Diagnostic Reasoning Skills in Veterinary Students and Recent Veterinary Graduates

by

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ABSTRACT

DIAGNOSTIC REASONING SKILLS IN VETERINARY STUDENTS AND RECENT VETERINARY GRADUATES

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University of Guelph, 2019

Advisor:  
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Recent veterinary graduates enter clinical practice with a comprehensive knowledge base and skill set but still report low confidence in their clinical problem-solving abilities. To elucidate the reasons behind this low self-confidence we conducted a cross-sectional study into the self-confidence scores of two graduating cohorts of DVM students in two clinical competencies related to diagnostic reasoning, and a mixed methods investigation into how the problem-solving process changes for DVM students post-graduation. Findings showed that the self-confidence scores of students declined as they progressed through Years 1-3 of the DVM program, stabilized during their externship placements and final year, and improved six-months post-graduation. Interviews with DVM graduates identified content overload, a theory-practice gap, and a fear of making diagnostic errors as experiences contributing to this low confidence. Study findings highlight the need for further study on the impact of self-confidence on diagnostic skill development in veterinary students and recent graduates.
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DECLARATION OF WORK PERFORMED

Study Design

Study designs for Chapter 2 and 3 were developed by Tavleen Dhinsa and Dr. Tracey Chenier with input and insight from the academic advisory committee (Dr. Deep Khosa and Dr. Joanne Hewson). The overall study design and methodology was conceived and designed by Dr. Tracey Chenier.

Data Collection

Survey data used in a secondary data analysis for Chapter 2 was collected as part of the DVM phase surveys and summarized in a report provided by Dale Lackeyram and Jennifer Spencer from the Open Learning and Educational Support Department at the University of Guelph. All e-survey and interview data from Chapter 3 was collected by Tavleen Dhinsa. Jane Dawkins and Elizabeth Lowenger assisted in advertising the e-survey and interviews to DVM graduates through the Ontario Veterinary College’s (OVC) social media accounts.

Data Analysis

All survey data for Chapter 2, and survey and focus group data for Chapter 3, were analyzed by Tavleen Dhinsa. An introduction to SAS coding and programming, and the development of base code for data analysis, was provided by William Sears. This base coding, used in the analysis of survey data for Chapters 2 and 3, was further modified and developed by Tavleen Dhinsa.

All chapters in this thesis are formatted according to the Second Edition Vancouver Style Reference Guide.

The results of Chapter 2 were presented in oral format at the Teaching and Learning Innovations Conference, University of Guelph in May 2018. The results of Chapter 3 were presented in poster format at the Teaching and Learning Innovations Conference, University of Guelph in May 2019, and the OVC Graduate Research Symposium in June 2019.
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<th>Description</th>
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<tbody>
<tr>
<td>ALT</td>
<td>Adult Learning Theory</td>
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<tr>
<td>CVO</td>
<td>The College of Veterinarians of Ontario</td>
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<tr>
<td>CBL</td>
<td>Case Based Learning</td>
</tr>
<tr>
<td>DAMNIT</td>
<td>(Degenerative or Developmental, Anomalous or Autoimmune, Metabolic, Mechanical or Mental, Nutritional or Neoplastic, Inflammatory, Infectious, Ischemic, Immune-mediated, Iatrogenic or Idiopathic, Traumatic or Toxic) Mnemonic</td>
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<tr>
<td>DPT</td>
<td>Dual Process Theory</td>
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<tr>
<td>DVM</td>
<td>Doctor of Veterinary Medicine</td>
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<tr>
<td>HDR</td>
<td>Hypothetico Deductive Reasoning</td>
</tr>
<tr>
<td>KT</td>
<td>Knowledge Translation</td>
</tr>
<tr>
<td>MAH</td>
<td>Merck Animal Health</td>
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<tr>
<td>OVC</td>
<td>Ontario Veterinary College</td>
</tr>
<tr>
<td>POVMR</td>
<td>Problem Oriented Veterinary Medical Record</td>
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<tr>
<td>PBL</td>
<td>Problem Based Learning</td>
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<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<tr>
<td>SDOT</td>
<td>Standardized Direct Observation Tool</td>
</tr>
<tr>
<td>SOAP</td>
<td>Subjective Objective Assessment Plan</td>
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<td>VIN</td>
<td>Veterinary Information Network</td>
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CHAPTER ONE

INTRODUCTION, LITERATURE REVIEW AND OBJECTIVES OF THE STUDY

Introduction

Diagnostic reasoning is a cognitive reasoning process used by clinicians in veterinary medicine and is a prominent component of their training. Effective diagnostic reasoning in clinical practice is a critical component of a clinician’s skills and is paramount to effective patient care. For veterinary students, development of diagnostic and clinical reasoning skills occurs through a variety of pedagogical and clinical settings, spanning lectures and laboratories, external work placements and clinical rotations. In particular, exposure to patients in the teaching hospital or private practice setting provides veterinary students with a rich and authentic experience, with the aim of a successful transition into clinical practice.

Previous literature, such as studies conducted by Farnsworth et al. 2008 (Texas A&M University) and Gilling et al. 2009 (Massey University) on the diagnostic reasoning experiences of veterinary students and graduates, reported that students generally felt that their programs provided them with “a good, strong framework in clinical decision making skills” and that they overall had feelings of “confidence in diagnostic reasoning abilities”. However, little information exists on the relationship between veterinary students’ perceived self-confidence and their actual diagnostic ability, and whether their level of confidence impacts their clinical performance following graduation. As well, little is known regarding changes in student self-confidence and performance scores in diagnostic reasoning as they progress through the veterinary program, or as intended learning outcomes increase in complexity.

Diagnostic reasoning in a clinical veterinary context reflects a constantly evolving thought process that must be flexible and adaptable to complex situations where typical patterns are not discernible. A strong knowledge base, established using ongoing evidence and past experiences from previous cases, forms the basis of a successful diagnostic reasoning process. In order to appropriately teach and assess diagnostic reasoning strategies, it is important to understand how students learn to reason in the clinical environment.
**Diagnostic Reasoning**

Rendon and colleagues (2015) defined diagnostic reasoning as “the cognitive process of using prior knowledge and information to address a clinical problem and reach an appropriate diagnosis”. The underlying pathway and basic requirement of successful diagnostic reasoning is for the individual to be able to clearly comprehend and explain the relationship between the presenting signs and the underlying disorder. The process by which the veterinarian interprets presenting information, stores previous effective or ineffective diagnostic reasoning experiences, and carries out the problem-solving process, can vary extensively and is influenced by the way information is organized as well as by contextual factors. Reliance on specific methodologies to conduct diagnostic reasoning also varies, depending on the individual's previous clinical experience and current mastery over content. For instance, individuals with extensive clinical experience predominantly rely on non-analytic reasoning methods, like pattern recognition, to address commonly presented problems, and will only revert to analytic reasoning if faced with a problem for which there is an unrecognizable pattern. Analytic reasoning, by comparison, is an extensive process that requires ample knowledge, greater pattern recognition, and an overall increased level of cognitive processing. It is utilized when the individual is faced with obstacles such as a complicated patient presentation or an unknown disease. Recent veterinary graduates, who have a wealth of factual knowledge but limited clinical experience to aid in their clinical processing, predominantly rely on non-analytic reasoning, with emphasis on pattern recognition. Pattern recognition, known as categorization or automatic retrieval, is a problem-solving approach used in commonly presented cases. Pattern recognition is heavily influenced by how information and knowledge is organized within the classroom and curriculum, and whether the student has repeated exposure to the same case or presenting signs. However, much like how no two students view and comprehend content the same way, no two veterinarians approach diagnostic reasoning and clinical problem-solving in the same manner. Veterinary students, in structured settings such as lectures and laboratories, are given the opportunity to develop their knowledge construct and mastery over content using common cases and examples. However, difficulty may arise when graduates enter clinical practice and are faced with an unknown or unknown disease.
unfamiliar case, for which pattern recognition is not adequate to reach a diagnostic outcome. In such instances, it becomes evident that students may not have developed their analytical reasoning skills to their fullest extent. One can speculate that this may be due to the large quantity of information taught during their degree, and the student’s focus on memorizing content for examinations instead of engaging in deeper or longer-term learning.\textsuperscript{11,12} Such surface learning in turn impacts their ability to activate and apply that knowledge in practice, and when faced with unknown or difficult cases, they may lack the confidence to move forward through a complex diagnostic process.\textsuperscript{5}

In order to build long term diagnostic reasoning skills, it is important for students to attempt to shift away from a heavy reliance on non-analytic reasoning (characterized by rapid pattern recognition and heavily dependent on clinical experience) and instead focus on analytic reasoning.\textsuperscript{9} This shift is not a complete separation from non-analytical reasoning, as many experienced clinicians will still use it in practice. Rather, it is a way to develop long term knowledge structures that provide veterinary students with the necessary tools and guidance when faced with a difficult or unfamiliar problem.\textsuperscript{6} Experienced clinicians often use a selective approach that utilizes components and the general framework of pattern recognition, but rely less on non-analytic reasoning as the primary diagnostic strategy.\textsuperscript{14} This method instead utilizes data collected from the initial diagnosis as a guide to direct and inform future clinical data collection.\textsuperscript{13} The more experience a clinician has, the more quickly they can utilize non-analytic reasoning and its components to successfully determine the relationship between presenting signs and the underlying cause. Often it is ideal to employ both non-analytical and analytical reasoning, however heavy reliance on pattern-based reasoning can be a hindrance and limit the clinician's personal knowledge acquisition and learning experience from each case. Additionally, this type of rapid intuitive-based reasoning can lead to errors regardless of the clinician’s expertise or mastery over the content, because pattern recognition is greatly affected by both situational factors and existing gaps and biases in the clinician’s reasoning process.\textsuperscript{10} As they progress through the program, veterinary students should ideally be encouraged to shift from primarily relying on pattern recognition to instead utilizing an analytical approach driven by greater cognitive processing and use of existing knowledge. This coincides with the
progressive development of their knowledge base throughout the veterinary program, allowing students to activate this knowledge and align it with clinical experience and analytical reasoning.

Before understanding the underlying processes of diagnostic reasoning, it is important to know the language and methods facilitating and guiding this process. Components that serve as a loose framework and facilitate the process of diagnostic reasoning include: pattern recognition, context formulation, acquisition and interpretation of data, hypothesis generation, differential diagnosis generation, diagnostic verification and test interpretation. These components form a stepwise process, and are often adapted by clinicians at varying levels of expertise to suit their needs. While generalized diagnostic and clinical reasoning strategies can be taught, every student has their own unique knowledge base and diagnostic reasoning experiences that impact how they learn to reason. The organization of these knowledge and information structures determines the quantity, quality, and ease of information extraction experienced by the student, and can be separated into components known as Semantic Qualifiers and Illness Scripts. It should be noted, however, that this is only one explanation of the mental process underlying medical problem-solving and has not been verified in other studies in veterinary pedagogy.

Semantic Qualifiers
Banda (2009) defines semantic qualifiers as “descriptors that are paired and used to compare and contrast clinical features, signs, diseases, and clinical phenomenon”. Veterinary students are subconsciously building their knowledge structures and memory banks of semantic qualifiers through their coursework and clinical exposure in labs and rotations. How this information, and the associated semantic qualifiers, are stored and retrieved determines how students fare when presented with a difficult or unknown problem. An indicator of a student with strong clinical reasoning skills is their ability to, when presented with a new case, separate presenting signs into descriptors, and utilize them to retrieve the necessary semantic qualifiers from memory. This successful retrieval of illness scripts will then serve to verify the student’s organization of existing knowledge structures, and strengthen their pattern recognition skills. Rapid pattern recognition is indicative of the student’s ability to understand and separate presenting features into semantic qualifiers that are specific to the problem.
Illness Scripts

Script theory suggests that experienced clinicians organize their vast medical knowledge into connected groups, or networks, called “illness scripts”. Bowen et al (2017) and Custers (2015) describe illness scripts as detailed knowledge structures, built over time through extensive clinical experience, that are used by clinicians as mental cue cards to represent specific diseases and diagnostic outcomes. Whereas semantic qualifiers are descriptors that can be paired and interchanged to describe a number of clinical conditions, illness scripts have a predictable and defined structure composed of three components: predisposing conditions/factors, pathophysiological insult/injury, and the clinical consequence of that particular diagnosis. Students begin to mentally store descriptors commonly associated with clinical signs, diseases, and conditions as illness scripts, through repeated exposure to common cases. Exposure to case-based material allows students to build their network, knowledge structures, and semantic qualifier bank, and when presented with difficult or unknown cases, be able to rapidly retrieve information and confidently carry out the process of diagnostic reasoning. For veterinary students, their comfort and ability in being able to separate and turn patient problems and features into semantic qualifiers and illness scripts greatly determines how strong their problem representation skills are. If they are unable to ascertain what information is important and relevant, from what is not, they will face difficulty with diagnostic reasoning. The purpose behind becoming skilled and comfortable in problem representation is that it allows the student to confidently and correctly process and separate relevant and pertinent information, and triggers clinical memory, aiding in the retrieval of associated illness scripts for diagnostic reasoning.

The relationship between semantic qualifiers and illness scripts provides insight into the unique and internal diagnostic reasoning process that is utilized by clinicians. Rapid and successful problem representation may, or may not be tied to diagnostic accuracy, however, research suggests that when the diagnostic process is mediated by semantic qualifiers and illness scripts, it is associated with greater diagnostic success. This should be of interest to veterinary educators hoping to assist students in
taking advantage of this method of knowledge organization and retrieval, especially when they are inundated with clinical information and data.

The use of semantic qualifiers and illness scripts is a useful strategy for efficient diagnostic reasoning, however it may not be prudent to place singular focus on using them independently or in the place of other strategies. While all students are given the same curriculum and content, educators can emphasize utilizing semantic qualifiers and illness scripts to guide students in building their own unique knowledge structures. This is because no two diagnostic experiences are the same, and no two clinicians, even with similar banks of semantic qualifiers and illness scripts, will approach a problem the same way. Explaining a process to a student, that often occurs subconsciously and internally without defined and explicit steps, is difficult. Experienced clinicians can generally expand on their overall thinking and thought process when approaching a new case, however the accuracy and ability to replicate this description is difficult to verify, validate, and generalize to the experiences of other clinicians. Diagnostic reasoning theories attempt to describe a subconscious process that is incredibly diverse and greatly driven by experience and knowledge organization.

**Prominent Theories in Diagnostic Reasoning**

When presented with a clinical problem, the veterinary student selects a diagnostic reasoning strategy on the basis of the perceived difficulty of the case, their own personal knowledge and grasp of the content, recognition of patterns in order to retrieve the necessary illness scripts, and prior diagnostic reasoning strategies they may have used successfully. Knowledge of the mechanisms by which students organize and retrieve information, distinguish descriptors and illness scripts, and rationalize their clinical reasoning process, can provide information on a subconscious and highly variable process. Theories and strategies of importance include Dual Process Theory, Hypothetico-Deductive Reasoning (HDR), and Adult Learning Theory (ALT).

It is important to know the rationale behind these theories, as they can serve to provide an explanation about the process of diagnostic reasoning. Theories commonly used to describe the various diagnostic reasoning strategies focus on the internal knowledge process and methods used and are not
explicit steps to clinical problem-solving. These theories attempt to explain how clinicians undergo the clinical problem-solving process and explain the role prior experiences and anecdotal evidence play in problem representation and knowledge retrieval. While this process is largely governed by evidence-based medicine, it also requires clinicians to regularly update their diagnostic outcome with imperfect and anecdotal information, often taken from testimonials or accounts like those given by pet owners.

Within a pedagogical context, knowing the various diagnostic reasoning theories can greatly assist veterinary educators in understanding how students rationalize and contextualize problems, and how they, as educators, can present veterinary medical information so that its acquisition, storage, retrieval, and application within a clinical context is as clear and definitive as possible.

**Dual Process Theory and Hypothetico-Deductive Reasoning**

Dual Process Theory (DPT) is the predominant approach to diagnostic reasoning and clinical problem-solving. According to the DPT, the organization, retrieval, and utilization of information is divided into two systems or processes that dictate reasoning: system-one is characterized as non-analytical and intuitive, and system-two is analytical and systematic. Information organization, storage, and retrieval in system-one processing often occurs very rapidly and heavily relies on the individual’s experience. System-one processing directs diagnostic reasoning to adopt a heavy dependence on inductive and logical forward reasoning. Inductive reasoning, within a diagnostic context, follows a stepwise process starting with problem presentation and ending with a diagnostic outcome. There is major overlap between how diagnostic reasoning occurs within non-analytic reasoning and that described in the DPT. Similar to the process undertaken in non-analytic reasoning, the information contained in system-one, together with the clinician’s experience, dictate how well the presenting problem is interpreted. As such, this level of intuitive and rapid processing is typically used by individuals with extensive experience and mastery over the content in question. Croskerry (2009) describes system-one analysis as being characterized by a short decision-making process, and like decision theory, being based on imperfect, anecdotal information and the clinician’s intuition. What this translates to, specifically in clinical practice, is a process that is affected by context, easily influenced by external factors and distractions, and
more frequently prone to error marked by “jumping to conclusions”. However, because system-one reasoning requires extensive clinical experience, its use by veterinary students may be minimal.

