can be administered relatively easily to and processed uniformly with a large number of students without creating a heavy burden on real patients.

Reflections on the methodology used

The overall design of this research was drawn from design-based research methodology, using a mixed-methods approach to address the multidimensional character of complex educational designs and outcomes in practice. The emergent design of studies and the use of specifically developed instruments required decisions to be made beyond the level of standardised procedures and their safeguards of quality. In this paragraph we will reflect on such decisions, the underlying considerations and their consequences for the quality and limitations of the studies.

Design-based research methodology

The decision to use design-based research methodology followed our aim to enhance the understanding of the use of real-life, complex tasks, while taking into account the complexities of the multiple, interacting ingredients and layers of interactions that make up educational practice. In design-based research, knowledge claims are grounded on design features with feasible explanations or arguments about their effectiveness and causal mechanisms that are supported by empirical research results.

With regard to the *clinical lessons*, we first established that their design framework fitted an arrangement of learning phases and functions, consistent with theories about competence development in clinical problem solving and instructional design (**Chapter 2**). In four cycles, ingredients of the task (in a broad sense) were subsequently studied and optimised. This provided empirical evidence for the effectiveness of the design and an enhanced understanding of why or how particular design features worked, thereby contributing to educational theory.

The design-based methodology enabled us to link knowledge development to practical relevance and educational innovation. Even so, the generalisability of the empirical results is compromised as we conducted our studies in just one educational setting. For example, our findings about the students' adaptive responses to teacher scaffolding patterns may be influenced by the nature of student-teacher relationships in higher education in the Netherlands.

A second potential source of bias in design-based research relates to the Hawthorne effect. Students and teachers are part of an innovation and receive more attention than usual. Frequently, a significant discontinuity exists between outcomes from standard forms of education and those at the centre of innovation.[27] Given the high levels of correlations between results on the course evaluations in successive years, however, it seems unlikely that our findings represent a temporary effect of increased attention.

As in most design-based research studies, in the execution of this research there have been variables that may affect the success of the design and that could not be controlled. Furthermore, the large number of sessions that are part of this course required the involvement of many different teachers, whose efforts to execute the programme as designed relied on communication and coordination. Nevertheless, overall it proved feasible to use design-based research methodology to study the issues that were related to our research question.

Mixed method

To answer the questions of this thesis a mixture of qualitative and quantitative instruments was used. The empirical studies about the cases and support by the teachers were built on a within-stage mixed-method design,[28] with observations of their impact on the students' problem solving behaviour as the dominant method. The other instruments used were complementary, seeking elaboration, enhancement or confirmation of findings.

The SCT-VM was developed as an instrument to establish the progress students made with regard to the quality of their judgements and decisions in clinical cases. Its psychometric qualities were the subject of the study described in **Chapter 4**. Table 2 provides an overview of the various methods/instruments used.

Direct observations of the *clinical lessons* as part of the on-going coursework allowed us to collect data on naturally occurring behaviours during execution of the programme. Given the lack of studies about similar instructional designs, the character of data collection and analysis was at first exploratory with a focus on overt behaviour and verbal interaction, seeking qualitative variation. In due course the coding scheme was refined and reorganised, and the emphasis in analysis changed towards dialogical patterns, patterns in behaviour and role fulfilment, and cross-case comparison. The resulting coding scheme had an activity structure at two timescales, approximating Polman's[29] distinction between the shorter time scale (*behavioural categories*) and longer-term activity structures (*problem solving and supportive learning phases*) .

As qualitative research is open and flexible, maintaining standards of quality and rigour in qualitative research is a complex and labour-intensive matter.[30] To ensure the quality of our data, interpretations and inferences from the observations, various steps were included in the procedures we used:

Table 2. Overview of the data collection methods used and participants involved

Data collection method	Participant involvement	Specific research purpose
Document analysis and member check	Core teaching staff (n=12)	To clarify the key principles that underlie the educational design of the clinical lessons
Observations	Students (n= 21 groups) and teachers (n=33), who participated in clinical lessons	Analysis of the executed programme: the cases, instructional format and teacher role fulfilment, and their impact on the student problem solving, learning and development processes. The observations covered: clinical practicals (n=21), tutorials (n=117) and demonstrations (n=7)
	Expert practitioners (n=6)	Trial case discussions to validate the observational coding scheme
IRR assessment	Researchers and teachers (n=5)	To establish the reliability of the observational coding
Stimulated recall interview	Teachers (n=16)	To reveal the teachers' views about their interpretation of occurrences within the observed case discussions and the rationale for their interventions
Case (vignette) analysis	Teachers (n=21) and students (n=9)	Analysis of the tutorial cases with regard to the presence/absence of particular case features affecting the case complexity
Case level questionnaire	Students (n=1814)	Immediate evaluation of clinical tutorials and practicals to shed light on the students' appreciation of the instructional format, the case and the teacher performances
Script concordance test (SCT-VM)	- Students (n=168) and expert practitioners (n=28)	Establish starting level and progress made with regard to clinical judgements and decisions in realistic cases (pre- and post-test)
	- Students (n=6) and teachers (n=20)	Think-aloud analysis of the SCT case vignettes and related hypotheses, trial SCT-VM
Course level questionnaire	Students (n=123, 105, 113, 113)	Annual evaluation of students' opinions about quality, effectiveness and appreciation of various aspects of cases, teacher support and instructional formats

- *Purposive sampling*:[31] tutorials and practicals were preselected within the on-going coursework to cover a representative variety of cases (animals, conditions, clinical problems), student groups and teachers, as well as various moments throughout the year. All cases, student groups and teachers were observed at least twice.
- *Coding scheme*: checking for fit and the review of irregular cases were part of the on-going process of reorganisation in the development of the coding scheme.[32] To check the breadth of our scheme and interpretations about the categories, three additional clinical tutorials were conducted with a group of six experienced

practitioners acting as students. In neither the category of reasoning behaviours nor in the problem solving phases were new codes added.

- *Consistency of analysis*: although the appropriateness of the concept of inter-rater reliability in qualitative research had been contested,[33] we assessed the consistency of the analyses by involving other researchers in repeated coding and comparison across their analyses. Following Cicchetti's[34] guideline (> $2n^2$, n= number of categories) over 450 fragments were repeatedly coded, covering the categories at both time scales.
- *Triangulation*: the systematic use of multiple methods provided corroborating evidence.[32,35] For example, the stimulated recall interviews provided insights about the teachers' motives in scaffolding the students but also confirmed the interpretation of observed behaviours.

Whereas other studies commonly used cross-sectional comparison to establish the differences between students at different stages of development, in this research student groups were monitored longitudinally. This allowed us to study the dynamics of the developmental process in terms of sequential patterns and gradual change during the year.

Comparison of findings across subsequent cycles of design optimisation is the basis of design-based research. As the cycles of redesign were chosen to parallel the change of student cohorts, the effects of particular design changes had to be monitored against differences between student cohorts and their programme during their first three preclinical years. We used the actual presence or absence of a particular feature as a ground for comparison rather than the change of year.

Direct observation of the executed programme provided us with rich data not only about the task design features that were the primary object of a particular study but also about interactions between the various ingredients of the design. The abundance of (qualitative) data required rigorous data organisation, focus and bounding. Although all the verbal protocols were coded, the scope of the succeeding analysis was limited to student and teacher behaviours, interactions and effects from the perspective of role fulfilment. Within-subject analysis was then focused on the specific content of data subsets, to obtain more sensitive results. With regard to data organisation, qualitative analysis software (AtlasTI) provided invaluable help.

Although we did not seek detailed quantification of the qualitative data, the total number of observed tutorials and practicals allowed us to provide indications of quantity and a sense of proportion.[36]

Outcome measures

The *clinical lessons* have been developed to ease the transition from preclinical learning to workplace learning in a clinical setting. In view of this aim, the outcome measures to establish the effectiveness of the *clinical lessons* should preferably have been chosen in relation to this transition: for example, a reduced number of transition problems, a higher level of clinical competence from the beginning of the clerkships or a reduced dependence on guidance from the clinical teaching staff.
For a number of reasons we decided otherwise. For one, the time between the start of the clinical lessons (intervention) and the moment an increased employability or a reduced number of transitional problems (effects) could be established was relatively long. Moreover, the aim of our studies was not limited to disclosure of the programme's effectiveness but also concerned understanding of how particular design features contributed to the intended effects.

Replacing final outcomes with intermediate endpoints or predictors is justified, provided that a causal relationship between the intermediate and ultimate endpoints is feasible. In the studies in this thesis, outcome measures were used that point at intermediate endpoints or effects, which are supposed to be part of a causal sequence relating the independent variables to the final outcome:

- A higher starting level of competence in solving clinical problems, prior experience of applying (general) theoretical knowledge in (specific) practical situations, and an enhanced image of clinical problems are assumed to reduce the problems that students encounter in the phase of transition to clerkships (Chapter 2).
- The degree to which a student's judgements and decisions in clinical cases match the judgements and decisions of a group of experienced practitioners is assumed to indicate their level of problem solving competence (Chapter 5).
- Changes of process-bound performance characteristics (e.g. speed and fluency of work), the perceived level of competence, and also the number of correct solutions (clinical judgements and decision) are assumed to reflect progress in problem solving competence (Chapters 3, 4 and 6).

Focus on the development of competence in clinical reasoning and problem solving fits well in situations in which transition problems are dominated by a lack of experience in applying previously gained knowledge in practice.[22] For the intermediate endpoints that were used (performance process characteristics, problem solving performance, perceived learning, perceived level of competence, assessed problem solving competence), earlier studies established their place in the chain of causal influences. We established how the various instructional design ingredients (cases, teacher support, formats) were effective in enhancement of problem solving competence. The extent to which this has eased transition into clinical practice was beyond the possibilities of this research.

Recommendations for educational practice and future research

As these studies aimed to establish if and how particular design features and measures caused the intended effects in a natural educational setting, the main findings in this thesis contribute to our understanding of instructional designs and are expected to have practical value. In this section we will reflect on the practical implications of our findings and consider suggestions for further improvement of this kind of design and areas of related research.