System-two reasoning takes an analytical and systematic approach, and is primarily used under ideal conditions where the clinical environment has a greater availability of resources, minimal uncertainty, and the diagnostic decision making process is cautious and rational. For students this ideal, structured environment can include exposure to designated clinical time and cases presented within a laboratory and lecture setting. This is an optimal setting to introduce and teach the methodological process necessary for diagnostic reasoning. While the clinical environment following graduation is less structured and controlled, ideally students’ learning in a classroom or laboratory setting should ease the translation of diagnostic reasoning into clinical practice. Diagnostic reasoning using this approach is highly characteristic of experienced veterinarians and is a gradual and logical thought process refined over time. In fact, system-two process underlies the framework for hypothetico-deductive reasoning. To clarify, hypothetico-deductive reasoning is a component of system-two processing and is not independent of the Dual Process Theory. System-two processing places an emphasis on hypothesis testing and inductive reasoning that is rooted in a focused, and rationale process. The deliberate nature of system-two processing can develop into a rapid and intuitive system-one response over time, as the student is able to build their own knowledge structures and network of semantic qualifiers and illness scripts.

Hypothetico-deductive reasoning (HDR) is commonly used by experienced clinicians and diagnosticians and is applied when solving cases that are unfamiliar or difficult. Hypothetico-deductive reasoning is applied in the absence of organized knowledge structures and descriptors such as illness scripts. This diagnostic strategy focuses on generating multiple hypotheses to allow the clinician, depending on their analysis of presenting features and factors, to include or exclude one or two diagnoses as a secondary strategy to their primary diagnosis. This process occurs bi-directionally as clinicians are constantly generating and testing hypotheses. Encouraging students to utilize the HDR approach provides practice in hypothesis generation and testing, especially during their initial experiences with independent clinical reasoning. Continuous or improper use of HDR may actually hinder the further development and
mastery of these skills.\textsuperscript{5,10} For example, in the human medical setting, Caulford et al (1994) assessed the competence of practicing physicians in Ontario, and revealed that failing to perform analytic confirmation following the testing of each hypothesis often resulted in premature case resolution and diagnostic errors.\textsuperscript{22} Similarly, Bergus et al (1995) investigated the sources of disparity during the clinical reasoning process for two groups of family physicians, and found that novice physicians were more prone to diagnostic errors when they oversimplified their interpretation of the diagnostic problem to be in line with only a single hypothesis, instead of actively testing and confirming all possible hypotheses.\textsuperscript{23}

\textit{Adult Learning Theory}

The final diagnostic reasoning theory of importance in this review is the “Adult Learning Theory” (ALT). Students enter their veterinary program as adults, and the curriculum should therefore reflect the needs of adult learners. The “Adult Learning Theory”, first proposed by Malcolm Knowles in 1980, states that the “repetitive, explicit, and realistic” exposure to authentic cases can be the best way to foster high powered learning and knowledge transfer from theory to practice.\textsuperscript{24} This theory adopts a case-based and problem-based learning approach to enhance the student’s memory of clinical medicine and clinical reasoning. The “Adult Learning Theory” proposes that a student’s clinical reasoning skills are enhanced when they are exposed to cases that properly reflect the aspects of diagnostic reasoning within an uncontrolled clinical setting.\textsuperscript{7,24} Additional factors that enhance long term knowledge retention following analysis of the presenting case or problem include: highlighting errors in the student’s analysis of presenting information, comprehension of content, accuracy in diagnostic outcome, and overall process of clinical reasoning.\textsuperscript{7} Providing immediate feedback and discussion following errors in clinical reasoning allows the student to continuously correct and build their knowledge base and illness scripts, and increases their pattern recognition capabilities. The ALT adopts a learner-centered approach that encourages mutual inquiry and collaboration amongst students and educators and ongoing self-assessment of one’s performance knowledge base.\textsuperscript{24} The effects of this approach on the student’s confidence in their diagnostic reasoning skills remain to be seen. Although this approach does impact the student’s overall learning experience and future clinical success, it also has the potential to be demoralizing, depending on
how the feedback is delivered. Using a case-based learning (CBL) approach that reflects the true nature of clinical practice is desired, wherein cases accurately reflect occurrences in real practice. The inclusion of false leads, extraneous information and other situational factors in practice cases can improve knowledge retention and organization, and improve the overall learning experience of veterinary students. Case-based exposure provides students with a strong awareness of cognitive errors and potentially, points of weakness in their clinical reasoning. Long term knowledge and skill acquisition is most effective when students are presented with situations that require application of the taught skill and knowledge. While these are not the only modes of teaching that can increase the development of diagnostic reasoning skills in students, they are the most commonly referenced pedagogical tools in the literature, especially for medical and veterinary medical education.

Steps in Diagnostic Reasoning
Bowen (2006) separates diagnostic reasoning into six major steps that are influenced by knowledge, context, and experience. The six relatively sequential steps include: (1) Exposure to a patient’s history and initial case presentation, (2) Data acquisition, (3) Accurate “problem representation”, (4) Hypothesis generation, (5) Selection and retrieval of illness scripts, and (6) Selection of the diagnosis or diagnostic outcome. This process typically occurs in a stepwise fashion, however, it is possible to move directly from “data acquisition” (step two) to “selection and retrieval of illness scripts” (step five). This jump in processing can be explained by examining the veterinarian’s overall clinical experience and quality of illness scripts. Veterinarians with extensive knowledge structures composed of diverse illness scripts will more quickly employ pattern recognition, be able to separate semantic qualifiers from data acquired, and connect them to the associated illness scripts. Step one of this process, known as the initial case presentation, occurs prior to the physical examination and verification of the patient's history. The owner provides the presenting complaint and information for the clinician to, at a later step, separate into defining clinical signs and semantic qualifiers that will guide the selection and retrieval of necessary illness scripts. Patient presentation is followed by data acquisition, or the retrieval of information, which includes important components of the patient's history, findings from the physical examination, and
results of laboratory testing. Once the clinician has sorted through their case descriptors (taken from presenting signs, history, owner account) and predominant findings, the selected semantic qualifiers and illness scripts are shortened into a one sentence summary that defines the specific case in abstract terms—the problem representation. Experienced clinicians often unconsciously carry out accurate problem representation. Students lacking clinical experience and extensive knowledge structures will encounter difficulty with problem representation, resulting in additional inquiry, physical examination, and the generation of multiple hypotheses. Novice clinicians carry out this process of hypothesis testing by gathering additional information and accepting or rejecting diagnostic considerations in a deliberate and analytic manner. Expert clinicians rely on nonanalytic reasoning to narrow their hypothesis list by rapidly recognizing any patterns in the presenting signs and selecting illness scripts that align with a diagnostic outcome. Finally, once the clinician has selected and retrieved the necessary illness scripts, developed their initial problem list and list of differential diagnoses, and proven or disproven proposed hypotheses, they will, ideally, arrive at a diagnostic outcome.

Diagnostic Reasoning in Medical Education and Practice

Diagnostic reasoning and clinical problem-solving within medical pedagogy is considered a foundational basic science, and regarded as a critical aspect of medical training. Development of diagnostic reasoning skills is a core requirement to the successful practice of medicine, and has implications on diagnostic accuracy and patient safety. Despite being a fundamental skill required to successfully transition and work in clinical practice, it has not always been explicitly taught within a pedagogical context. The assumption, until recently, has been that students will develop these skills through acquiring a large body of knowledge and through observing experienced clinicians. However, the success of such approaches has been difficult to assess and verify. Rather, focus has shifted within medical pedagogy to assisting students in developing their own clinical reasoning skills and building their knowledge structures through clinical practice and observation, instead of solely relying on memorizing content. Studies investigating diagnostic reasoning within the medical field highlight how problem-based learning (PBL) and case-based learning (CBL) methods, in conjunction with a traditional curriculum
format, have shown to be potentially useful tools to assist medical students in formally developing their clinical reasoning skills.\textsuperscript{19,26,27} Adopting a CBL or PBL approach is designed to increase the student’s development of problem-solving skills over time and through extensive application.\textsuperscript{13,28} Both methods offer benefits in their own right, and at a higher level have a similar overarching approach to clinical reasoning. One difference between CBL and PBL lies in the level of importance placed on acquiring new knowledge versus utilizing previous knowledge structures. Problem-based learning, delivered to students in small groups, begins with a presenting problem and requires students to engage in independent learning. Students must seek out the required problem-specific knowledge to be able to generate and test hypotheses, and attempt to reach a diagnostic outcome. Despite PBL being an exercise based in group work, this self-directed learning also appears to assist in knowledge retention and interpersonal skill development.\textsuperscript{13} By comparison, CBL utilizes an instructor-guided approach through suggested readings and lectures, and is often a small, supplemental component added to a traditional curriculum.\textsuperscript{28} This approach includes cases presented in lectures that the class can then work through with the guidance of the instructor. Goss et al (2012) studied the effectiveness of a traditional versus PBL curriculum on diagnostic skill development in medical students, and found that when compared to a solely PBL curriculum, a traditional curriculum appeared to favor and support the students diagnostic skill development.\textsuperscript{29} Problem Based Learning in conjunction with a traditional curriculum, may be a promising way for educators to support diagnostic skill development in veterinary students however, it’s standalone use, in comparison to a traditional curriculum, may not be optimal for skill development.\textsuperscript{29} There are potential limitations to these learning styles, such as whether students lacking extensive knowledge structures can readily engage in clinical problem-solving, especially when faced with unfamiliar or difficult cases. PBL utilizes a low student-to-faculty ratio, increasing time and resources, which may limit its successful implementation. An additional concern is that students may possess extensive knowledge on specific topics covered within PBL modules, or specific case examples used by clinical educators, but less knowledge in other topics not covered in class, unless they independently seek that knowledge.\textsuperscript{30}
Ideally, it has been suggested that both PBL and CBL methods should be incorporated into traditional teaching approaches, for maximal effectiveness.\textsuperscript{13,28}

**Diagnostic Reasoning and Knowledge Translation**

The Canadian Institutes of Health Research (CIHR) defines knowledge translation as the “dynamic and iterative process that includes the synthesis, dissemination, exchange and ethically-sound application of knowledge”.\textsuperscript{31} Knowledge translation (KT) plays a major role in the student’s success both in their training program and in clinical practice. According to Toews (2011), the translation process within a medical and veterinary context is facilitated by the exchange, synthesis, dissemination, and application of knowledge.\textsuperscript{32} Student confidence and success in comprehending, storing, and retrieving knowledge and content is impacted by how well the presenting information can be translated and applied from a curriculum-based setting to a clinical setting. Students that lack a strong knowledge base, or possess an inefficient reasoning process, often struggle with their early practice experience.\textsuperscript{13} Poor organization of information within the classroom, and a lack of real-life learning opportunities, may contribute to ineffective transfer of diagnostic skills from a curriculum setting to a clinical/practice setting.\textsuperscript{5,8} New graduates face additional obstacles when they experience client expectations of providing high quality patient care, often in the presence of strict time constraints and daily practice routines. In the early stages of their career, they are also continuing to develop their clinical skills and diagnostic reasoning abilities, eventually progressing towards independence in a clinical setting.\textsuperscript{8}

A gap in knowledge translation from the classroom to clinical practice may be addressed at the curricular level. According to Rendon et al. (2015), in order for confidence in clinical problem-solving and diagnostic reasoning skills to improve, students must engage in deliberate and repetitive practice, seek feedback on their diagnostic accuracy, and regularly reflect upon, assess, and then modify their diagnostic reasoning process accordingly.\textsuperscript{9} Even so, the responsibility of supporting and maintaining both diagnostic skill development and effective knowledge translation must be equally shared between students and veterinary educators. Additionally, veterinary educators can support this translation by encouraging students to constantly engage in critical thinking and self-reflection, read additional scientific
literature not limited to those covered in lecture notes and class readings, and seek out additional independent experiences. At the curriculum level, this translation may be supported through the provision of relevant and well-structured case scenarios for students. Finally, in order to determine future knowledge translation deliverables, it may be useful for veterinary educators to utilize feedback from recent veterinary graduates on the specific knowledge translation tools that greatly aided their success in diagnostic reasoning and in clinical practice.

Clinical Pedagogy
Clinical educators are tasked with simultaneously fostering high quality patient care and assessing the clinical skills of students in order to facilitate their progress towards independence following graduation.\(^8\) Unfortunately, when knowledge is organized according to how it is structured in a curriculum, this may limit it’s translation into a clinical setting.\(^5,8\) For students, organizing information according to its explicit deliverance in the program (i.e. courses) may not be an effective way to promote the development of reasoning skills. If students do not integrate and directly apply their knowledge across various subjects, they may develop a theory-practice gap, which can impede their ability to translate classroom knowledge into clinical practice.\(^33,34,35\) Integration is especially necessary for the successful adoption of case-based and problem-based learning approaches and as a way to encourage students to think as clinicians starting from the time they enter into the program through to entry into practice.\(^35,36\) Integration of knowledge is particularly useful when using case-based learning approaches, as a way to foster clinical skill development.\(^37\) Fernandez et al (2018) assessed student perceptions following a CBL approach, and found that while most veterinary students indicated that this approach improved their ability to apply course material and grasp important concepts, there was concern that this approach may not be suitable for all students.\(^37\) This is because CBL approaches require complex problem-solving, which may place an excessive cognitive load on students that possess weak knowledge bases and lack self-regulation.\(^37,38\) By contrast, Creevy et al (2018) assessed the clinical skill performance in veterinary students that were delivered material either as an online learning module (that integrated content across courses) or via traditional discipline-based lecture, and found that there was no difference in performance
between students in the two groups. This suggested that the online module was as effective in delivering course content as a traditional lecture.\textsuperscript{39} It is apparent that, despite the advantages of integrating knowledge across disciplines, there is still debate surrounding whether a discipline based, or integrated curriculum is the best way to deliver content heavy curricula.\textsuperscript{35} As such, in order to assess students’ diagnostic reasoning and clinical problem-solving strategies, veterinary educators must first understand how students organize their knowledge and learn to reason in their clinical environment.\textsuperscript{8} The fundamental principles of theories like “Adult Learning Theory” may serve as guides to how clinical reasoning can be best taught to increase knowledge acquisition and translation.\textsuperscript{7} In order to facilitate the development of the extensive knowledge structures clinicians rely on, it is important to determine which pedagogical strategies help students to integrate their clinical skills, reasoning skills, and knowledge early in their education.\textsuperscript{18}

Clinical educators have typically focused on analytical models of clinical reasoning that assess how well a student is able to analyze the relationship between presenting signs and reach an appropriate diagnosis or diagnostic outcome for further inquiry.\textsuperscript{6,40} However, this strategy is insufficient to assist students in developing their clinical reasoning skills. The adoption of an additive approach to reasoning composed of multiple diagnostic reasoning strategies and aids that explicitly describe the potential relationship between signs and subsequent diagnoses, such as the Problem-Oriented Veterinary Medical Record (POVMR), Hypothetico Deductive Reasoning, Subjective-Objective-Assessment-Plan Records (SOAP), or DAMN-IT (Degenerative or Developmental, Anomalous or Autoimmune, Metabolic, Mechanical or Mental, Nutritional or Neoplastic, Inflammatory, Infectious, Ischemic, Immune-mediated, Iatrogenic or Idiopathic, Traumatic or Toxic) mnemonic, appears to be advantageous.\textsuperscript{41} This is a not a novel finding, as it has been proven that students best learn when they are provided with real life examples that require the explicit application of the diagnostic methods being taught. While existing research on tools necessary to facilitate diagnostic skill development is fragmented and inconclusive, there is some evidence to suggest that methods that emphasize both analytical and non-analytical reasoning (i.e., Hypothetico Deductive Reasoning) may be an advantageous approach to diagnostic
reasoning.\textsuperscript{13,42,44} Ark and colleagues (2006) found that a group of students that reasoned through the presenting case or problem using both analytical and non-analytical processing had diagnostic accuracy that was as good as, if not better than, the group using just non-analytical reasoning.\textsuperscript{45}

From both a pedagogical and clinical standpoint, there is much that veterinary educators can do to foster the student’s skill development and acquisition, retention and retrieval of knowledge. Fostering an environment that is conducive to building formal knowledge structures, like semantic qualifiers and illness scripts, through extensive experience with patients, in turn facilitates the process of pattern recognition and over time builds the student’s clinical expertise.\textsuperscript{19} According to Norman (2006) and in line with inclusive pedagogy, clinical educators should encourage learners at all levels to use their experience to guide their diagnostic reasoning and clinical problem-solving.\textsuperscript{21} Kassirer (2010) suggested that medical students even in their first year of training would benefit from exposure to case-based learning, provided the example cases were appropriate to their level of knowledge.\textsuperscript{7} Additionally, it is important to emphasize that clinical expertise can be strengthened by practicing the direct application of knowledge instead of simply memorizing content. By simply encouraging and guiding students to utilize both analytical knowledge structures and experiential knowledge in their diagnostic reasoning and clinical problem-solving process, veterinary educators can create an environment that is conducive to diverse, individualistic, but rigorous diagnostic reasoning.\textsuperscript{45}

Educators should also be aware that, despite pedagogical alterations, no two students will have the same diagnostic experience or experience the process of navigating diagnostic reasoning in the same linear fashion. This diversity in experiences can be beneficial and not a hindering factor, provided that the student has been given a strong clinical and diagnostic framework. There are a number of steps that clinical educators can take so that the students build a strong clinical and diagnostic framework. This includes encouraging students to compare and contrast potential diagnoses based on presenting information and the probability of each diagnostic outcome; providing students with feedback on diagnostic errors; assisting in the separation of meaningful case information from irrelevant clinical features; and placing emphasis on the conceptualization of information instead of memorization.\textsuperscript{8}
Aiding the Transition from Veterinary School to Clinical Practice

There is little information on potential changes in clinical experience, diagnostic reasoning skills, and confidence of veterinary graduates in the early stages of their transition into clinical practice. The transition period from veterinary student to clinician, and the subsequent first year in clinical practice, is marked by a large shift in the volume and scope of responsibilities towards patients and clients, and is often accompanied by a time-constrained environment. A lack of real life experience has been shown to hinder the transition from student to veterinarian, and increases the difficulty of achieving successful performance in the initial year of clinical practice. Research and anecdotal evidence has indicated that a difficult transitory period from veterinary student to practitioner can alter the professional course and success of the clinician, and impact whether clinicians leave their profession. Therefore, re-creation of this clinical environment and the conditions of clinical practice within an academic setting greatly enhances the students’ development of knowledge structures and diagnostic reasoning. Student perceptions on their preparedness, and their self-confidence, can greatly impact the transition. Gilling et al (2009) examined how well graduates felt the Massey University DVM program prepared them for practice. That study revealed that a pivotal factor impacting a smooth transition from student to practitioner was how prepared the graduates felt for the dramatic increase in responsibilities towards the patient and client. Graduates that felt unprepared for the breadth of responsibilities and demands in practice recalled experiencing a difficult transition period. By contrast, a study by Routly et al (2002) on the support needs of veterinary surgeons revealed that 38% of recent graduates who had a positive experience during the transition period chose to continue professional development through additional courses and certification.

Despite compelling evidence of the impact of this transition period, there is an absence of research on how veterinary educators can support the student’s clinical skill development, foster self-confidence and resilience, and prepare students for clinical practice. Furthermore, even as there has been a growing demand for veterinary graduates to possess “day one competencies” such as diagnostic reasoning, clinical problem-solving and judgement, there is little evidence as to how these skills are
developed in the veterinary context and how veterinary educators can guide students in their development.5

Curriculum Design and Gaps in Diagnostic Reasoning in Veterinary Education and Practice

Curriculum design plays a major role in how veterinary students understand, acquire and develop their diagnostic reasoning and clinical problem-solving skills. For example, diagnostic reasoning is generally embedded into the veterinary curriculum at most veterinary schools rather than explicitly taught as a skill, which can limit its acquisition and development.5,47 Walsh et al (2001) identified three necessary components of a successful veterinary curriculum: (1) attributes that students should have acquired by the time of graduation must be explicitly defined, (2) a thorough internal assessment process is needed in order to ensure students are meeting the expectations of the faculty/program/school, and (3) an external outcomes assessment mechanism must be in place to ensure that the goals of the veterinary degree program are appropriate and being met.40 These recommendations are useful from a pedagogical standpoint as they provide veterinary educators and those involved in curriculum design with the necessary steps to produce successful veterinary graduates, however they offer little insight into how students acquire the attributes (e.g., diagnostic reasoning, clinical problem-solving, self-confidence, communication skills) set out by the DVM program.

Diagnostic reasoning has been extensively covered in medical research and pedagogy, however, there has been little focus on how diagnostic reasoning skills are acquired in veterinary medical education.40 Veterinary educators cannot assume that clinical exposure through labs and rotations will result in a simple transfer of knowledge, or that the students will develop reasoning skills simply by acquisition of knowledge and facts.13 Transference of diagnostic reasoning methods taught in veterinary school into clinical practice upon graduation has not been previously studied, and there is little research to identify which methodology, strategy, and curriculum-based modification works best for students. This highlights the need for increased attention devoted to veterinary medical education, to determine the best approach to ensure veterinary students learn strong clinical reasoning skills and to ease their transition and success in clinical practice.40

Providing students with the necessary support to prepare for and
navigate this significant change – from student to clinician-in-charge, will hopefully influence their independence and demonstration of their knowledge and skills in clinical practice.\textsuperscript{13}

\textbf{Conclusion}

Recently, faculty at the Ontario Veterinary College (OVC) have observed that some students may be experiencing declining self-confidence as they progress through the DVM program and appear to lack adequate experience and abilities in problem-solving, pattern recognition, and reasoning skills. While these observations were anecdotal in nature, they are none the less concerning as competency in these skills is necessary for both clinical success and client care. To assess whether students are meeting the DVM program’s learning outcomes and meeting competency requirements, the OVC has been conducting regular internal assessments on student self-confidence and performance scores in core clinical competencies. However, a thorough analysis of reported scores and their implications for students and educators at the OVC has not yet been performed.\textsuperscript{29} Unfortunately, because these assessments do not extend once the graduate has spent more than six months in practice, they fail to capture any long term changes in self-confidence, competency, and skill development that may have occurred once graduates have had time to adjust to the demands and breadth of responsibilities in practice. As such, this research strived to expand on the experiences and perceptions of recent veterinary graduates, in order to address both these gaps in knowledge and the concerns highlighted by OVC faculty.

Through two independent research studies, the research in this thesis sought to address the absence of literature on the diagnostic reasoning skills of recent veterinary graduates, assess the relationship between self-confidence and diagnostic skill development in DVM students at the OVC, and utilize student feedback to evaluate how their DVM programs prepared graduates for clinical reasoning in practice.

The objective of study one in this thesis was to use student, externship host, and employer survey data to assess the self-confidence and performance scores of two cohorts of veterinary graduates from the OVC in diagnostic reasoning, problem-solving, and clinical judgement, and explore whether these scores changed as the students progressed through the DVM program and entered clinical practice.
Utilizing a mixed methodology, study two in this thesis sought to explore recent veterinary graduates’ perceptions and experiences in how they approach clinical problem-solving; investigated how the process of clinical problem-solving changed over time as veterinary graduates gained more experience in clinical practice; and assessed how recent graduates felt the approaches to diagnostic reasoning taught during their DVM program prepared them for clinical practice. Specifically, the work described in this thesis aimed to answer the following research questions:

1. How do recent veterinary graduates of the Ontario Veterinary College approach the diagnostic reasoning process?
   - What do they find difficult? Why?
   - What diagnostic reasoning methods do they know and use in their clinical reasoning and problem-solving process?
   - Have they altered their approach to diagnostic reasoning since graduating?

2. What do recent DVM graduates remember about how diagnostic reasoning was taught and were they able to effectively apply this to clinical practice following graduation?

3. What resources do they use in conducting clinical practice, and how often?

Finally, this literature review serves to provide the reader with the necessary information to understand the role and impact of diagnostic reasoning within a clinical and pedagogical context.

Knowing how to properly select and utilize clinical problem-solving strategies, processes, and theories is valuable for veterinary students, even if the process itself is highly diverse and unique from one student to the next. Comfort with diagnostic reasoning processes can provide students with the confidence needed as they transition into clinical practice. While the landscape of literature on diagnostic reasoning within a veterinary context is sparse, there is some strong evidence on the theories, steps, and strategies in human medicine and higher education in general that indicate success in application and long-term benefits for students. There is a clear need to extend this pedagogy into the veterinary context, through the further study of diagnostic reasoning of veterinary graduates, and the adoption of teaching strategies which ensure that future graduates have the necessary skill set and confidence to succeed in clinical practice.
References


CHAPTER TWO

EVALUATION OF DVM STUDENTS' SELF-CONFIDENCE IN DIAGNOSTIC REASONING, PROBLEM-SOLVING, AND CLINICAL JUDGEMENT SKILLS AT THE ONTARIO VETERINARY COLLEGE.

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Abstract

Veterinary students at the Ontario Veterinary College (OVC) consistently report low self-confidence scores in their diagnostic reasoning, problem-solving, and clinical judgement skills as they progress through the Doctor of Veterinary Medicine (DVM) program. This low self-confidence impacts how graduates adjust to the increased responsibilities common to clinical practice. Ensuring students graduate with mastery over these skills, and defining how to assess proficiency in them, is a challenge for veterinary educators and students alike. Surveys of the 2017 and 2018 graduating cohorts of veterinary students were conducted to assess students’ self-confidence and perceived proficiency in diagnostic reasoning skills as they progressed through each of the four years of the DVM program. Additional surveys assessing student performance in the same skills were collected from externship hosts following an eight-week work placement, and from employers following graduation. Findings revealed that the self-confidence scores of veterinary students declined as they progressed through Years 1-3 of the DVM program, stabilized during their externship placements and fourth year, and improved six-months post-graduation. Across both cohorts, students rated their diagnostic reasoning, problem-solving, and clinical judgement abilities lower than their skills as rated by their externship hosts and employers. While externship hosts provided higher performance scores, they ranked overall performance and perceived proficiency in these skills lowest out of the sixteen core competencies assessed. We suspect that the decline in self-confidence scores may be attributable to students having difficulties meeting the increasingly complex and difficult learning outcomes for each year, indicating a direction for further research.

Key words: diagnostic reasoning, self-confidence, veterinary education, pedagogy
**Introduction**

Diagnostic reasoning, problem-solving, and clinical judgement are essential skills required in veterinary medicine and play key roles in the majority of daily activities performed by practicing veterinarians.\(^1\) They are driven by the cognitive processes of using prior knowledge and information to address a clinical problem, reach an appropriate diagnosis and develop a treatment plan.\(^2\) The translation of these skills into clinical practice is not only of importance for veterinary graduates, but also for veterinary educators and healthcare providers serving in a myriad of academic roles.

Veterinary students at the OVC acquire experience with competencies such as diagnostic reasoning, problem-solving, and clinical judgement primarily through time spent in lectures, laboratories and clinical rotations. Despite being provided with a blend of clinical exposure through classrooms and clinics, research indicates that veterinary students from varying DVM programs report a low level of confidence in these competencies.\(^1,5\) Additionally, despite the emphasis placed on acquiring and utilizing these essential skills, there is little research on how the skills are developed in veterinary training and in particular, a lack of information on how veterinary programs can guide students in their development.\(^1\)

In a clinical setting, problems working through a clinical case may arise when veterinary students and recent graduates are faced with atypical and challenging case presentations to which straightforward reasoning or pattern recognition is not applicable.\(^2\) Faculty at the OVC recognize that while senior students possess an extensive knowledge base, they may be lacking confidence in their ability to problem solve, recognize patterns, and perform effective diagnostic reasoning. For veterinary students and recent graduates, their first exposure to an unstructured clinical environment is unlike that of a classroom or laboratory setting. Previous studies, such as those conducted by Farnsworth et al. (2008) (Texas A&M University) and Gilling (2009) (Massey University) on the diagnostic reasoning experiences of veterinary students and DVM graduates, reported that students generally felt that their programs provided them with “a good, strong framework in clinical decision making skills” and that they overall had feelings of “confidence in diagnostic reasoning abilities”.\(^6,7\) However, over the last ten years, there has been little follow up study on the self-confidence of veterinary students and recent graduates in core competencies.
including diagnostic reasoning, problem solving, and clinical judgement. There is a lack of information on the relationship between the diagnostic ability of veterinary students and their perceived self-confidence, and how their self-confidence may impact their clinical experience once they enter the workforce. In order to appropriately assess a recent graduate’s diagnostic reasoning strategies, it is important to understand how graduates learn to reason in the clinical environment. Seeking student feedback on this learning is paramount to analyzing and addressing the apparent low level of self-confidence and performance scores in core clinical competencies, and may serve to guide future pedagogical modifications.

The professional DVM program at the OVC is composed of a mixture of traditional classroom instruction, laboratory exposure, clinical externships, and independent fourth year clinical rotations. The program is divided into four years, each with detailed learning outcomes and goals that increase in complexity as the student progresses through the program. For clinical competencies like diagnostic reasoning, problem-solving, and clinical judgement, students develop their skills and increase their confidence through various opportunities in the classroom and clinic. Ultimately, once they reach graduation, students should be able to identify and analyze clinical problems and compose a plan of action based on existing best evidence. Recent research suggests that senior veterinary students may lack adequate experience, confidence, and abilities in problem-solving, pattern recognition, and reasoning skills. Existing evidence in veterinary research on the role of personal resources (e.g., self-efficacy, self-confidence, reflective behavior) in the development of clinical competency provide some insight into the diagnostic skill development of veterinary students, however these studies may not be capturing recent changes in veterinary pedagogy and medicine.

To assess where competencies such as diagnostic reasoning, problem-solving, and clinical judgement are taught in the DVM curriculum, and how well courses within each year are meeting learning outcomes, the OVC conducts yearly surveys to collect student self-confidence and performance scores. The objectives of this study were to utilize student, externship host, and employer survey data to assess the self-confidence and performance scores in diagnostic reasoning, problem-solving, and clinical
judgement, of two cohorts of veterinary graduates from the OVC, and to explore whether these scores changed as the students progressed through the DVM program and entered clinical practice.

**Materials and Methods**

**Ethical Consent**

This study was reviewed and approved by the University of Guelph’s Research Ethics Board (approval #11JL026).

**Study Design**

A cross sectional study of the 2017 and 2018 graduating cohorts of DVM students at the Ontario Veterinary College was conducted from surveys of student self-confidence scores in two core clinical competencies related to diagnostic reasoning (Diagnostic Ability, and Problem-Solving and Clinical Judgement). Surveys were distributed to veterinary students at the completion of each year of study within their program, through the Qualtrics® online survey tool. Additional surveys were conducted following completion of the third-year externship, and again post-graduation following 6 months of employment in clinical practice. These supplementary surveys assessed student self-confidence in specific outcomes related to diagnostic testing, history taking, problem-solving, and clinical judgement. Surveys were also collected from externship hosts at the end of the student's eight-week work placement at the beginning of their final year of study, and from graduates’ employers after 6-months of employment in clinical practice. Student, graduate, externship host, and employer survey data collection occurred between the years 2013-2018 (i.e. upon completion of each of the four years of the program, the externship and at six months post-graduation for each of the two class cohorts) with the purpose of collecting and analyzing student perceptions and self-confidence scores in the DVM competency framework and its associated year-specific learning outcomes (Table 2, Table 3). These evaluations utilized the Universal Assessment Rubric (UAR) and measured student performance and confidence in 16 core competencies. Our study focused on two competencies: 1. Diagnostic Ability; and 2. Problem-Solving and Clinical Judgement.
Survey Data
Surveys administered to DVM students, externship hosts, DVM graduates, and employers consisted of questions using either a 4-point, 5-point, or a 7-point Likert-type scale with the option to provide responses to open-ended text entry and demographic questions (Figure 1). Despite the potential “survey fatigue” associated with questionnaires using extended Likert-type scales, survey data using a 7-point Likert-type scale was not dichotomized and collapsed to fit a 4 or 5-point Likert-type scale, in order to avoid the loss of both information during statistical analyses and reliable estimates.14,15

Data Analysis
Survey data was organized and analyzed using SAS® 9.4.16 Participants were included in the study sample if they provided informed consent upon entering the DVM program and had completed the surveys. Incomplete surveys were excluded from the study sample and data analysis. Mean self-confidence scores in specific learning outcomes and clinical competencies were calculated for each of the two graduating cohorts for Year 1-3 surveys. Descriptive statistics that included cohort specific mean scores and standard deviations were used to describe the data.

Data from the third year externship, Year 4, and DVM graduate and employer surveys were analyzed using a two-sample location test (Z-test) for equal means to determine statistical differences between the mean self-confidence scores from the 2017 and 2018 graduating cohorts. Statistical associations were considered significant if the p-value was < 0.05.

Results

Year 1-3 Surveys
Year 1 surveys were completed by 179 students (Table 1). Assessment of student self-confidence and diagnostic reasoning abilities in the Year-1 survey focused on two outcomes (Table 2). Students described themselves as “confident” (2017) and “somewhat confident” (2018) in their ability to evaluate diagnostic tests based on test performance (Outcome 1). Students felt “fairly confident” (2017) and “confident” (2018) in their ability to conduct professional conversations with clients and colleagues (Outcome 2).
Year 2 surveys were completed by 169 students (Table 1). Year-2 surveys assessed the self-confidence and diagnostic reasoning abilities of veterinary students in four learning outcomes (Table 2). For Outcome 1, students described themselves as “confident” (2017) and “somewhat confident” (2018) in their ability to critically evaluate information to select appropriate diagnostic tests and treatments. For Outcome 2, students felt “somewhat confident” (2017) and “fairly confident” (2018) in their ability to use problem-solving processes to interpret information from diagnostic tests and procedures. For Outcome 3, students described themselves as “slightly confident” (2017) and “somewhat confident” (2018) in conducting dermatological and neurological examinations and radiological tests. Finally, students felt “confident” (2017) and “fairly confident” (2018) in their ability to develop a problem list and medical record for common domestic animals.