Recommendations for instructional designs

The findings in this research underline the value of providing students earlier in their study with ample opportunity to practise with real patients and authentic cases. The effects cases actually have on student learning depend largely on their function in the learning process. In some designs authentic cases are used as a relevant context for knowledge acquisition and to clarify or emphasise the relevance of particular knowledge for practice. In this research cases were primarily used to offer students practice in solving realistic problems and applying theory in practical situations.

The first recommendation regarding instructional design concerns authenticity. In order to facilitate processes of reasoning and problem solving which closely resemble authentic clinical practice, it is recommended that researchers should strive for a level of functional fidelity. Limiting replication to those task characteristics that are functional for the intended information processing processes prevents learning disturbances resulting from inauthentic and irrelevant authentic ingredients.[14,15] In clinical problem solving, functional task characteristics are those that create the flow and content of information that match the information (processing) requirements of the problems to be solved.

Second, careful selection and preparation of the cases is required. Although most cases from practice can be used for educational purposes, high-quality cases represent the critical issues, judgements and decisions from practice, engage students in meaningful activities and suit the students nearing the next level of development. These are not intrinsic characteristics of clinical cases but require deliberate choices, for example about which information to provide and when. An analysis of case features, as we used in the study described in Chapter 4, can be useful to determine more precisely which features determine a particular case's complexity and its information requirements. This helps to decide which information should be provided beforehand in order to create an open case without depriving students of the cues they need for their preparation.

Third, the instructional format should link the work process (problem solving) to learning and development processes, to raise the effectiveness of learning from the cases and support transfer from an educational setting to (clinical) practice. Repeated moments of reflection and feedback, support with case preparation, explicitly building mental models, and comparing cases and solutions are means to raise the experiences to a level of deliberate practice. Explicitly allocating time for these activities proved to be effective against skipping reflection and feedback.

Fourth, it is recommended that students are given some support with their approach to and analysis of a case, particularly in the first weeks of a course. Without guidance, the first steps from the initial case information to decisions about which subjects and issues to study again, appeared to be rather difficult for the students. A guideline, based on a list of questions to be answered successively, proved to be a valuable resource before the students internalised elements of case approach and strategies to direct their own preparation.

Recommendations for teaching

Our findings disclosed that in the *clinical lessons*, as in most educational designs, teachers play a major role in facilitating learning. Nevertheless, whereas in other instructional settings teachers primarily provide access to or impart knowledge to their students, in this type of case-based learning the emphasis is on enabling and scaffolding processes of reasoning, discussion and reflection, stimulating in-depth, meaningful learning and monitoring development of competence. Effective role fulfilment requires proficiency with regard to case content, as well as understanding of the difficulties which students encounter in the problem solving and learning processes, and knowing effective means of supporting them (pedagogical content knowledge).

Specific to the designs and principles that we studied in this thesis the combination of just-in-time provision of required information, an appropriate level of scaffolding and feedback, and monitoring of students' level of performance is demanding. Competent teachers demonstrated being able to facilitate a problem solving process that closely resembles authentic practice, supplemented with an in-depth discussion about the relevant issues and a high level of active involvement of all students. Frequent and early teacher interventions, and also lack of attention given to reflection and constructive feedback, turned out to be a major source of disturbance to the quality of the case discussions and learning. The first recommendation about teaching, therefore, is to adopt the delayed scaffolding pattern as described in Chapter 3 and to practise with minimal alterations of the case information to adjust the level of case complexity to the students' capacities and needs.

Even though the ability to manage complex instructional designs effectively depends in part on the teacher's prior experiences and talents, thorough preparation can ease fulfilment of the combined teacher roles during the case discussions. Part of this preparation could take the form of teacher training on managing this kind of instructional design. Also, anticipating possible case scenarios and the complexities or dilemmas the students may encounter can help to prepare for the potential hindrances affecting student learning. Along the line of this second recommendation about preparation lies the third, that is, to take the opportunity periodically to share experiences, views and strategies with other teachers.

Efforts to share experiences and views are not only beneficial for individual teachers but also support achievement of a certain degree of consistency between teachers. The students repeatedly stated that differences between the teachers' approaches to cases and expectations about the students affected the case discussions and the students' motivation. Intermittent teacher meetings and continued optimisation of teacher materials contributed to a reduction of the perceived inconsistencies. Finally, the incorporation of major changes in clinical practice such as 'evidence based veterinary practice' requires long-term cultivation and consistency among teachers before they can become fully integrated in the content of a course.

Recommendations for curriculum design

Solving clinical problems is nowadays recognised as a key competence in providing (veterinary) medical care. It requires, almost concurrently, the gathering and selection of information needed, relation of findings and recognition of patterns, reasoning about problem aspects (testing hypotheses, weighing uncertainties, estimating probabilities) and making judgements and decisions. Expert performance relies on an extensive network of highly integrated knowledge from many different (sub)domains, organised in accordance with practice and prior experiences. Following their recognition as a key competence, curricula in medical and allied professions nowadays include courses or other elements concerning the way professional judgements and decisions are made about conditions, their impact on health or well-being and possible interventions.

Clinical problem solving may be one of the most demanding parts of clinical practice to learn, beyond mere application of (general) theoretical knowledge to a specific case. The development of this competence is a long-term process and requires continued support of knowledge integration at several levels, encounters with real patients and clinical situations, and practice with the components that make up the problem solving process. Obviously, clerkships contribute substantially to the development of competence and attainment of graduate level.