Year 3 surveys were completed by 174 students (Table 1). Year-3 surveys assessed the self-confidence of veterinary students in three learning outcomes (Table 2). For Outcome 1, students felt “slightly confident” (2017) and “somewhat confident” (2018) in their ability to select appropriate diagnostic tests, treatment options, and prevention strategies. For Outcome 2, students felt “slightly confident” (2017) and “somewhat confident” (2018) in conducting appropriate diagnostic tests, interpreting the findings, and using these findings to develop a list of diagnostic hypotheses. For Outcome 3, students described themselves as “slightly confident” (2017) and “somewhat confident” (2018) in conducting appropriate diagnostic tests and interpreting their results to develop a treatment plan.

The mean overall self-confidence scores for perceived preparedness to enter the next phase of study in the program of both cohorts declined as they progressed through years 1 to 3 of the DVM program (Table 3). Students from the 2017 cohort experienced a significant decline from Year 1 to Year 2 (p<0.001) and from Year 2 to Year 3 (p<0.0001). Students from the 2018 cohort similarly experienced a significant decline from Year 1 to Year 2 (p<0.0001) and from Year 2 to Year 3 (p<0.0001).

Third Year Externship Surveys

Externship surveys were completed by 116 students from each cohort (Table 1). Of the 16 program core competencies assessed by the externship survey, students ranked Diagnostic Ability at 14th
(2017) and 12th (2018) in terms of most to least confident, which corresponded to a self-confidence rating of “slightly confident” (Table 4). Students ranked their self-confidence in the Problem-Solving and Clinical Judgement competency 12th (2017) and 10th (2018) out of the 16 competencies and provided a rating of “fairly confident” (Table 4). There was a significant difference between the self-confidence scores provided by each cohort for both the Diagnostic Ability (p=0.04) and Problem-Solving and Clinical Judgement (p=0.01) competency. Across both cohorts, students ranked (out of the 16 competencies) their diagnostic reasoning, problem-solving, and clinical judgement abilities lower than their abilities as rated by their externship (Table 4).

Across both cohorts, 110 externship hosts from each year rated the Diagnostic Ability as “fairly confident” and ranked this competency at 14th (2017), and 11th out of 16 (2018). Externship hosts rated the Problem-Solving and Clinical Judgement skills of both cohorts as “fairly confident” and ranked this competency at 12th (2017) and 15th (2018) of the 16 competencies assessed (Table 5).

Year 4 Surveys

Year 4 surveys were completed by 105 students (Table 1) and assessed student self-confidence and perceptions on proficiency in the two competencies evaluated by this study: Diagnostic Reasoning, and Problem-Solving and Clinical Judgement (Table 6). Students across both cohorts felt “slightly confident” in their Diagnostic Reasoning ability, and between “slightly confident” and “fairly confident” for Problem-Solving and Clinical Judgement (Table 6). There was no difference (p > 0.05) between the mean self-confidence scores in each learning outcome between the two cohorts. Based on the formal assessment rubric, faculty assessments following Year 4 rotations indicated that 91% of students from the 2017 cohort, and 92% of students from the 2018 cohort met or exceeded graduating expectations across all rotations where diagnostic reasoning ability was assessed. Similarly, 91% of students from the 2017 cohort, and 95% of students from the 2018 cohort met or exceeded graduating expectations across all rotations where problem-solving and clinical judgement were assessed.
Graduate and Employer Feedback Post-Graduation

Graduate and employer feedback surveys assessed the graduate’s self-confidence and perceptions of proficiency in two competencies: Diagnostic Ability, and Problem-Solving and Clinical Judgement. Graduate feedback surveys were completed by 70 students (Table 1). Graduates across both cohorts rated their Diagnostic Ability, and Problem-Solving and Clinical Judgement abilities as “average” (Table 7). No differences were detected when comparing competency scores across cohorts (p > 0.05). When surveyed, 21 (2017) and 12 (2018) employers rated the Diagnostic Ability, and Problem-Solving and Clinical Judgement abilities of recent graduates as “high” for both cohorts (Table 7). Across both cohorts, graduates rated their diagnostic reasoning, problem-solving, and clinical judgement abilities lower than their employers (Table 7). Employer performance scores and graduate self-confidence scores did not differ statistically for the two cohorts.

Discussion

The findings presented in this study suggest that the self-confidence and perceived proficiency of veterinary students and recent graduates in the core competencies of diagnostic reasoning, problem-solving and clinical judgement, declined as they progressed through Years 1-3 of the DVM program, remained low but stabilized during their externship placements and final year of the program, and subsequently improved six-months post-graduation. This decline within the first three years was consistent across both cohorts as they progressed through the DVM program. Contrasting performance scores provided by externship hosts and employers indicated that students consistently rated their self-confidence and perceived proficiency in these core competencies lower than their actual skills as rated by their externship hosts and employers.

The reasons for the decline in self-confidence are not clear, however several possibilities exist. In Year 1, the two learning outcomes assessed were rather straightforward, consisting of evaluating the performance characteristics of tests (i.e., sensitivity, specificity, predictive values), and listening and communication skills. In comparison, the outcomes assessed in Year 2 increased in difficulty, and included interpretation of test results, conducting specific examinations (radiology, neurology,
dermatology) and developing a problem list. Year 2 represented the first exposure to these more focused and specialized skills for veterinary students, and their lack of previous experience likely contributed to the decreased self-confidence scores compared to Year 1. Outcomes assessed in Year 3 continued to increase in complexity, and included selecting appropriate tests, interpreting findings, developing a list of differential diagnoses, and suggesting treatment options. The outcomes assessed in Year 3, while complex, were intended to expose students to the clinical responsibility and demands they would experience in their 8-week externship placement. This time-period represented a significant jump in the diagnostic reasoning skills required of students. The decline in self-confidence seen in our study contradicts previous studies from a decade ago, where feedback from veterinary students and graduates from other schools, obtained at the time of graduation, indicated they felt they had a strong understanding and confident grasp over their diagnostic decision-making abilities, and specifically in developing diagnostic lists. Porter et al (2013) noted a similar trend in low self-confidence for human nursing students as they progressed through their programs however, in contrast to our study, these students reported the lowest level of self-confidence during year one of their program. Karim et al (2013) similarly found that even after three years of preclinical studies, one year of simulated clinical experience, and spending 11-weeks in a surgical rotation, senior medical students reported low self-confidence in their diagnostic and treatment procedural skills. It is perhaps not surprising, then, that student self-confidence scores appeared to decrease as they progressed through the program. Even still, this decline in self-confidence is concerning since confidence can strongly influence clinical skill development and performance.

Analysis of the externship student and host surveys further highlighted the low confidence and perceived low performance that students had with diagnostic ability, problem-solving and clinical judgment. Veterinary students and graduates possess extensive knowledge bases by this stage of their training, but may be lacking the ability to apply critical non-technical skills, such as the appearance of self-confidence, that have been linked to long term clinical success. An analysis by Heath et al (2000) on veterinary employability criterion revealed that Australian employers highly valued non-technical skills
such as self-confidence when selecting veterinary graduates for their practice.\textsuperscript{21} Surprisingly, while employers regarded the graduates’ mastery over content and theoretical concepts in veterinary science as “essential” or “very important”, these skills were ranked lower in importance than personal attributes like self-confidence.\textsuperscript{21} Cake et al (2016) conducted a systematic review on professional (non-technical) competencies in veterinary education, which revealed that employers are placing growing importance on graduates possessing both technical and non-technical skills.\textsuperscript{22} While this is not a novel finding, it does highlight a potential concern when looking at the externship-host competency rankings in this study. Veterinary students were assessed by externship-hosts as skilled in non-technical competencies (e.g., professional conduct and congeniality, communication with professionals), however they underperformed in some technical skills (e.g., veterinary factual knowledge, diagnostic ability, problem-solving and clinical judgement). Additionally, while externship hosts and employers in this study provided proficiency scores higher than those provided by the veterinary students and recent graduates, they placed these competencies much lower, or last in their overall ranking of the 16 competencies. This was similar to the findings presented by Vinten et al (2016) in their assessment of clinical skill development in senior veterinary students, in which surveyed educators and employers indicated that they found students to be functional but not skilled in clinical reasoning.\textsuperscript{1} By contrast, May’s (2008) analysis of learning outcomes in the Royal Veterinary College’s veterinary curriculum suggested that modern veterinary graduates were meeting or exceeding performance standards and demonstrating a greater knowledge of veterinary science and stronger technical and professional skills in comparison to their predecessors.\textsuperscript{12} By contrast, our findings indicate that there has been an erosion in the perception by students and recent graduates of their proficiency, especially within competencies like diagnostic reasoning, problem-solving, and clinical judgement.

Students continued to demonstrate low self-confidence throughout their fourth year, which is comprised of clinical rotations both within the OVC teaching hospital setting and at external private clinics. This clinical year requires that students begin to manage more complex cases, albeit under high supervision. Students do not experience true independence or autonomy in their clinical decision-making,
and one would expect that this safety net may allow students to develop self-confidence in the reasoning process. Appointments in a teaching hospital setting are typically much longer than in private practice, allowing students time to think and discuss their approach to cases with senior clinicians and faculty. According to several authors, there is a need to incorporate the “real life” aspects of decision making (e.g., time constraints, independence, financial barriers) into veterinary pedagogy.\textsuperscript{1,10,23} A study by Jaarsma et al (2008) on the perceptions of alumni from a traditional lecture-based or reformed student-centered veterinary curriculum found that many cited low self-confidence in their clinical capabilities during the program because of a lack of exposure to primary care cases, minimal extramural or externship experience, and few opportunities to work independently with responsibility.\textsuperscript{10} Similarly, Rosch et al (2014) studied clinical skill development in veterinary students and found that providing students with opportunities to practice in a moderately supervised clinical environment was an ideal way to support learning, diagnostic skill development, and practical competence.\textsuperscript{24} Incorporating these real-life factors may improve how well veterinary educators are able to articulate and recreate their experiences in diagnostic reasoning for their students. For example, Benner et al (2008) found that experienced clinicians and senior nurses could generally expand on their overall thinking and thought process when approaching a new case but faced difficulties in articulating this experience for students to then independently replicate.\textsuperscript{25} The results of the Year 4 surveys in our study support this finding, as self-confidence scores provided by senior students stabilized, with feedback indicating that they generally felt somewhat or fairly confident in their abilities. We speculate that clinical experience from their third-year externships and being able to shift past the initial “shock” of applying their knowledge in practice, helped to prepare them for their final year clinical rotations.

In comparison to the Year 3 externship and Year 4 surveys, recent graduates with six-months experience demonstrated improved confidence and perceived proficiency in diagnostic reasoning, problem-solving, and clinical judgement. Clearly, with six-months of practice experience, students felt significantly more comfortable with their approach to diagnosis and case management. In addition, their employers indicated satisfaction, rating them higher than the self-assessed proficiency as reported by the
graduates. This increase in graduate self-confidence and competency was similar to that reported by Walsh et al (2002).26 In that study, the post-graduate success of veterinary students from the University of California School of Veterinary Medicine and the attributes that prepared them for practice were assessed.26 Their findings suggested that explicitly defining learning outcomes and requirements for degree advancement and clinical success was a prominent factor that positioned students to meet the breadth of responsibilities in practice.26 The findings presented in our study both support and contradict Walsh et al (2002).26 To elaborate, while student self-confidence scores provided during Years 1-4 of the program suggested that the students may have felt unprepared to meet the demands of practice, employer surveys showed that graduates were indeed meeting the expectations of employers and demonstrating strong clinical competence and self-confidence. Conversely, the improved scores provided in graduate surveys highlight a potential misconception about whether self-confidence scores during Years 3-4 of the DVM program are providing a complete picture of how competent students are in their clinical capabilities. These surveys may be failing to consider how much this decline may be attributed to stressors that all students face when first entering a non-academic clinical environment (e.g., externship, clinical rotation, internships).22,27,28

The perceived role of confidence, whether it is a display of low self-confidence or overconfidence, on the development of proficiency in diagnostic reasoning skills remains unclear. While we found that low self-confidence contributed to students providing lower perceived proficiency scores in learning outcomes that assessed their diagnostic reasoning, problem-solving, and clinical judgement skills, other studies have suggested that overconfidence in students can also be a significant bias that can hinder the reasoning process.25,29 Unfortunately, most of the studies that assessed the potential impact of low-confidence or overconfidence on the diagnostic reasoning process primarily observed this phenomenon within physicians in human medicine.25,29,30,31,32 Further research is needed to determine what it is about diagnostic reasoning that veterinary students find difficult, and whether or not the tools educators give them to develop these skills are effective. Additional insight into the perceptions and experiences of recent graduates in how their diagnostic skills further develop within the first six-months
in practice after graduation, and whether they alter their approach to diagnostic reasoning over this time, would help to inform veterinary educators about the best methods of teaching this important core competency.

Limitations
This study examined student perceptions by the utilization of self-confidence scores and did not evaluate actual performance or proficiency with diagnostic reasoning. Presently, there is no validated tool available that can effectively and accurately measure the student’s full range of skills, knowledge, and attitudes surrounding clinical competence. The complex nature of diagnostic reasoning means student self-confidence scores may not be an accurate reflection of a student’s competency. Additionally, we were unable to compare and contrast findings across cohorts because each survey varied in the type of Likert scale used to collect student self-confidence scores. A reliable method to measure clinical reasoning would greatly assist clinical educators in assessing the quality and extent of clinical skill development as students progressed through the DVM program, and in elucidating the potential reasons behind declining self-confidence scores. Additional limitations of self-reporting include varying perspectives of individual students, and the potential for self-assessments to lack objectiveness or be influenced by additional situational factors.

The study was limited to the veterinary students at the OVC, however the findings presented in this study may be cautiously generalized to other veterinary institutions and curricula where the DVM programs focuses on teaching diagnostic reasoning and clinical problem-solving skills in a similarly embedded format.

Conclusion
Veterinary students at the OVC consistently reported declining self-confidence scores in their diagnostic reasoning, problem-solving, and clinical judgement skills as they progressed through the DVM program. Some decline in scoring may be attributed to students being faced with increasingly difficult and complex learning outcomes as they advance through the program and obtain more knowledge. This low self-confidence can become an issue when the students graduate with a large knowledge base and enter
into clinical practice, where their ability to provide high quality patient care is greatly dependent on the clinical skills developed during their tenure in the program. The findings of this study highlight the need for further study on the reasons for low self-confidence in the development of diagnostic reasoning skills in veterinary students, and the steps with which this development can be supported to ensure that graduates are given the necessary skill set and confidence to succeed in clinical practice.
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</thead>
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</tr>
<tr>
<td>• Year 3 Student and Externship Host Survey following an 8-week placement.</td>
</tr>
<tr>
<td>• Year 4 Student Survey</td>
</tr>
<tr>
<td>• Graduate and Employer Surveys.</td>
</tr>
<tr>
<td><strong>5-Point Likert-Type Scale</strong></td>
</tr>
<tr>
<td>• Years 1 through Year 3 Student Surveys (2017 Graduating Cohort) assessing Competency One (Diagnostic Reasoning) and Competency Two (Problem-Solving and Clinical Judgement Student).</td>
</tr>
<tr>
<td><strong>7-Point Likert-Type Scale</strong></td>
</tr>
<tr>
<td>• Years 1 through Year 3 Student Surveys (2018 Graduating Cohort) assessing Competency One (Diagnostic Reasoning) and Competency Two (Problem-Solving and Clinical Judgement Student).</td>
</tr>
</tbody>
</table>

Figure 1: The Likert-Type Scales Used for Years 1-4 surveys, Year 3 Student and Externship Host surveys, and Graduate and Employer Surveys (administered 6-months post-graduation). Likert-Type scales used for survey data collection varied across the two cohorts (2017, 2018) assessed.
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<table>
<thead>
<tr>
<th>Year</th>
<th>Frequency for 2017 Cohort (n/N) (percent %)</th>
<th>Frequency for 2018 Cohort (n/N) (percent %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>80/120 (66.7)</td>
<td>99/120 (82.5)</td>
</tr>
<tr>
<td>Year 2</td>
<td>93/120 (77.5)</td>
<td>76/120 (63.3)</td>
</tr>
<tr>
<td>Year 3</td>
<td>91/120 (75.8)</td>
<td>83/120 (69.1)</td>
</tr>
<tr>
<td>Externship</td>
<td>116/120 (96.6)</td>
<td>116/120 (96.6)</td>
</tr>
<tr>
<td>Externship Hosts</td>
<td>110/120 (91.6)</td>
<td>110/120 (91.6)</td>
</tr>
<tr>
<td>Year 4</td>
<td>61/120 (50.8)</td>
<td>44/120 (36.6)</td>
</tr>
<tr>
<td>6-Months Post Graduation</td>
<td>39/120 (32.5)</td>
<td>31/119 (26.1)</td>
</tr>
</tbody>
</table>
Table 2: Year 1-3 Diagnostic Reasoning, Problem-Solving, and Clinical Judgement Student Self-Confidence Scores. Direct Comparison of means between the two cohorts was not possible due to the use of differing Likert scales as indicated.