The *clinical lessons* demonstrated that this educational design and mixture of design principles can be effective. The results from our studies confirmed that experiences with realistic clinical settings and patients fuel the development of problem solving competence, knowledge structures which suit the way a case is presented in practice and an enhanced image of clinical problems. The first recommendation concerning curriculum design therefore consists of a number of closely related measures:

a. Incorporate clinical problem solving longitudinally in the curriculum, to suit the long-term nature of development of this competence.
b. Focus on facilitating reactivation, elaboration and integration of prior knowledge rather than on extending knowledge or covering new issues.
c. Create coherence in the approach to clinical problems, use complementary teaching formats emphasising other aspects of clinical problem solving and build in variation and progress in cases.

d. Arrange long-term monitoring of progress, with regular feedback and support for students' internalisation of criteria regarding the quality of their work and results.

Second, this type of instructional design may be applicable in another stage in the curriculum, but probably requires adaptations. Both the extent of the students' prior knowledge and the approaching clerkships appeared to have significant influences on the students' motivation and performance in this design. If the design is used in an earlier stage in the curriculum, the necessary adjustments may involve a reduction of the case complexity, extending the procedural support to case preparation and analysis, providing assistance with linking the case details to theoretical notions, case-specific modelling of causal influences and mechanisms and with generating and testing hypotheses about the case. Also, the opportunities in the practicals to experience and develop a realistic image about patients are probably even more important than during the last preclinical year.

Suggestions for design improvements and further research

Given the intricacies of conducting (design-based) research on a course as multifaceted as the *clinical lessons*, it is likely that we left out factors that affect students' learning environment and circumstances. Furthermore, along with finding answers to the central questions in this thesis, new issues and design improvements evolved.

First, the studies in this thesis were conducted as part of the *clinical lessons*. A longitudinal study of clerkships would be the obvious means to determine whether their effects last over a longer period of time. Taking this further, it may be worth extending the *clinical lessons*, in trimmed-down form, to the clinical phase. This would offer additional opportunities to share difficult cases and related transition problems, and extend 'deliberate practice' with linking specific problems and cases to general theories and current knowledge.

Second, in the study about just-in-time information provision we classified cases based on the presence of particular characteristics that influence case complexity. These characteristics were derived from the literature. Even though the classification served the purpose of differentiating between the various cases, this instrument could also be valuable for assessing sequences of cases and building on progress in case complexity. Further studies are needed to examine the validity and reliability of the instrument in relation to this particular application.

Third, for the most part, teacher interventions aimed at scaffolding the problem solving process took the form of (a series of) questions. Since clinical problems are frequently made up of a complex mixture of causal factors and enabling conditions, it seems sensible to make better use of explicit modelling. Developing a structured representation of the patient's condition and situational influences may support the students' understanding of the underlying processes and variables more effectively than the use of long lists and sequences of questions.[37,38] Embedding modelling practices into the instructional design, accompanied by research on the effects on students' problem solving strategies and epistemology, is warranted.

Fourth, since the beginning of the twenty-first century the importance of multiple problem solving strategies and the effectiveness of instructional designs reinforcing non-analytic reasoning has been repeatedly emphasised.[39-41] Although the design of the *clinical lessons* deliberately left room for other case approaches, based for example on recognition and comparison with similar cases, teachers did not significantly support any other than a hypothetico-deductive strategy. To advance the development of multiple strategies, research is needed into the didactics of scaffolding non-analytic strategies and the potential hindrances affecting students' support by teachers.

Finally, the test we developed to establish the progress students made with regard to their professional judgements and decisions was based on the script concordance test methodology. To date, the SCT format has been used for research purposes and formatively. Further research is required to solve some issues that relate to summative use of an SCT: how will participation in a test with ambiguities in the cases, questions and answers affect the students' behaviour as regards a summative test? how should be corrected for guessing if the SCT is intended to establish a grade rather than progress? Furthermore, how can this type of test be used optimally for pre-test sensitisation? What would be the effects of format modification regarding open questions about feasible hypotheses? The possibilities of an SCT for assessing judgements and decisions under uncertainty are considerable but further research and development are needed to reveal their full potential.

Final remarks

The assumption that students learn to reason like experts by engaging in problem solving tasks and having experienced teachers model their way of reasoning appears to be deeply rooted in educational practice. This assumption is at odds with the empirical research findings and current views about the development of expertise.[42-45] Not only the concept of one general problem solving strategy but also the advantages of teaching students exclusively to reason in an analytic manner have been challenged by research.[39,45,46] Perhaps the principal barrier to students being able to use similar lines of reasoning to the experts is that they cannot possess the knowledge organisation and richness that experts rely on. The accuracy of expert decisions and solutions depends not so much on strategy as on their mastery of the domain and familiarity with the particular problem.