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Mean Rating: 2017 Cohort (SD)</th>
<th>Mean Rating: 2018 Cohort (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[1= Not at all confident, 2= Slightly confident, 3= Confident, 4= Fairly confident, 5= Very confident]</td>
<td>[1= Not at all confident, 2= Slightly confident, 3= Neither Confident nor Unconfident, 4= Somewhat confident, 5= Fairly Confident, 6= Confident, 7= Very confident]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluate diagnostic tests based on test performance characteristics.</td>
<td>3.29/5 (1.05)</td>
<td>4.60/7 (1.25)</td>
</tr>
<tr>
<td>Conduct professional conversations with clients and colleagues that demonstrate empathetic listening and communication skills.</td>
<td>3.81/5 (0.87)</td>
<td>5.77/7 (1.07)</td>
</tr>
<tr>
<td><strong>Year 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critically evaluate information in order to select appropriate diagnostic tests, treatments, and preventative strategies.</td>
<td>3.30/5 (0.82)</td>
<td>4.30/7 (1.32)</td>
</tr>
<tr>
<td>Apply problem-solving processes when interpreting information derived from selected tests and procedures.</td>
<td>3.51/5 (0.79)</td>
<td>4.59/7 (1.25)</td>
</tr>
<tr>
<td>Conduct dermatological and neurological examinations and radiological tests.</td>
<td>2.92/5 (1.00)</td>
<td>3.86/7 (1.46)</td>
</tr>
<tr>
<td>Develop a problem list and medical record for common domestic animals.</td>
<td>3.87/5 (0.82)</td>
<td>5.28/7 (1.26)</td>
</tr>
<tr>
<td><strong>Year 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Know and select the appropriate diagnostic tests, treatment options and prevention strategies of common diseases in a variety of domestic and non-domestic species relevant to the Canadian context.</td>
<td>2.62/5 (0.80)</td>
<td>4.22/7 (1.07)</td>
</tr>
<tr>
<td>Conduct appropriate diagnostic tests and interpret results and findings, in order to develop a list of diagnostic hypotheses.</td>
<td>2.74/5 (0.74)</td>
<td>4.33/7 (1.16)</td>
</tr>
<tr>
<td>Conduct appropriate diagnostic tests and interpret results and findings, in order to develop a plan for treatment.</td>
<td>2.73/5 (0.80)</td>
<td>4.20/7 (1.16)</td>
</tr>
</tbody>
</table>
Table 3: Year 1-3 Mean Overall Self-Confidence for Progressing to the Next Phase of Study Scores. Cohort specific mean ratings and standard deviations in scores are reported.

<table>
<thead>
<tr>
<th>Program Year</th>
<th>Mean Rating 2017 (SD) [1= Not at all confident, 2= Slightly confident, 3= Confident, 4= Fairly confident, 5= Very confident]</th>
<th>Mean Rating 2018 (SD) [1= Not at all confident, 2= Slightly confident, 3= Neither Confident nor Unconfident, 4= Somewhat confident, 5= Fairly Confident, 6= Confident, 7= Very confident]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>3.55/5 (0.26)</td>
<td>5.18/7 (0.58)</td>
</tr>
<tr>
<td>Year 2</td>
<td>3.40/5 (0.34)</td>
<td>4.50/7 (0.51)</td>
</tr>
<tr>
<td>Year 3</td>
<td>2.69/5 (0.05)</td>
<td>4.25/7 (0.05)</td>
</tr>
</tbody>
</table>
Table 4: Student Self-Confidence and Externship Host Performance Scores in Two Core Competencies related to Clinical Reasoning. Learning outcomes, cohort specific mean ratings, and significance of differences between cohort specific student self-confidence scores and significance of differences between host performance scores are reported.

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Mean Rating 2017 (SD)</th>
<th>Mean Rating 2018 (SD)</th>
<th>P-Value</th>
<th>Rank out of 16 Core Competencies (2017, 2018) §</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student Confidence Ratings in Competencies at the End of the Externship</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Reasoning</td>
<td>2.78 (0.44)</td>
<td>2.89 (0.41)</td>
<td>0.04*</td>
<td>14, 12</td>
</tr>
<tr>
<td>Problem-Solving and Clinical Judgement</td>
<td>2.81 (0.38)</td>
<td>2.93 (0.32)</td>
<td>0.01**</td>
<td>12, 10</td>
</tr>
<tr>
<td><strong>Host Ratings of Students’ Ability to Perform Competencies at the End of the Externship</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Reasoning</td>
<td>3.19 (0.49)</td>
<td>3.10 (0.49)</td>
<td>0.17</td>
<td>14, 11</td>
</tr>
<tr>
<td>Problem-Solving and Clinical Judgement</td>
<td>2.94 (0.56)</td>
<td>3.06 (0.32)</td>
<td>0.05*</td>
<td>12, 15</td>
</tr>
</tbody>
</table>

1= not confident, 2= slightly confident, 3= fairly confident, 4= very confident

§Rankings were ordered from most (1) to least (16) confident compared within the 16 core competencies of the program.

Note: ** p < 0.01, * p < 0.05
Table 5: Externship Host Ratings of Students’ Ability to Perform Competencies, as ranked against all 16 of the program competencies assessed. Ranking was from most competent (1) to least competent (16).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Veterinary Factual Knowledge</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Acquiring a Case History</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Communication with Clients</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Conducting a Clinical/Physical/Necropsy Exam</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Handling Animals Safely and Humanely</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Consideration of Animal Welfare</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td><strong>Problem-Solving and Clinical Judgement</strong></td>
<td><strong>12</strong></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td>Diagnostic Ability</td>
<td><strong>14</strong></td>
<td><strong>11</strong></td>
</tr>
<tr>
<td>Technical and Procedural Skills</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Case Ownership and Continuity of Care</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Written Communication</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Communication with Professionals</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Participation</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Occupational and Public Health</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Professional Conduct and Congeniality</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Skills</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 6: Year 4 Student Self-Confidence Scores. Learning outcomes, cohort specific mean ratings, and significance of differences between cohort specific student self-confidence scores are reported.

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Mean Rating 2017 (SD)</th>
<th>Mean Rating 2018 (SD)</th>
<th>P- Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Competency One: Diagnostic Reasoning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correctly interpret test results.</td>
<td>2.79 (0.45)</td>
<td>2.76 (0.86)</td>
<td>0.83</td>
</tr>
<tr>
<td>Utilize diagnostic test results to refine the assessment of a case.</td>
<td>2.91 (0.47)</td>
<td>2.77 (0.78)</td>
<td>0.30</td>
</tr>
<tr>
<td>Identify how their interpretation of diagnostic test results could be improved.</td>
<td>2.48 (0.60)</td>
<td>2.60 (0.85)</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Competency Two: Problem-Solving and Clinical Judgement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistently use a systematic approach to assessing a case.</td>
<td>2.92 (0.49)</td>
<td>2.92 (0.79)</td>
<td>1.00</td>
</tr>
<tr>
<td>Develop and prioritize a problem list based on findings of the physical exam and an assessment of the environment.</td>
<td>3.06 (0.40)</td>
<td>3.02 (0.76)</td>
<td>0.78</td>
</tr>
<tr>
<td>Generate a realistic differential diagnosis list and explain the likelihood for the listed differential in a particular case.</td>
<td>2.81 (0.47)</td>
<td>2.78 (0.84)</td>
<td>0.85</td>
</tr>
<tr>
<td>Develop a diagnostic plan that includes cost-benefit analysis.</td>
<td>2.68 (0.59)</td>
<td>2.52 (1.04)</td>
<td>0.37</td>
</tr>
<tr>
<td>Develop and maintain a diagnostic and treatment plan that is reflective of how a case progresses over time.</td>
<td>2.69 (0.56)</td>
<td>2.68 (0.93)</td>
<td>0.92</td>
</tr>
</tbody>
</table>

1= not confident, 2= slightly confident, 3= fairly confident, 4= very confident.
Table 7: Graduate Self-Confidence and Employer Performance Scores 6-Months Post-Graduation. Learning outcomes, cohort specific mean ratings, and significance of differences between cohort specific student self-confidence scores and significance of differences between employer performance scores are reported.

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Mean Rating 2017 (SD)</th>
<th>Mean Rating 2018 (SD)</th>
<th>P- Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graduate Self-Confidence Ratings in Competencies 6-Months Post-Graduation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Reasoning</td>
<td>3.26 (0.75)</td>
<td>3.23 (0.50)</td>
<td>0.84</td>
</tr>
<tr>
<td>Problem-Solving and Clinical Judgement</td>
<td>3.28 (0.45)</td>
<td>3.34 (0.89)</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>Employer’s Rating of Graduates’ Ability to Perform Competencies 6-Months Post-Graduation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Reasoning</td>
<td>4.24 (0.83)</td>
<td>4.25 (0.45)</td>
<td>0.96</td>
</tr>
<tr>
<td>Problem-Solving and Clinical Judgement</td>
<td>4.00 (0.80)</td>
<td>4.08 (0.79)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

1= Poor, 2= Low, 3= Average, 4= High, 5= Very High.
CHAPTER THREE

DEVELOPMENT OF DIAGNOSTIC REASONING AND PROBLEM-SOLVING SKILLS: PERCEPTIONS OF RECENT VETERINARY GRADUATES.

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Abstract

Recent veterinary graduates enter clinical practice with a comprehensive knowledge base and technical skill set gained through various learning opportunities. Despite this, surveys of recent graduates report low confidence in diagnostic reasoning and clinical problem-solving. To elucidate the reasons behind their low confidence, e-surveys and one-on-one semi-structured interviews were conducted with 2014-2018 DVM program graduates (n=81 e-surveys; n=10 interviews). Questions explored which parts of the diagnostic reasoning process recent graduates found difficult, how the process of clinical problem-solving evolved through gaining experience and assessed whether they felt the approaches to diagnostic reasoning taught in their veterinary programs prepared them for clinical practice. Respondents indicated that their initial problem-solving experiences following graduation were “very challenging” (difficulty rating of 2.65 out of 5), with 39.6% of survey respondents citing “making a differential diagnosis list” as the most challenging aspect of clinical reasoning. Diagnostic reasoning tools that assisted graduates in problem-solving included consultation with a senior veterinarian (93.8%) and utilizing the POVMR (Problem-oriented veterinary medical record) approach (65.4%). Thematic analysis of the interviews resulted in three themes: A difficult transition from a student to veterinarian role; Coping with a difficult transition period; and Modifications in the graduates’ approach to diagnostic reasoning in practice. Interview participants identified various experiences contributing to low confidence and perceived lack of proficiency in their diagnostic reasoning abilities, including content overload during the program, difficulty connecting theoretical knowledge to cases in practice, and a fear of making diagnostic errors. The study provides a unique insight into how recent veterinary graduates viewed their diagnostic
reasoning and problem-solving skill development during a veterinary program and following practice experience post-graduation.

**Key words:** diagnostic reasoning, veterinary education, pedagogy

**Introduction**

Veterinary students who choose to enter clinical practice must successfully transition from a structured educational environment to the clinical practice work environment, which is recognized to be increasingly demanding and driven by client expectations.\(^1\)\(^2\) Important components of this transition include developing independence in the clinical setting while managing a markedly higher caseload, and significant responsibilities towards patients and clients than encountered in any clinical role undertaken during their time within the Doctor of Veterinary Medicine (DVM) program.\(^3\)\(^4\) Recent veterinary graduates report a range of experiences during this transition period, with most graduates reporting a positive experience however, for those who found the experience negative, it was often reported to be strongly the case.\(^1\) Some negative experiences may include dissatisfaction with the work environment or a challenging adjustment period that may hinder development of attributes necessary for practice, such as clinical knowledge, compassion and personal and intellectual autonomy.\(^5\) The factors contributing to a successful transition into practice are still unclear.\(^4\) Some graduates rapidly gain professional autonomy when they transition from the classroom to the clinic, whereas others require extensive support and guidance from senior veterinarians and clinical staff.\(^3\) A difficult transition from veterinary student to practitioner can have implications on the quality of care for clients and patients, the graduate’s success as a clinician, and impact whether or not they leave their profession.\(^3\)\(^5\) Additionally, situational factors such as prior clinical experiences and the nature of the clinical environment they are entering, impact how recent graduates continue to develop their diagnostic reasoning skills following entry into practice.\(^7\) Identification of factors limiting the graduates’ learning, skill acquisition, and performance in practice may assist educators in addressing these problems at the classroom level.\(^1\) Addressing these challenges in the clinical environment may also positively impact graduates’ professional development and employment retention.\(^3\) Veterinary medicine as a profession experiences an annual employment turnover
rate of 28-30%, which is markedly higher than the national average for all industries.\textsuperscript{8} While this turnover may be the result of a number of influencing factors, there is some evidence that the initial year in practice may play a major role in the retention of veterinary professionals.\textsuperscript{3}

According to Gilling and colleagues (2009), the impact of veterinary programs on this transition period remains uncertain.\textsuperscript{3} The DVM curriculum should provide graduates with the necessary knowledge and experience to develop their diagnostic abilities allowing success in clinical practice.\textsuperscript{5} While a strong knowledge base forms the foundation of clinical competency, little is known about the development of diagnostic reasoning skills and its impact on performance post-graduation.\textsuperscript{9,10} Competency in diagnostic reasoning is a critical skill for clinicians to acquire, and one that greatly impacts the overall client and patient experience.\textsuperscript{13} For many veterinary students and recent graduates, the process by which they develop proficiency in the diagnostic, therapeutic, and prognostic components of clinical care is unclear because diagnostic reasoning is generally embedded into the curriculum at most veterinary schools rather than being explicitly taught as a skill.\textsuperscript{11,12} Additionally, the specific diagnostic reasoning methods and theories taught to students vary across veterinary programs and may include approaches such as the Problem Oriented Veterinary Medical Record (POVMR), the SOAP method (Subjective, Objective, Assessment, Plan), the Hypothetico-Deductive Reasoning (HDR) Method, and the Exhaustive Approach to Differential Lists.\textsuperscript{14} While there is existing literature on these approaches and how they are applied, further research is needed by veterinary educators to determine the efficacy of their application to clinical practice, as well as their perceived usefulness by veterinary students.\textsuperscript{14,15}

Veterinary graduates enter clinical practice with a wealth of knowledge and clinical experience gained through their DVM program and extensive time spent in a variety of clinical settings.\textsuperscript{5,16} Despite this, recent evidence suggests that veterinary students and recent graduates have low self-confidence in their skills related to diagnostic reasoning and problem-solving.\textsuperscript{17} Practitioners hosting students on clinical externships similarly ranked student performance in areas related to diagnostic reasoning among the lowest of 16 proficiencies evaluated.\textsuperscript{17} These findings are concerning for educators, students, and future veterinary employers alike. Previous studies have suggested that students who lack a strong
knowledge base or possess inefficient reasoning skills often struggle with their early practice experience. In addition, if students do not integrate and apply their knowledge across several subjects, they may develop a theory-practice gap which impedes the translation of their knowledge into a clinical practice setting. For veterinary educators, little research presently exists to provide guidance on how diagnostic reasoning skills are best taught to ensure students graduate with strong problem-solving abilities. Feedback from recent veterinary graduates can be informative as to how the veterinary curriculum impacts the development of diagnostic reasoning and problem-solving skills, along with their overall preparedness for clinical practice. Exploring the diagnostic reasoning experiences of recent veterinary graduates during the transition into clinical practice and assessing how well the DVM program prepared them, would serve as a useful resource for clinical educators and help inform future curricular changes.

Using a mixed methods approach, the objectives of this study were to explore the perceptions and experiences of recent veterinary graduates to gain insight into how they approached clinical problem-solving upon graduation and elucidate perceived challenges related to what they found most difficult about the diagnostic reasoning process. Specifically, we investigated how the process of clinical problem-solving changed over time as DVM graduates gained more experience in clinical practice after graduation and assessed how they felt the approaches to diagnostic reasoning taught during their veterinary programs prepared them for practice.

**Materials and Methods**

**Ethical Consent**

This study was reviewed and approved by the University of Guelph Research Ethics Board (approval #17-05-016).

**Survey Data**

Using a purposive sampling method, e-surveys were distributed to 2014-2018 graduates of the Ontario Veterinary College (OVC), and to veterinarians registered with the College of Veterinarians of Ontario (CVO) listing their graduation year as between 2014-2018. Participants were required to have
worked at least three months in veterinary practice. Surveys were advertised and distributed through the CVO’s LISTSERV, and in partnership with the OVC’s social media accounts (Instagram®, Facebook®, and Twitter®).

Survey data was collected using the Qualtrics® online survey tool. Survey questions assessed participant perceptions about diagnostic reasoning processes and tools, early experience in clinical practice, and general feelings of preparedness following graduation (Figure 1). A 5-Point Likert-type scale was used to collect participant feedback on the perceived difficulty scores (1= Extremely Challenging, 5= Not challenging at all) in solving clinical problems. A 7-point Likert-type scale (1= Extremely Useful, 7=Extremely Useless) was used to collect participant feedback on the perceived usefulness of specific diagnostic processes that could be employed in solving clinical problems. Participants were only able to provide usefulness scores for diagnostic tools they had, in a previous question, indicated an awareness of. Participants were given the option to provide open-ended comments for additional feedback and context. Incomplete surveys were excluded from the study sample and data analysis.

**Survey Data Analysis**

Survey data was stored and analyzed using SAS® 9.4. Descriptive statistics assessed mean scores, response frequency, and percent frequency amongst each of the five participating graduating years. A one-way nonparametric analysis using the Wilcoxon rank sum test was used to compare the distribution of Likert scores between all participating cohorts. On the basis of a significant Kruskal-Wallis p-value (p <0.05), pairwise comparisons, using an adjusted P-value, were conducted between the two cohorts of interest. This was used for questions utilizing a 5-point and 7-point Likert-type scale, which included analysis of ranked scores on the perceived difficulty in solving clinical problems, graduate preferences in utilizing specific diagnostic tools in clinical practice, and graduate ratings on the usefulness of common diagnostic reasoning tools. The Pearson Chi-Square Test was used to assess any differences between cohorts in their awareness of, and preference in, diagnostic reasoning tools, aids, and processes. While pairwise comparisons between cohorts was not the primary focus of this study, it was explored for
additional context on the diagnostic reasoning experiences of recent veterinary graduates. If there was a significant difference in the responses from a specific cohort (p < 0.05) then further analysis using pairwise comparisons was performed by year and between two cohorts. Statistical associations were considered significant if the p-value was < 0.05.

*Interview Structure*

Following completion of the e-survey, participants were invited to take part in a one-on-one interview. In order to qualify for the interview, participants must have provided consent at the end of the e-survey and have graduated from a veterinary program between the years of 2014-2018. In an effort to reduce informational redundancy, a predetermined desired number of interviews was not established, and completion of data collection was based on the achievement of data saturation. Interviews were conducted in-person or by telephone, Skype, or FaceTime, since participants were geographically displaced. A semi-structured interview guide was used in all discussions and focused on further investigating recent DVM graduates’ perceptions of their approach to diagnostic reasoning following graduation, their views on the diagnostic reasoning tools and methods taught in the veterinary program, and examined how they may have modified their approach to diagnostic reasoning since entering clinical practice (Figure 1). A component of the one-on-one interview discussion required graduates to work through a standardized case example to provide insight into their diagnostic reasoning approach in practice.

*Interview Data Analysis*

Interviews were transcribed verbatim and de-identified by the primary author within one month following the completion of each interview. Interview data was stored and organized using Quirkos® and manually analyzed. Interviews were read multiple times to increase familiarity with the data and for open coding, and were analyzed using an inductive thematic approach in which open codes were used to guide theme development. Quality criterion, specifically member checking and peer debriefing, was used to ensure rigor of analysis. Member checking was used following the completion of each interview to validate participant feedback and responses. Peer debriefing was satisfied as the general
methodology, data, and results were separately reviewed by the principle investigator and a graduate student, and the general methodology and finalized results were reviewed by the academic advisory committee overseeing the graduate student’s program.

Results
Descriptive Statistics
Surveys were disseminated to 586 DVM graduates from the OVC plus any veterinarians registered with the CVO’s LISTSERV that had graduated between the years 2014-2018. Surveys were completed by 81 DVM graduates. Out of the 81 participants that completed the survey, 19 indicated a willingness to be interviewed, of which 10 provided their correct contact information and participated in the one-on-one interviews (OVC graduates=8, non-OVC graduates=2) (Table 1).

Quantitative Results
Respondents indicated that, following graduation, they found solving clinical problems to be “moderately challenging”, corresponding to a mean difficulty score of 2.7 out of 5 (Table 2). There was no difference (p>0.05) in how each cohort rated their perceived difficulty in solving clinical problems. Recent graduates identified “making a list of differential diagnoses” (39.5%) and “making a relevant treatment plan” (32.1%) as the most challenging aspects of diagnostic reasoning following graduation.

A high percentage of respondents indicated that they preferred asking a senior veterinarian for assistance when solving clinical problems, with 93.8% indicating this would be their first option. Additional diagnostic aids identified as most useful by participants included: textbook and course notes (65.4%), online resources (65.4%), and Veterinary Information Network (VIN; an online community, continuing education, and information resource for veterinarians) (62.9%) (Table 3). Across cohorts, there was no difference in the graduates’ preferences for diagnostic reasoning aids (p>0.05). Assessment of frequency of tool use indicated that participants used diagnostic aids “multiple times per day” (67.9%) or “at least once a day” (13.5%). Participants selected POVMR (65.4%), the DAMNIT Mnemonic (58.0%), and Hypothetico-Deductive Reasoning Method (40.7%) as their preferred diagnostic reasoning tools (Table 4).
Qualitative Results

Thematic analysis of the interviews resulted in three major themes: Difficult transition period from a student to veterinarian role; Coping with a difficult transition period; and Modifications in the graduates’ approach to diagnostic reasoning in practice (Figure 2).

Theme One: Difficult Transition from Student to Veterinarian

Interviewees indicated that, upon graduation, they found their initial problem-solving experiences to be moderately hard or very hard. All interviewees indicated that they felt overwhelmed with the number of cases in practice and the amount of data and information they had to remember from veterinary school. Many found that they were inundated with an overwhelming amount of information, cases, and responsibilities and felt that they required an extensive knowledge base and multiple hypotheses in order to succeed both in diagnostic reasoning and as a clinician. Representative comments from interviewees included:

“*You get an overwhelming amount of data and information in vet school but it’s hard to work through it all because you’re told not to disregard anything.*”

“The important pieces of information are lost in a big mix of what the owners are saying. In an exam you’d be given just the important pieces, versus in real life you’re given a lot.”

“*Just a general overwhelming feeling makes it hard to sort through your thoughts. If I had a quiet room and had time to myself, it would be different.*”

Interview respondents highlighted content overload in the DVM program as a factor that impeded their problem-solving process. Several graduates found that once they entered practice, this content overload further contributed to a theory-practice gap and impeded their diagnostic skill development. Specifically, respondents communicated that they would try to connect the vast amounts of theoretical information and concepts taught during their time in the DVM program to cases in practice, but were unable to do so because of a lack of training in how to make this connection and prior clinical experience to refer back to. Specifically, they “*wanted to try and find the right answer, exactly the right plan and dose and outcome [...] right away*” but were often unable to do so because they lacked “*prior experience to look back on*”. One respondent commented that they had difficulty connecting theoretical principles to
cases because there was “still a lot of differences between cases shown in class versus in the clinic.”

Additional examples included:

“Not having experience to draw upon or a bank of anecdotal examples makes it difficult when you're given an unfamiliar case.”

“Immediately upon graduation I still found I had a lot of theory and I had all the background information in my head, but I had trouble applying it to the clinical problem in front of me.”

Graduates felt that they “had the thesis to know what needed to be done next” but were often “told which test to use” by senior veterinarians during their training, which caused them to feel apprehensive and paranoid of making clinical errors when working independently. Many felt “slow” and “inefficient” and would often have to step out with every appointment in order to consult their notes and senior veterinarians to avoid making a clinical error.

Specific aspects of the diagnostic reasoning process identified by graduates as being challenging included composing and prioritizing a differential diagnoses list and generating a prioritized list of diagnostic tests. Participants commented that it was “difficult to prioritize diagnoses” which would often result in the production of a “a long list of differentials” and an inadequate plan or course of action. When asked to explain why they found prioritizing diagnostic tests to be difficult, participants indicated that they were “paranoid of always missing” a differential diagnosis that was “less likely but still possible”. All interviewees reported feelings of low self-confidence, self-doubt, and apprehension when faced with an unfamiliar problem because they were worried about “making a diagnostic error” and missing critical pieces of the patient's history amidst the vast sea of information provided by the owner. Interviewees felt that the consequences of diagnostic errors were higher in practice than in the controlled and supervised setting to which they had become accustomed to (e.g., classroom/laboratory) because they were now presented with a real scenario and not a theoretical practice problem. Respondents voiced feeling apprehensive and being unsure of their clinical capabilities because now there were “consequences associated with everything” they did:

“I felt like I was less confident in myself, maybe it was the pressure of having a real animal instead of a red checkmark. The consequences were much higher outside of class.”
“It was overwhelming because suddenly something you would have presented to you on paper is now given to you in real life.”

Theme Two: Coping with a Difficult Transition Period

At the time of the interview following at least three months in clinical practice, participants indicated that their confidence in their clinical abilities had improved and found it easy to solve clinical problems and arrive at a diagnosis and plan for treatment. Participants attributed this improved confidence in their clinical abilities and their ability to cope with the demands of practice to collaborative relationships with senior veterinarians and colleagues, and to gaining experience. Every interviewee expressed that, because of gaining clinical experience they now generated a narrower range of differentials and had increased knowledge and confidence when problem-solving in practice. Positive experiences and diagnostic success improved their self-confidence, perceptions of proficiency, and in the long-run impacted how they approached problem-solving in practice:

“If you did well the last time it increases your confidence that you will be able to help this one.”

“If I had a good experience and if I was correct in that case, I would carry that experience and practise over.”

Many found that within three months of being in practice their knowledge and confidence had improved and they no longer felt guilty using the resources available to them in practice and asking for assistance when needed. One participant commented that they “no longer felt bad” about asking for assistance from experienced veterinarians and colleagues because “even vets that have been in practice for a while need help”. Respondents viewed collaborative relationships with senior veterinarians and colleagues to be an invaluable resource that they felt helped to fill the theory-practice gap they experienced during their initial three months in practice. In addition to addressing any gaps in knowledge, collaborating with colleagues allowed graduates to verify their diagnostic reasoning approach and avoid potential clinical errors. Finally, collaborative relationships provided graduates with the opportunity to gain insight into diverse clinical experiences and helped to speed up the development of their own diagnostic reasoning process:
‘I use my coworkers to bounce ideas and we problem solve together [...] it's invaluable to have different perspectives from different people.”

‘The group discussions help [...] fill in the holes that you might have missed. This has helped speed up my own diagnostic process whether or not I experienced those things first hand.’

Interviewees indicated their current difficulty with clinical problem-solving varied on a case-by-case basis, with many still struggling when faced with a complex or unknown problem. With some experience, interviewees generally felt confident in their abilities and found that the process of problem-solving became easier over time. One respondent found that the process of problem-solving became easier over time because they had sufficient experience “to draw on” and had developed their pattern recognition abilities enough to know “what works and what doesn’t”.

Theme Three: Modification to Approaches to Diagnostic Reasoning

After discussing how they coped and adjusted to the demands of practice, graduates were able to explain how their approach to diagnostic reasoning, perceptions of competence, and use of problem-solving strategies changed as they spent more time in practice. When prompted to work through a case example and provide insight into their diagnostic reasoning approach in practice, interview participants indicated they relied on diagnostic tools, key words in the patient’s presenting complaint and case history, and their gut feelings/instinct.

Graduates identified POVMR, Hypothetico-Deductive Reasoning, differential lists, and SOAP Records as their preferred diagnostic reasoning tools when working through the interview case example. Graduates viewed these tools to be a reliable way to tackle each case step-by-step, as the tools assisted them in making educated assumptions about the list of likely differential diagnoses and develop a treatment plan. A majority of graduates mentioned differential lists as their most utilized tool when problem-solving in practice. Differential lists and SOAP Records were specifically singled out as “irreplaceable tools” because they simplified the process of “prioritizing diagnostics” and allowed for case information to be separated and presented in an easy to follow visual format. While they still utilized
and relied on these tools, graduates found that their current approach to diagnostic reasoning was to pick and choose aspects of each tool to fit the demands of the case after spending more time in practice:

“I like that they [all methods] are all organized like you can pick out the key important points, use that to guide test selection, then add the results of the tests. A lot still applies.”

Respondents indicated that the use of key words in the patient’s presenting complaint and case history to drive their diagnostic process was often dictated by how frequently the owners mentioned these words. In the interview case example, this included looking for clinical features and keywords that were indicative of bad health (e.g., bad breath, drooling) (Figure 1). Respondents explained that owner emphasis on certain terms or events in the case history impacted how they prioritized the needs of the owner and patient. When faced with a “red flag” or standout term, respondents indicated it would often set them out on a completely new process or direction of problem-solving. Difficulties in identifying key terms or developing “tunnel vision” however, was specified as something that would impede their diagnostic process and result in the production of an overly long list of differentials:

“I felt like it was hard to prioritize diagnoses, or I would have a long list of differentials.”

“It was hard to prioritize which was important because I find that a lot of our clients are cost restricted, so I find I have to come down to a really small differential list really quickly to save funds for potential treatment.”

Several participants expressed that a difficulty in developing a list of differential diagnoses and a treatment plan in turn negatively affected their treatment course, as they found that they often had an overwhelming number of differentials and were unable to decide which ones pursue further.

Interviewees revealed that, over time as they gained clinical experience, they relied less on diagnostic tools and more on keywords and their instinct/gut feelings to refine their diagnostic reasoning process. Respondents specified that they tried not to use key words and pattern recognition as their primary approach to diagnostic reasoning because they “did not want to jump to any conclusions before approaching the case properly.” Participants would utilize key words provided by the owner to separate important information from filler content, and to refine and verify their differential diagnoses list. Respondents recalled that unlike their initial experiences in problem-solving, where one or two distracting
terms could derail their reasoning process, they now used these terms to build towards a diagnostic outcome or resolution. Feedback from participants suggested that as they gained clinical experience, the appearance of clinically irrelevant terms would not cause them to “jump to conclusions”, but rather would help them “look for abnormalities or new things for future cases”. Finally, respondents that mentioned “instinct/gut feelings” as a guiding approach to problem-solving were unable to elaborate or provide further clarity on how this heuristic factor facilitated their reasoning process. They simply described it as something that was “instinctive” with one participant stating that it served as the “fundamental basis of everything” they did.

Discussion

Responses from both the surveys and one-on-one interviews reported a challenging transition from the role of student to veterinarian. In the present study, interview respondents identified content overload in the DVM program, difficulties connecting knowledge and theoretical concepts to cases, and the consequences associated with diagnostic error as factors that negatively impacted their transition into practice. Despite these difficulties, at the time of the interview, graduates expressed that they were able to cope and gain confidence in their clinical capabilities and competency in practice over time.

Both survey and interview respondents reported experiencing a steep learning curve when transitioning from a student role to that of a veterinarian and found that this experience greatly impacted their initial perceived difficulty of the diagnostic reasoning process in practice. Research suggests that the level of difficulty faced by graduates during this transition and the initial period in practice can have implications on their skill acquisition, self-confidence, and professional development in practice.1,5,7,32,33 However, specific factors impacting this critical period have received minimal attention in veterinary research.3,6,12,34

Similar to our findings, Vinten et al (2016) reviewed skill development in veterinary students, and identified content overload and a lack of clinical experience as factors that impeded skill development in practice.12 Research suggests that content overload can result in students acquiring a superficial grasp of a wider range of topics, which can impede the problem-solving process when faced with an unknown or
difficult problem.\textsuperscript{9,33} For some graduates in this study, content overload impeded both their understanding of complex problems in practice, and their application of relevant knowledge and theoretical principles to clinical situations.