Awareness that clinical problems require an extensive knowledge base while transfer across problems is low has fuelled the belief that students should first and foremost be exposed to a large number of cases.[39] Combined with the finding that students benefit from non-analytic approaches as much as from analytic strategies, the suggestion easily takes hold that learning to solve clinical problems is merely an issue of numerous cases. Our results do not support this view. Time-on-task matters, provided it is spent on the right activities, that is, activities valid with regard to the problem solving process as well as activities contributing to learning and development, such as making meaningful comparisons between cases, metacognitive regulation of the problem solving process and error analysis, reflection and feedback. By facilitating these activities and aiming high, teachers contribute substantially to students' clinical problem solving competence.

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Summary

This thesis focuses on the development of a programme in veterinary medicine, the '*Clinical Lessons*', which are intended to bridge the gap between theory and practice. The programme is based on the premise that many of the difficulties which students run into during the transition into clinical practice result from a lack of experience in applying knowledge in real practice situations. It is focused on the development of competence in solving clinical problems, employs an instructional model with alternating clinical practicals, tutorials and demonstrations, and extends throughout the last preclinical year, before students enter their clerkships (years 5 and 6). Following the design-based research methodology, the studies in this thesis aim to reveal when and how particular features of the educational design affect learning, by monitoring the effects of changes in the design or comparing differences in design characteristics.

Chapter 1 outlines the reasons that induced the development of the *clinical lessons*, the aims of this research, its specific focus and methodology, and the relevance of the results. Linking theory and practice is one of the main concerns in curricular design. In medical education, students may experience this especially in the transition from preclinical learning into the clerkships. Along with changes in daily activities, workload, roles and responsibilities, the complexities of clinical practice and uncertainties about their own level of competence are reported to be sources of considerable stress. According to theories about script development and knowledge encapsulation, in this transition phase processes of knowledge restructuring, integrating experiences and acquiring tacit, workplace-bound knowledge take place and affect performance and self-confidence. Previous studies already revealed that, in order to enhance the students' preparedness for practice, they should be offered sufficient exposure to real patients and authentic clinical cases during the preclinical phase. The *clinical lessons* aim at providing students with this opportunity. Following this, the main question in this thesis concerns an optimal design of the *clinical lessons*, with an emphasis on case characteristics, the support students receive from their teachers, the instructional format and adjustments to suit the students' development of competence.

Chapter 2 demarcates a frame of reference for analysis of the *clinical lessons*' design, and examines the extent to which the design is valid with regards to achieving its aims and objectives. The learning processes and functions that should be facilitated were identified, starting from the course objectives and existing insights about instructional design and the development of clinical problem solving competence. Together they made up the frame of reference for analysis of the actual design. Next, the key features of the *clinical lessons'* design were extracted from a content analysis of course documents and confirmed in a member check. Comparison of the clinical lessons' key features with the learning functions to be fulfilled, revealed that the programme design meets the conditions about functions. The design also facilitates processes at three levels: (problem solving) reasoning, learning and development. Furthermore, three potential weaknesses or uncertainties in the design were recognised: the quality of the cases (information, openness), effective teaching (student and teacher roles) and adjustment to the development of competence (progress, coherence).

Chapter 3 explores the impact of just-in-time provision of case information on teacher and student behaviour in the problem solving process. In order to provide students, at their request, with additional case information, teachers have to fulfil different roles: providing information, scaffolding and monitoring performance. Two opposite patterns were observed about the way teachers managed to combine roles. Some teachers scaffolded the problem solving process by providing immediate guidance or intervening in direct response to the students' choices and performance (concurrent scaffolding: CS). Others delayed such interventions until a time-out in between phases or at the end of the process, when the students reflected on their choices and findings and received feedback from their peers (delayed scaffolding: DS). For the students, the just-in-time provision of information enabled a flow of case information that resembles authentic practice. In general students adapted their case approach to the scaffolding pattern of their teacher. Analysis of the irregular case discussions and the results from the student questionnaire revealed that providing clarity on teacher roles and expectations, delayed scaffolding and that facilitation of reflection and feedback are conditional for student learning and motivation, whereas concurrent scaffolding is counterproductive.

Chapter 4 zooms in on optimisation of the case design, in particular with regard to the authenticity and complexity of a case. Optimal cases engage students in (cognitive) activities, problems and experiences that reflect professional practices, at a level that they can handle and improve upon. The required authenticity of a case can be at odds with its level of complexity. In order to meet both requirements, cognitive load theory suggests providing, beforehand, part of the information that is needed. Our study aimed to determine which information should be provided beforehand in clinical problem solving tasks. We classified cases according to their information attributes and compared the course of discussions and preparation time of cases with opposite characteristics. Overall, the cases engaged students in the reasoning activities that make up clinical problem solving, created similar cognitive challenges and encouraged a high level of time-on-task. Case information attributes with an increased level of complexity such as the use of diffuse, multifaceted problems or a lack of cues for analysis, did lead to changes in the students' approaches. In particular, the extent of the information provided beforehand affected the students' levels of preparation, case approach and reasoning. It is recommended to strive in case vignettes for high functional fidelity rather than authenticity.

Chapter 5 reports on the development of a script concordance test in veterinary medicine (SCT-VM) and assessment of its psychometric qualities. The test was developed to establish, independent from other influences, the extent of the progress students made in terms of improved judgements and decisions. The SCT format has been designed specifically to assess the ability to weigh information in the light of hypotheses, when reasoning on clinical problems in contexts of realistic uncertainty. Scores on an SCT are considered to reflect the level of advancement in 'illness script' development. The SCT-VM was made up of a large sample of realistic cases, judgements and decisions; the test was administered twice, pre- and post-course of the *clinical lessons*. The answer key was compiled with reference to the professional judgements and decisions of a panel of 28 experienced practitioners. From a substantive appraisal of the cases and items, analysis of the test results, and the responses from the experienced practitioners, it was concluded that this test validly represents the problems, decisions and uncertainties of clinical practice. In spite of the uncertainties included in the test, the reliability and validity of the test and its results could be evaluated and proved to meet measurement criteria.

Chapter 6 establishes the effectiveness of the *Clinical Lessons* design as a whole. The effectiveness was defined in terms of: a) changes in the students' approaches to clinical problems, which indicate progress in the development of problem solving competence, b) improvements in the quality of their solutions to clinical problems as shown in the results of the SCT-VM, and c) its effectiveness as perceived by the students with regard to making and justifying clinical judgements and decisions. We employed methodological triangulation of results from the student questionnaires, performance observations and assessment tests, all concerning the same cohort of students. On all three dimensions of effectiveness, the results were consistent, and confirmed that the programme design led to the projected growth of student competence in solving clinical problems. The strength of the results on the SCT-VM signifies that the progress the students made in this course was substantial.

Chapter 7 provides an overview of the main findings of the studies in this thesis, reflects on their meaning with regard to the theoretical frame of reference and the methodology used, and considers the implications and recommendations for further research and educational practice. As for the main findings, the programme design proved valid and feasible with regards to achieving its aims and objectives. Its effectiveness in practice was confirmed by a combination of: a) realistic cases and problems and b) student activities, valid with regard to clinical problem solving and conducive to learning, with c) a high level of time-on-task, leading to d) changes in performance during the year consistent with progress in competence, e) confirmed by the outcomes on an SCT test and f) perceived by the students as effective and beneficial. Recognising the limitations of our empirical results imposed by the chosen methodology, it is nonetheless argued that this educational design, the underlying model and principles can be successfully applied in other contexts. Besides the answers that were found to the research questions of this thesis, some issues remained unresolved and new questions came to the fore. Further studies which may be particularly valuable for (veterinary) medical educations include the pedagogy of scaffolding development of multiple problem solving strategies, incorporation of explicit modelling in case-based tutorials and practicals, and further instrumental development of a classification of case complexity and the SCT as an assessment method.

Samenvatting

Centraal in dit proefschrift staat het onderzoek naar het ontwerp van een programma in het curriculum diergeneeskunde, de *klinische lessen,* dat is gericht op het verbeteren van de overgang van theorie naar praktijk. Het programma is gebaseerd op de veronderstelling dat de moeilijkheden en stress die veel studenten ervaren wanneer zij hun eerste praktijkervaringen opdoen, deels voortkomen uit een inadequate kennisorganisatie en gebrek aan ervaring in het toepassen van kennis in reële praktijksituaties. Het programma is gericht op ontwikkeling van competentie in het oplossen van klinische problemen, heeft de vorm van klinische practica, werkgroepen en demonstraties, en omvat het gehele vierde jaar voorafgaand aan de coschappen (jaar 5 en 6). Uitgaande van een design-based research methodologie beogen de studies in dit proefschrift antwoord te geven op de vragen of, wanneer en hoe specifieke ontwerpkenmerken van de *klinische lessen* leren en competentie-ontwikkeling effectief faciliteren.

Hoofdstuk 1 schetst de aanleiding voor de inbedding van de *klinische lessen* in het curriculum, de redenen voor dit onderzoek, de specifieke focus en methodologische benadering, en de relevantie van nieuwe inzichten voor verdere theorievorming en de onderwijspraktijk.
De verhouding tussen theorie en praktijk is een van de essentiële kwesties in het ontwerpen van curricula. In medische en verwante opleidingen ervaren studenten een te overbruggen verschil met name in de transitie van het preklinisch onderwijs naar de coschappen. Naast de veranderingen in de dagelijkse activiteiten, de werkbelasting, nieuwe rollen en verantwoordelijkheden blijken het omgaan met complexe klinische problemen en onzekerheid over de eigen kennis of kunde bronnen van substantiële stress. Volgens de theorieën over de ontwikkeling van ‘ziektescripts’ en ‘kennis-encapsulatie’ vinden in de transitiefasen processen van integratie van nieuwe ervaringen en kennisreorganisatie plaats, die het functioneren en zelfvertrouwen tijdelijk ongunstig kunnen beïnvloeden. Uit eerdere studies komt naar voren dat, om de voorbereiding van studenten op de praktijk te verbeteren, zij reeds tijdens de preklinische fase eigen ervaringen moeten kunnen opdoen met authentieke klinische casus en echte patiënten. Met de *klinische lessen* wordt beoogd studenten daartoe ruimschoots gelegenheid te bieden. De hoofdvragen in dit proefschrift betreffen een optimaal ontwerp van de *klinische lessen,* met een nadruk op de kenmerken van optimale casus, een optimale begeleiding door docenten, de didactische vormgeving en eventuele aanpassingen die passen bij toename van competentie.