Competency in developing and prioritizing differential diagnoses and treatment plans are essential skills for veterinarians, however little is known about the concepts underlying these processes or what aspects of clinical practice for new graduates result in difficulties in completing these tasks.\textsuperscript{35} A potential explanation for these challenges may be a failure to connect and apply knowledge gained in the classroom to poorly structured problems.\textsuperscript{9,20,36} According to Smith (2008), this theory-practice gap can result in the production of an excessively long list of differential diagnoses or suggested tests without a clear direction for the treatment plan.\textsuperscript{9} Both interview and survey respondents identified developing and prioritizing differential diagnoses as the most difficult part of problem-solving in clinical practice post-graduation. For interview respondents in our study, this gap could, in addition to producing an overly long list of differentials, block them from being able to progress through the case and develop a treatment plan. The challenge of bridging the divide between the theoretical concepts and knowledge required for classroom learning (structured problem-solving) versus clinical practice (ill-defined problem-solving) has been identified as an ongoing challenge in veterinary education. This may be because students face difficulties when engaging in independent, real-world clinical decision making where they are not able to both observe and actively participate in, the application of knowledge. This is in complete contrast to what occurs in classroom learning to guide skill development.\textsuperscript{36,37,38} This was corroborated by interview respondents who reported that they felt their programs provided them with the necessary knowledge and information, but still felt unprepared for practice and experienced difficulties independently problem-solving. This feedback contradicts previous research on graduates from other veterinary programs, who reported gaining both a strong understanding of theoretical concepts as well as practical skills from their programs.\textsuperscript{3,39} Addressing this theory-practice gap is important in order to optimize the professional development and self-confidence of veterinary graduates, as well as the perceived competence of graduates by owners and colleagues in the workplace.\textsuperscript{12,20}
The heightened responsibility and consequences associated with diagnostic error impacted how difficult interview respondents in our study found problem-solving in practice. This apprehension is not uncommon, as veterinarians are often faced with needing to provide a diagnostic plan that balances the demands and restrictions of the owner while also maintaining ethical responsibility to the patient.40 The bulk of clinical experiences gained by veterinary students during their training is under supervised conditions where they are not given complete autonomy. Interview respondents in our study considered the classroom as a safe place to make diagnostic errors and engage in deliberate practice, where lack of responsibility and consequences was a key environmental factor. By contrast, Vandeweerd et al (2012) found that veterinarians did not view their schools to be an ideal environment to experience diagnostic errors, as any learning from these experiences was viewed as theoretical and not useful in building their clinical proficiency.37 Research overwhelmingly suggests that incorporating real life factors like “responsibility” into the diagnostic reasoning process at the classroom level may be an effective way to guide skill development in accordance with the realities of clinical practice.1,12,41,42 Interview participants in our study agreed that clinical experiences that lacked responsibility and consequences of error affected their transition into practice and contributed to feelings of self-doubt, paranoia and low self-confidence. According to Vinten et al (2016), while it may be difficult to incorporate these factors into the DVM program, it is better to address this issue at a curriculum level instead of this learning occurring beyond graduation.12 Unfortunately, completely integrating factors such as “responsibility” and “consequences of diagnostic error” into an already over-packed veterinary curriculum is difficult and is limited by ethical and animal welfare restrictions.40,43,44 These limitations require students and recent graduates to be self-motivated, seek feedback, and constantly engage in critical reflection to improve their diagnostic reasoning skills, however this may be difficult for graduates that are already feeling overwhelmed and lacking confidence in their clinical abilities.45,46 Further research on the role of factors such as “responsibility” and “consequence” as they relate to diagnostic skill development is necessary, as it may be relevant for clinical educators to address this before veterinary students enter an environment where the consequences of clinical error are higher.
Contributing factors to DVM graduates building confidence and professional autonomy upon entering practice remain unclear. In our study, despite graduates experiencing a difficult transition into practice, most learned to cope with the demands of practice through collaborative relationships with colleagues and gaining clinical experience. Interview and survey participant preferences for collaborating with senior veterinarian or colleagues for support and guidance during the initial clinical period is consistent with existing literature. Vanderweerd et al (2012) evaluated the diagnostic decision-making process in veterinarians and revealed that it was common for less experienced veterinarians to refer to more experienced practitioners when presented with unknown or difficult cases. Additional experience and the exposure to a variety of cases in practice equipped graduates with more efficient diagnostic reasoning skills which resulted in a narrower range of differential diagnoses. Graduates were able to develop a well-thought out treatment plan by developing self-confidence in their knowledge base, improved pattern recognitions skills, and stronger clinical capabilities. Similar to our findings, a study by Dhinsa et al (Chapter Two, unpublished data) showed that the self-confidence and perceived proficiency of DVM graduates improved once they had spent more than six months in clinical practice.

To our knowledge, this is the first study in veterinary medicine that used graduate feedback when working through a standardized sample case to examine changes in their diagnostic reasoning and problem-solving approach. Using an example case is an effective way to gain insight into how individuals navigate clinical information and problem-solve. It is important to understand how veterinary practitioners navigate clinical information presented in cases and how this informs their decision-making process, as it impacts animal care, client satisfaction, and veterinary education. Both e-survey and interview respondents in this study indicated a preference for data driven, comprehensive tools such as POVMR, SOAP Records, and Hypothetico-Deductive Reasoning. There has been little research on these diagnostic tools such as POVMR and SOAP Records, however, the Hypothetico-Deductive Reasoning approach has received some attention in veterinary research as a supportive learning strategy that promotes the acquisition of knowledge and data-driven schemata. Existing evidence on tools used to facilitate diagnostic skill development is inconclusive and highlights an area for further study.
Furthermore, as few publications have reported on this topic in veterinary medicine, our current understanding of this process is largely confined to research in human medicine. The use of keywords to guide decision making is an approach used by students across medical and veterinary disciplines and is reflective of their pattern recognition skills. For interview participants in this study that had spent at least three months in practice, rapid separation of key words and retrieval of relevant knowledge suggested a strong grasp over diagnostic reasoning and pattern recognition. Interviewees indicated that this process was guided by their instincts, or gut feelings, even though they could not elaborate on what that meant. Instinct, however, may not be a reliable method for recent graduates that lack extensive clinical experience and are new to independent clinical decision making. It was noted by participants however, that as they gained experience, their approach to diagnostic reasoning shifted from a strict reliance on specific tools, to one that involved a mixed approach composed of components of various diagnostic tools, their instinct, and pattern recognition. This change may be indicative of strong reasoning skills as experienced clinicians often use a combined approach when problem-solving in practice. The adoption of an additive approach to diagnostic reasoning composed of multiple strategies and aids (e.g., POVMR, HDR, SOAP Records, pattern recognition) that explicitly describes the potential relationship between signs and subsequent diagnoses, appears to be advantageous. With this end goal in mind, it may be beneficial to introduce a mixed or combined approach to problem-solving within veterinary student training, as a way to encourage students to think as clinicians starting from the time they enter into the program and throughout their training up to graduation.

Limitations

Survey response rate was not reported because it was not possible to determine the number of participants listed in the CVO’s LISTSERV recruitment email. The estimated survey response rate (13.8%) was omitted from the results as it may be an overrepresentation of the actual response rate.

Second, potential personal biases associated with opinion-based data (i.e., graduate feedback in the one-on-one interviews) may have influenced the findings and may limit the generalizability of our
findings. As such, because graduates were asked to critique how well their respective DVM programs prepared them for practice, their opinions may have been overly critical or positive depending on their perceptions of their institution overall. Similarly, graduate responses on their experiences in practice may be subject to bias and influenced by factors such as a negative transition into practice and their perceptions of senior veterinarians and colleagues at their clinic.

Finally, depending on how long they have been in practice, the interview participants recollection and responses on their initial period in practice may be subject to recall bias.

Conclusion

Recent veterinary graduates in this study experienced a difficult transition from the student to veterinarian role upon graduation, which impacted how they subsequently developed their diagnostic reasoning skills in practice. Interviews with recent graduates identified content overload in the DVM program, a theory-practice gap, and fear of diagnostic errors as factors that inhibited a successful transition into practice. These experiences had varying implications on how graduates approached diagnostic reasoning and how this process changed as they were exposed to the demands of practice. Over time, through collaborations with colleagues and gaining knowledge and self-confidence, veterinary graduates in this study were able to cope and adjust to the demands of clinical practice. This study provides a unique insight into the experiences and perceptions of recent veterinary graduates in skills like diagnostic reasoning and clinical problem-solving within the classroom and clinical practice settings. Present findings serve to enhance the understanding of clinical educators in veterinary medicine and provide a novel insight into the experiences of recent graduates, and their thoughts about how the DVM curriculum prepared them for their early days in practice.
REFERENCES


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### E-Survey Questions

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<td>1. What year did you graduate from the DVM program?</td>
<td>- 2014</td>
</tr>
<tr>
<td></td>
<td>- 2015</td>
</tr>
<tr>
<td></td>
<td>- 2016</td>
</tr>
<tr>
<td></td>
<td>- 2017</td>
</tr>
<tr>
<td></td>
<td>- 2018</td>
</tr>
<tr>
<td>2. When you first graduated how challenging was it for you to solve clinical situations - to arrive at a diagnosis and plan for treatment?</td>
<td>- Extremely challenging</td>
</tr>
<tr>
<td></td>
<td>- Very challenging</td>
</tr>
<tr>
<td></td>
<td>- Moderately challenging</td>
</tr>
<tr>
<td></td>
<td>- Slightly challenging</td>
</tr>
<tr>
<td></td>
<td>- Not challenging at all</td>
</tr>
<tr>
<td>3. What aspect of diagnostic reasoning did you find most challenging when you first graduated?</td>
<td>- Making a problem list</td>
</tr>
<tr>
<td></td>
<td>- Making a list of differential diagnoses</td>
</tr>
<tr>
<td></td>
<td>- Planning initial diagnostic tests that were relevant, and useful</td>
</tr>
<tr>
<td></td>
<td>- Refining the differential diagnostic list.</td>
</tr>
<tr>
<td></td>
<td>- Making a relevant treatment plan</td>
</tr>
<tr>
<td></td>
<td>- Other</td>
</tr>
<tr>
<td>4. When you first graduated what tools did you use to help you problem-solve? Check all that apply.</td>
<td>- Ask for help from a senior veterinarian in the practice.</td>
</tr>
<tr>
<td></td>
<td>- Ask for help from a technician in the practice.</td>
</tr>
<tr>
<td></td>
<td>- Textbook and course notes.</td>
</tr>
<tr>
<td></td>
<td>- Veterinary Information Network (VIN)</td>
</tr>
<tr>
<td></td>
<td>- Online resources (Plumb, Merck Manual, etc.)</td>
</tr>
<tr>
<td></td>
<td>- Other (specify).</td>
</tr>
<tr>
<td>5. In your first three (3) months in practice after graduating, how often did you need that help or use those resources that were available?</td>
<td>- Multiple times per day</td>
</tr>
<tr>
<td></td>
<td>- Once a day</td>
</tr>
<tr>
<td></td>
<td>- Multiple times per week</td>
</tr>
<tr>
<td></td>
<td>- Weekly</td>
</tr>
<tr>
<td></td>
<td>- Rarely</td>
</tr>
</tbody>
</table>

### Semi-Structured Interview Guide

<table>
<thead>
<tr>
<th>Question</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where and when did you graduate?</td>
<td></td>
</tr>
<tr>
<td>2. When you first graduated, how challenging was it for you to solve clinical problems - to arrive at a diagnosis and plan for treatment?</td>
<td>- What is the reasoning or rationale behind your score?</td>
</tr>
<tr>
<td></td>
<td>- Has this [your score / feelings of being challenged] changed overtime? Please explain.</td>
</tr>
<tr>
<td>3. What was it about diagnostic reasoning that was difficult for you when you first graduated?</td>
<td>- Following graduation when you were confronted with a case you had never seen before, what made it hard to work through that?</td>
</tr>
<tr>
<td>4. Did the approaches to the diagnostic process that you learned in vet school help you work your way through cases during school (exams, rotations)?</td>
<td></td>
</tr>
<tr>
<td>5. What method or approach to diagnostic reasoning did you use when you first graduated? Please provide the names of these tools or resources (approximately 1-2)</td>
<td>- Do you still use that method today? Why or why not?</td>
</tr>
<tr>
<td></td>
<td>- What was it about those tools that attracted you to using them?</td>
</tr>
<tr>
<td>6. Have you amended or altered that method in some way so that it works better for you?</td>
<td>- If yes, can you describe the amendment and its process?</td>
</tr>
<tr>
<td>7. Finally, to further understand and assess your approach within a clinical context we will go through a short</td>
<td></td>
</tr>
</tbody>
</table>
6. **What approaches to the diagnostic process did you learn in veterinary school? Check all that apply.**
- Problem Oriented Veterinary Medical Record (POVMR)
- Exhaustive Approach to Differential Lists
- Comparison Tables or Flow Charts
- Hypothetico Deductive Reasoning Method
- The Four Phases of Medical Problem-solving
- The DAMNIT Mnemonic
- None
- Other

7. **Please indicate how useful you found the _____ method (selected in question six) in helping you develop your diagnostic reasoning skills.** *
- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

* participants were asked this question for each approach they had selected in question six.

---

Example. The purpose of this example is to see how you work through a case and assess what approaches you use.

Mrs. P., one of your regular clients, brings “Max” her 6-year-old Labrador Retriever in to your clinic. She says the dog has developed very bad breath. She also explains that her grandson has been visiting and playing with the dog a lot, and that “Max” has also been drinking more than usual recently and drooling a lot.

- How would you approach this case?
- How do you sort through the information provided by the owner and separate what information is important and what is not?
- Does your previous experience with a similar case impact how you approach a new patient? If yes how?
- What makes the process different the next time you see a similar case?

---

**Figure 1: Survey Questionnaire and Semi-Structured Interview Guide Utilized in Mixed Methods Data Collection.** A component of the semi-structured interview guide included a fictional sample case to assess the participants diagnostic reasoning and clinical problem-solving approach.
Figure 2: Thematic map of major themes identified from interview participant responses. Major themes, sub-themes, and their connections, as identified during thematic analysis, are reported.
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Tables

Table 1: Frequency Distribution of Survey Respondents. DVM Cohort, frequency distribution, and percent frequency are reported.

<table>
<thead>
<tr>
<th>DVM Cohort</th>
<th>Frequency</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>2015</td>
<td>24</td>
<td>29.6</td>
</tr>
<tr>
<td>2016</td>
<td>32</td>
<td>39.5</td>
</tr>
<tr>
<td>2017</td>
<td>15</td>
<td>18.5</td>
</tr>
<tr>
<td>2018</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 2: Perceived Difficulty in Solving Clinical Problems Following Graduation. Cohort specific and overall mean difficulty scores are reported.

<table>
<thead>
<tr>
<th>DVM Cohort</th>
<th>Mean Difficulty Score (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>3.0 (.)</td>
</tr>
<tr>
<td>2015</td>
<td>2.8 (0.8)</td>
</tr>
<tr>
<td>2016</td>
<td>2.7 (0.8)</td>
</tr>
<tr>
<td>2017</td>
<td>2.3 (0.9)</td>
</tr>
<tr>
<td>2018</td>
<td>2.7 (0.7)</td>
</tr>
<tr>
<td><strong>Overall Mean Score</strong></td>
<td><strong>2.7 (0.8)</strong></td>
</tr>
</tbody>
</table>

1= Extremely Challenging, 2= Very Challenging, 3= Moderately Challenging, 4= Slightly Challenging, 5= Not challenging at all.
Table 3: Recent Graduates’ Preferences for Frequency of Selecting Diagnostic Aids when Solving Clinical Problems. Frequency distribution, percent distribution, and comparison between cohorts’ responses using the Pearson Chi-Square test, are reported.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Frequency of Selecting Diagnostic Reasoning Tool by Cohort YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Senior Veterinarian</td>
</tr>
<tr>
<td>2014 (n=1)</td>
<td>1</td>
</tr>
<tr>
<td>2015 (n=24)</td>
<td>23</td>
</tr>
<tr>
<td>2016 (n=32)</td>
<td>31</td>
</tr>
<tr>
<td>2017 (n=15)</td>
<td>12</td>
</tr>
<tr>
<td>2018 (n=9)</td>
<td>9</td>
</tr>
<tr>
<td>Frequency (N=81)</td>
<td>76</td>
</tr>
<tr>
<td>Percent (%)</td>
<td>93.8</td>
</tr>
<tr>
<td>Pearson Chi-Square P-Value</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Table 4: Recent Veterinary Graduates’ Ratings on the Usefulness of Common Diagnostic Reasoning Tools. Cohort specific and overall mean usefulness scores, and comparison between cohorts’ responses using a Wilcoxon Rank Sum Test, are reported. Significant p-values prompted post-hoc pairwise comparisons using the Kruskal Wallis test to determine any significant differences in responses by year and between two cohorts for the DAMNIT Mnemonic.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>POVMR Mean Score (SD)</th>
<th>Exhaustive Approach to Differential List</th>
<th>Comparison Tables or Flow Charts</th>
<th>Hypothetico Deductive Reasoning Method</th>
<th>The Four Phases of Medical Problem-Solving</th>
<th>DAMNIT Mnemonic Mean Score (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>2.0 (. )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.0 ( . )</td>
</tr>
<tr>
<td>2015</td>
<td>2.0 (0.9)</td>
<td>2.3 (0.5)</td>
<td>3.0 (1.0)</td>
<td>3.0 (1.4)</td>
<td>3.0 ( . )</td>
<td>3.0 (1.3) b</td>
</tr>
<tr>
<td>2016</td>
<td>1.8 (0.8)</td>
<td>2.7 (1.4)</td>
<td>3.2 (1.5)</td>
<td>2.3 (1.0)</td>
<td>1.5 (0.7)</td>
<td>2.2 (1.3) a</td>
</tr>
<tr>
<td>2017</td>
<td>2.7 (1.1)</td>
<td>3.6 (1.5)</td>
<td>7.0 ( . )</td>
<td>3.6 (2.0)</td>
<td>0</td>
<td>3.8 (1.8) b</td>
</tr>
<tr>
<td>2018</td>
<td>1.8 (0.4)</td>
<td>2.5(0.5)</td>
<td>2.5 (2.1)</td>
<td>1.7 (0.5)</td>
<td>4.0 ( . )</td>
<td>2.3 (0.5)</td>
</tr>
<tr>
<td>Mean Score (SD)</td>
<td>2.0 (0.9)</td>
<td>2.8 (1.2)</td>
<td>3.4 (1.8)</td>
<td>2.6 (1.3)</td>
<td>2.5 (1.3)</td>
<td>2.7 (1.3)</td>
</tr>
<tr>
<td>Exact P Value</td>
<td>0.38</td>
<td>0.71</td>
<td>0.48</td>
<td>0.12</td>
<td>0.50</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

1= Extremely useful, 2= Moderately useful, 3= Slightly useful, 4= Neither useful nor useless, 5= Slightly useless, 6= Moderately useless, 7= Extremely useless.