Hoofdstuk 2 bakent het referentiekader voor analyse van het ontwerp van de *klinische lessen* af en onderzoekt in hoeverre het uitgewerkte ontwerp valide is voor het bereiken van de gestelde doelen.
De leerprocessen en -functies die nodig zijn voor het bereiken van de leerdoelen werden bepaald op basis van bestaande inzichten op het terrein van ontwikkeling van competentie in het klinisch probleemoplossen en 'instructional design' (ID). Dit geheel van processen en functies vormde het referentiekader voor verdere analyse van het ontwerp. De voornaamste ontwerpkenmerken van de *klinische lessen* werden verkregen uit een inhoudsanalyse van de beschikbare documentatie en bevestigd via een 'member check'. Vergelijking van de ontwerpkenmerken met de benodigde processen en functies toonde aan dat het ontwerp aan deze voorwaarden voldeed. Het programmaontwerp faciliteert processen en functievervulling op drie niveaus: het (probleemoplossend) redeneren, het leren en de competentieontwikkeling. Daarnaast werden drie terreinen van potentiële zwakte of onzekerheden in het ontwerp geïdentificeerd: de kwaliteit van de casus (informatie, openheid), een optimale didactiek (rolvervulling studenten en docent) en de afstemming op ontwikkeling in competentie (progressie en coherentie in het programma).

Hoofdstuk 3 onderzoekt de effecten van just-in-time verstrekking van casusinformatie op het oplossingsproces door studenten en de begeleiding door docenten.
Het op verzoek geven van aanvullende casusinformatie aan studenten vergt van docenten de vervulling van drie rollen: informatieverstrekker, (proces)begeleider en beoordelaar. Bij observaties van de onderwijsuitvoering kwamen in de wijze waarop docenten die combinatie van rollen hanteerden, twee patronen naar voren. Een deel van de docenten intervenieerde in directe reactie op vragen of keuzen van studenten (concurrent scaffolding: CS). Anderen daarentegen stelden interventies uit tot aan het eind van een fase in het patiëntonderzoek of van de gehele bespreking, wanneer studenten reflecteerden en feedback kregen op het proces, keuzen en bevindingen (delayed scaffolding: DS). Voor de studenten leidde just-in-time informatie tot een gedoseerde stroom van aanvullende casusgegevens gelijkend op de praktijk. Zij bleken hun casusaanpak aan te passen aan de interventies van de docent, ongeacht welk patroon. Analyse van besprekingen met een afwijkend verloop en de resultaten van vragenlijst over afzonderlijke besprekingen lieten, niettemin, zien dat voor het leren en de motivatie van studenten, helderheid over de docentverwachtingen, 'delayed scaffolding' en het faciliteren van reflectie en feedback, voorwaardelijk zijn.

Hoofdstuk 4 onderzoekt optimalisatie van het casusontwerp, in het bijzonder ten aanzien van de authenticiteit en complexiteit van casus.
Optimale casus betrekken studenten in (mentale) activiteiten, problemen en ervaringen die karakteristiek zijn voor de professionele praktijk, op een voor hen passend niveau. Om een passend niveau van complexiteit zonder reductie van authenticiteit te realiseren suggereert de 'cognitive load' theorie o.a. de benodigde informatie deels vooraf te verstrekken. De studie in dit hoofdstuk beoogde te bepalen, in geval van klinische casus, welke informatie vooraf moet worden verstrekt. Daartoe werden eerst de casus geklasseerd aan de hand van hun informatiekenmerken. Vervolgens werden de casusbesprekingen en voorbereidingen onderling vergeleken bij casus met tegengestelde kenmerken. De gekozen vormgeving van de casus bleek geëigend om studenten te betrekken in de cognitieve uitdagingen en activiteiten die het klinisch probleemoplossen kenmerken, met een hoog percentage 'time-on-task'. Bevestigd werd tevens dat casus met informatiekenmerken op verschillende niveaus van complexiteit leidden to waarneembare verschillen in de bespreking en voorbereiding ervan. Met name het kenmerk 'omvang van de vooraf beschikbare informatie' bleek van invloed op de bespreking en voorbereiding door de studenten. Aanbevolen wordt bij de casusinformatie vooraf te streven naar voldoende omvangrijke informatie en een functioneel niveau van authenticiteit.

Hoofdstuk 5 schetst de ontwikkeling van een 'script concordance test' op het terrein van de diergeneeskunde (SCT-VM) en bepaling van zijn psychometrische kwaliteiten.
De SCT-VM werd ontwikkeld om, individueel en onafhankelijk van docentinterventies, te bepalen welke progressie studenten aan het eind van de *klinische lessen* hebben gemaakt in het oplossen van klinische problemen, in termen van correcte oordelen en conclusies. Het SCT-format is ontworpen om vast te stellen in hoeverre beschikbare informatie adequaat wordt gewogen in realistische situaties van onzekerheid. Scores op een SCT worden indicatief geacht voor de mate waarin ontwikkeling van 'ziektescripts' is gevorderd. De ontwikkelde SCT-VM omvat een groot aantal (120) casus, oordelen en beslissingen; de bijbehorende antwoordsleutel werd samengesteld aan de hand van de antwoorden van een panel van 28 ervaren practici. De test werd twee keer afgenomen (pre-/posttest). Op basis van een analyse van de testresultaten (items, inhoud) en de responses op de bijbehorende vragenlijst werd geconcludeerd dat de SCT-VM een valide representatie vormt van de problemen, onzekerheden en gevraagde beslissingen uit de eerstelijns praktijk. Ondanks de onzekerheden die deel

uitmaken van de casus en items bleek de betrouwbaarheid (generalisability) van de test en resultaten te kunnen worden vastgesteld en te voldoen aan kwaliteitscriteria.

Hoofdstuk 6 bepaalt de effectiviteit van het *klinische lessen* programma als geheel.
Als indicatoren voor de effectiviteit van het programma werden gesteld: a) een door de studenten gepercipieerde progressie in het maken en verantwoorden van klinische oordelen en keuzen, b) veranderingen in de probleemaanpak door studenten, passend bij toename van competentie, en c) kwalitatief betere oplossingen (oordelen, keuzen) bij klinische problemen, blijkend uit hogere scores op de SCT-VM. Om de gerealiseerde voortgang van studenten te bepalen werd methodische triangulatie gebruikt van de resultaten op de studentvragenlijsten, de geobserveerde casusbesprekingen en de SCT-VM, bij één cohort studenten. Op alle drie dimensies van effectiviteit bleken de resultaten consistent en werd bevestigd dat het programma heeft geleid tot de beoogde toename van competentie in het oplossen van klinische problemen. De resultaten duiden op een substantiële progressie hierin.

Hoofdstuk 7 plaatst de belangrijkste bevindingen uit de verschillende studies in samenhang, reflecteert op de betekenis daarvan in relatie tot het gebruikte theoretische referentiekader en de gehanteerde methodologie, en formuleert consequenties en aanbevelingen voor de onderwijspraktijk en vervolgonderzoek.
Als geheel bleek het programmaontwerp valide en haalbaar ten aanzien van de gestelde doelen. De effectiviteit in de praktijk werd bevestigd door de combinatie van: a) realistische casus en klinische problemen, b) betrokkenheid van studenten in de activiteiten die valide zijn voor het leren oplossen van klinische problemen, en c) een hoge mate van 'time-on-task', die leidden tot d) veranderingen in de probleemaanpak, die passen bij een toename in competentieniveau, e) bevestigd door de resultaten op een SCT en f) door de studenten ook ervaren als nuttig en effectief. Onder erkenning van de beperkingen die het gevolg zijn van de gekozen onderzoeksopzet, wordt niettemin beargumenteerd dat dit ontwerpmodel en de bijbehorende principes ook bruikbaar zijn in andere contexten. Ondanks de antwoorden op de onderzoeksvragen bleven andere kwesties onopgelost en kwamen nieuwe vragen naar voren. Voor (dier)geneeskundig onderwijs wordt het belang aangegeven van vervolgonderzoek naar het faciliteren van diversiteit in oplossingsstrategieën, effecten van het expliciet modelleren van oorzakelijke factoren op de kennisorganisatie, de verdere ontwikkeling van classificaties van casuscomplexiteit en de SCT als toetsinstrument.

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SPJR.

Curriculum Vitae

Related publications

Stefan Ramaekers (1958) was born and raised in Maastricht. After secondary school at the Henric van Veldeke College, he studied physiotherapy (Heerlen), worked at various places in medical rehabilitation and did his masters in Health Sciences education (Maastricht University). Since 1986, he has worked as a teacher, at undergraduate as well as postgraduate level, and became involved in educational innovation and curriculum design. His experiences as a teacher, in course development and the reform of curricula in health professions (EHC Lusaka, Zambia; RL Maastricht; HvA Amsterdam) prepared him for a change in role. In 1998, he became a teacher trainer and consultant on course and curriculum development in higher education at IVLOS (Utrecht). Since then, he has participated in a large number of projects, including the (re)design of degree and postgraduate programmes in Economics, Pharmacy and Veterinary medicine. In conjunction with his work as a consultant, he started in 2005 with his PhD research, which allowed him to further explore a few of his long-standing areas of interest: the use of authentic tasks, enhancing the development of competence in reasoning/decision making, alternative methods of assessment.

Journal articles

1. Ramaekers, SPJ, Pilot, A, van Keulen, J, van Beukelen, P, Kremer, WDJ (submitted). Authenticity and complexity of cases; making two conditions meet.
2. Ramaekers, SPJ, van Keulen, J, van Beukelen, P, Kremer, WDJ, Pilot, A (2011). The effectiveness of a programme design for the development of competence in solving clinical problems. *Medical Teacher, 23* (in press).
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1. Ramaekers, SPJ, van Keulen, H, Kremer, WDJ, Pilot, A, van Beukelen, P (2009). *Effective teaching in case-based education: the impact of teacher behaviours and interventions on students' reasoning strategies and learning*. AMEE 2009, August 29 – September 2, Málaga.
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2. Ramaekers, SPJ, van Beukelen, P, Kremer, WDJ, van Keulen, J, Pilot, A (2010). *A proof-of-concept study of an instructional design for development of competence in solving clinical problems*. ORD 2010, June 23-25, Enschede.
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