§ Degenerative or Developmental, Anomalous or Autoimmune, Metabolic, Mechanical or Mental, Nutritional or Neoplastic, Inflammatory, Infectious, Ischemic, Immune-mediated, Iatrogenic or Idiopathic, Traumatic or Toxic

a,b Within the DAMNIT column, cohorts with differing superscripts indicated a significant difference in tool usefulness.

Note: * p <0.05
CHAPTER FOUR

Conclusion and General Discussion

Proficiency in core clinical skills such as diagnostic reasoning, clinical judgement, and problem-solving is critical for success in veterinary practice, yet little is presently known about how veterinary students acquire these skills, or how they are best taught in the veterinary curriculum.\textsuperscript{1,2} The transition from student to practicing veterinarian is influenced by a student’s individual knowledge base, prior clinical experience, and proficiency in both technical and non-technical skills (e.g., communication, interpersonal skills, self-confidence). The DVM program, in addition to providing students with a comprehensive knowledge base, should foster an enriching environment where students are able to develop their skills, gain critical clinical experience, and enter practice self-assured and confident in their abilities. The objectives of the research in this thesis were therefore to assess the relationship between self-confidence and diagnostic skill development in DVM students at the OVC, evaluate what specific aspects of the diagnostic reasoning process recent graduates found challenging, and examine how recent DVM graduates approached diagnostic reasoning post-graduation.

Surveys from DVM students during their program indicated a lack of self-confidence and low perceived proficiency in three important clinical competencies: diagnostic reasoning, problem-solving, and clinical judgement. Self-confidence scores of the 2017 and 2018 OVC graduating cohorts declined for these three competencies as students progressed through Years 1-3 of the DVM program, corresponding with increasing complexity of the associated learning outcomes. These scores stabilized during their externship placements after Year 3 and throughout their final year in the DVM program, and further improved six months post-graduation. The reasons behind improved self-confidence and perceived proficiency scores six months post-graduation were elucidated through one-on-one interviews reported in Chapter 3. Veterinary graduates (2014-2018) identified content overload in the DVM program, a theory-practice gap once they entered practice, and a fear of making diagnostic errors, as factors that contributed to a difficult transition from a student to veterinarian role. Feedback from recent graduates suggested that,
over time, they were able to cope with the demands of practice and reported improved self-confidence, clinical proficiency, and diagnostic reasoning ability. Participants attributed this change in self-confidence and diagnostic ability to gaining more experience in practice and to the utilization of tools and methods (e.g., SOAP Records, POVMR) taught to them during the DVM program as well as through consultation with more experienced colleagues. This research highlights areas for further study specifically surrounding how the teaching of diagnostic reasoning skills could be approached in the DVM program, and how student feedback can be utilized to identify areas for improvement in program content and delivery.

Low self-confidence scores and feedback from recent graduates in this study corroborates previous research which suggested that academic performance may not provide educators with a full picture of a student’s competency, employability, and future success as a veterinarian. To elaborate, while recent veterinary graduates display extensive knowledge bases and are clinically competent, they may be lacking critical "skills, knowledge, aptitudes, and attitudes” (e.g., self-confidence) that predict clinical success. According to a study by Heath et al (2002) on veterinary employability criteria, “appearing self-confident” and “seeking assistance when necessary” were found to be the most highly sought after personal attributes by Australian employers. This is because employers expected the veterinary programs to equip graduates with the necessary factual knowledge and technical skills, and recognized that employee hiring could be further enhanced from also assessing professional skills and qualities required for success as a veterinarian. Conlon et al (2012) surveyed licensed Ontario veterinarians, OVC students, faculty, interns and residents to gain insight into the personal characteristics that were regarded as the most important attributes of a veterinarian. Of the 25 characteristics assessed, respondents identified ethical behavior, sound judgement, communication, and critical and creative thinking as the top attributes they would look for when granting admission to the DVM program. Other studies on critical success factors in veterinary medicine have highlighted a need for training in areas of interpersonal characteristics and self-confidence. Beyond providing students with the experience and
knowledge to build competency and proficiency in clinical skills, DVM programs should foster personal growth in their students.\textsuperscript{5,10}

Veterinary students and recent graduates surveyed for this research highlighted areas that they felt would benefit from improvement within the DVM program. These recommendations, covered in depth in the next section, address changes to the program's content and delivery to improve self-confidence and perceived proficiency, ease the students’ transition into clinical practice, and enhance employability. Cake and colleagues (2018), in their report on employability and resilience in the context of veterinary medicine, defined employability as a “set of adaptive personal and professional capabilities that enable a veterinarian to gain and sustain employment, contribute meaningfully to the profession and develop a professional pathway that achieves satisfaction and success”.\textsuperscript{4} The report highlights that veterinary educators can support skill acquisition in practice by explicitly defining the factors required for clinical success and by providing learning opportunities that require students to balance the needs and expectations of employers, clients and owners.\textsuperscript{4} Walsh et al (2002) similarly highlighted steps that veterinary educators and individuals involved in curriculum design can take to ensure that DVM graduates are sufficiently equipped with the skills and attributes necessary to meet the expectations of clinical practice.\textsuperscript{12} According to Walsh et al (2002), three steps necessary to support a successful transition from veterinary student to clinician include: explicitly defining the attributes that students should have acquired by the time of graduation; conducting routine internal assessments to ensure that students are meeting the expectations of the program; and establishing and conducting external outcome assessments to ensure that the goals of the veterinary program are appropriate in scope and relevant to the current landscape and demands of care.\textsuperscript{12} Emphasis on explicitly defining the capabilities and skills required of veterinary students and graduates for clinical success, and regular curricular reviews, will allow for ongoing improvements in program delivery and is in line with recommendations provided by external stakeholders and governing bodies in veterinary medicine.\textsuperscript{4}
Recommendations for Veterinary Educators and Curricula

As a result of this research, several key elements were identified as significant opportunities for development. These include the need for development of validated tools that measure diagnostic reasoning skills, addressing the content overload of DVM programs that leads to a theory-practice gap once graduates enter practice, and implementing tools that help optimize the transition from the student to the role of the veterinarian at the time of graduation.

Assessing Diagnostic Reasoning Skills

To our knowledge, there are currently no validated tools that properly measure the diagnostic reasoning skills of veterinary students.\textsuperscript{13} Review of literature on clinical skill development in human medicine and nursing has similarly highlighted an absence of existing tools and comprehensive frameworks that properly measure diagnostic skill development and proficiency.\textsuperscript{53,54} There are tools that have shown some promise in assessing diagnostic reasoning in the clinical setting, such as direct observation tools, team-based simulations, and retrospective clinical case analyses.\textsuperscript{54} These tools provide students with the opportunity to reflect upon prior clinical decisions and require the participation of real patients and examiners. These approaches are also adaptable to the clinical environment, can be implemented using real patients or simulated patients, and measure diagnostic reasoning using in-training evaluation reports and assessment tools such as the standardized direct observation tool (SDOT).\textsuperscript{54} These tools, however, have not been studied as assessment modalities or frameworks to measure diagnostic reasoning, and current research has focused primarily on the educational and instructional value of their use.\textsuperscript{54,55,56} Furthermore, because diagnostic reasoning is a heuristic process that is highly context bound, these tools are susceptible to environmental and individual biases and should not be used as the sole strategy when assessing skill development and proficiency.\textsuperscript{54} Similarly, self-confidence scores provided by students can be influenced by situational factors and personal biases, and therefore may not provide veterinary educators with an accurate evaluation of the student’s actual clinical competence and preparedness for practice.\textsuperscript{14} Furthermore, self-confidence scores, unlike performance measurements, offer little evidence as to whether the DVM program is actually producing competent veterinarians. The
development of assessment tools to accurately measure clinical reasoning competence would be of benefit to veterinary educators.

Reducing the Theory-Practice Gap

Veterinary medicine and other professional programs have a history of content-heavy curricula wherein the consistent addition of new knowledge and information occurs, often without the appropriate trimming away of old material. Interviewees in our study overwhelmingly commented that the large amount of content in the DVM program limited both a comprehensive acquisition of theoretical knowledge and their ability to apply this knowledge when faced with an unfamiliar or complex case in practice. This content overload impeded their diagnostic skill development as they progressed through the DVM program and contributed to a difficult transition into practice. Graduates entered practice with a wealth of knowledge but found it difficult to sort through their knowledge bank to develop a prioritized diagnostic and treatment plan.

There are several potential approaches to dealing with content overload in a program. Earlier streaming within a DVM program may help to reduce extraneous information and encourage students to undergo deep learning in fewer topics of greater interest. Furthermore, veterinary medicine has become increasingly complex, and owners now demand a very high level of medical and surgical options for their animals. As a by-product of this complexity, one wonders whether it is reasonable to expect a DVM student to learn and understand such a wide range of factual information for all species, in just four years. Malcolm Knowles’ adult learning theory (ALT), states that students should be provided “experiential opportunities that are relevant to their career aspirations”. The British Veterinary Association and the Royal College of Veterinary Surgeons also recommend early specialization for the modern veterinary student. One potential complication of earlier streaming, however, is the nature of the licensing examination, which continues to test clinical knowledge of all veterinary species given that successfully passing the examination results in a veterinary license that is not limited in scope. Since the licensing examination is intended to assess skills of the general veterinary practitioner, students should recognize that their training is intentionally broad, and be coached to recognize that achieving depth in specific
areas of training is intended for after graduation, through pursuing continuing education opportunities in areas of professional interest to them. By managing the expectations of students regarding the scope and intent of a DVM program, students are less likely to measure their own training against the performance of specialty clinicians and interpret that they are unprepared as a graduate. In the long-term however, it may be relevant to explore whether the licensing examination can be changed to provide students with the option to either gain general licensure or specifically in one species.

Veterinary educators can also incorporate learning strategies and pedagogical methods into the curriculum that can best manage the content overload in the DVM program. Research and comprehensive curricular reviews of medical curricula suggest that active learning approaches are a promising approach to content management. Active learning is an educational approach that has demonstrated considerable success within pedagogical research and in the management of content heavy curricula, specifically within human medicine. This approach promotes deep learning and the development of higher-order reasoning skills by requiring students to engage with educational content through active reflection (e.g., critical reflection logs), collaboration with colleagues (e.g., practise cases and problems), and critical thinking exercises. Cognitive and educational psychologists have highlighted active learning as a successful method to help students navigate content overload. Active learning also supports long-term knowledge acquisition and translation to real-life situations. It is advantageous for students to refer to this strategy, which shifts learning acquisition away from memorizing content towards promoting deep learning and provides students with the resources to develop a comprehensive knowledge framework. As students become more comfortable with this approach, they may also find it easier to apply it in their clinical externships and rotations when working through a long or complicated patient presentation and history, or when faced with biasing influences (e.g., situational factors). This approach should, over time, strengthen both their clinical reasoning skills and their ability to retrieve relevant information for immediate case application. Ideally then, when students are presented with a difficult case in practice, they will be able to sort through the case information and their knowledge base, isolate the
clinical descriptors (e.g., semantic qualifiers) and link them to pertinent illness scripts, in order to reach a diagnostic outcome.\textsuperscript{30,31}

Furthermore, because it is difficult to reduce the amount of information in a DVM program, clinical educators can “scaffold” student learning using appropriate case-based learning materials for the stage of the program, thereby teaching students how to navigate program content in accordance with skill development.\textsuperscript{31,32} Scaffolded learning, within a pedagogical context, is characterized by the progressive addition of new information and concepts onto existing knowledge gained from the previous program year and across multiple courses.\textsuperscript{31,32} Using a variety of approaches to reduce content and encourage active learning through the use of relevant cases, veterinary educators must continue to manage the content-heavy curriculum to maximize learning and reduce theory-practice gap.

Interview respondents from Chapter 3 indicated that they experienced difficulties connecting theoretical knowledge gained during their DVM programs to cases in practice, and cited factors such as client expectations and an overwhelming caseload as drivers behind this theory-practice gap. Factors like stress and case overload are inherent to veterinary practice and are especially impactful on recent graduates, therefore they are conditions that students must be trained to work under successfully.\textsuperscript{33,34} As such, providing training opportunities for students to practise under controlled conditions of moderate stress, with the requisite support, is another way veterinary educators can help bridge this theory-practice gap. This can be achieved by providing students with problem-solving opportunities that incorporate situational factors, integrate knowledge across courses, and support long term skill development.\textsuperscript{35,36} The introduction of problem-based learning (PBL) and case-based learning (CBL) into the traditional veterinary curriculum has shown some success in bridging the theory practice gap.\textsuperscript{35,37} Howell et al (2002) assessed this in their evaluation of the University of Tennessee College of Veterinary Medicines integration of PBL into the traditional curriculum.\textsuperscript{37} Students were introduced to PBL via week long “Application-Based Learning Exercises” at various points across six semesters and multiple courses.\textsuperscript{37} Graded as a pass/fail these exercises progressively increased in difficulty, focused on one case, and required students to discuss hypotheses, mechanisms involved, clinical errors, and develop their own
diagnostic plan and course for treatment.\textsuperscript{37} Faculty and student assessments showed a positive reaction to PBL, providing evidence for potential curricular modification.\textsuperscript{37} Changes in veterinary pedagogy and clinical education have introduced new ways veterinary educators can incorporate PBL or CBL modules into the curriculum in a less resource-intensive way. The incorporation of short PBL modules at the end of each program year that require integration of information from across multiple courses (e.g., anatomy, radiology, clinical medicine, bacteriology, virology, pharmacology and pathology) holds the potential to provide significant real-life learning opportunities for students. They are however, are recognized as being very resource intensive to deliver effectively. Such exercises would also be a useful way for veterinary educators to evaluate student progress with diagnostic reasoning skills and their general preparedness for clinical practice. Allowing students to make diagnostic errors in a safe environment, such as CBL exercises, has the benefit of building stronger diagnostic reasoning skills.\textsuperscript{31,38} Additionally, providing students with interpersonal (e.g., conflict resolution, client demands) and professional skills necessary for successful veterinary practice is essential, in helping train students to manage their stress, caseload, and external client and owner demands, particularly if this training allows for skill acquisition to occur under conditions that mimic the clinical environment.\textsuperscript{2,39,40} Critical reflections, while an essential component of effective problem-solving and decision making, are not a panacea and their impact may be limited by their tedious and time-intensive nature.\textsuperscript{52}

For veterinary students and recent graduates, much of their clinical experience occurs under structured and controlled environments within a teaching hospital environment, where real animals and clients are a part of the learning process, but access to care and the decisions made are influenced by the nature of the caseload of a referral setting. To address this limitation, veterinary pedagogy should, through approaches like CBL, strive to incorporate the “real life” aspects of clinical decision making reflecting general practice into classes and labs. This approach is best implemented at a gradual pace and integrated through each year in the DVM program, in order to facilitate deep learning, long term skill development, and to give students time to reflect on their experiences in each year of the program.\textsuperscript{35,41} According to Vinten (2016), it is paramount to align the curriculum approach to diagnostic reasoning and clinical
problem-solving to “the true nature” of these competencies in clinical practice.\textsuperscript{42} Adopting this approach to teaching will allow veterinary educators to deliver the knowledge and technical skills required to address professional and personal (e.g., stress, isolation, burnout) challenges impacting the transition into practice.\textsuperscript{3,4} Recent advancement in the field of experiential education suggests that the integration of CBL and simulation technology offers a novel ways to address challenges like decreased teaching time for clinical faculty, shortened appointment times, and ethical and welfare concerns associated with teaching using real live animals.\textsuperscript{43,44,45}

Addressing Mental Health Challenges Facing Veterinary Students and Graduates
Feelings of stress, being overwhelmed, and doubting the validity of their knowledge and clinical capabilities, were frequent comments made by interviewees in Chapter 3, especially when independently problem-solving in practice. This feedback is not surprising, as a growing amount of research has reported veterinarians experiencing elevated levels of stress, anxiety, fatigue, and suicidal thoughts.\textsuperscript{4,46} These elevated mental health risks may extend to the transition into clinical practice as this is a stressful period for recent graduates.\textsuperscript{34,46} Veterinary programs should provide students with ongoing mental health support, initiatives, and programs to build their resilience and self-confidence. In accordance with recommendations from the Merck Animal Health (MAH) Veterinary Wellbeing Study, veterinary programs should continue to develop and publicize mental health resources aimed at addressing key issues highlighted by students. These include keeping a healthy work-life balance, financial management of student debt, and reducing stigma surrounding mental health within the classroom and workplace.\textsuperscript{47}

Future Directions
The research presented in Chapters 2 and 3, alongside previous literature, provides grounds for the consideration of further research looking into the diagnostic skill development of veterinary students and recent graduates.

Further exploration is needed on the relationship between confidence on the development of proficiency in diagnostic reasoning skills within a veterinary context. Contradicting findings in the literature suggests that both overconfidence and under-confidence can have negative implications on
clinical skill development and can hinder the students diagnostic reasoning process. Comparisons between current DVM students and experienced graduates may help describe how self-confidence and perceived proficiency in core clinical competencies (e.g., diagnostic reasoning, problem-solving, clinical judgement) changes as they are able to spend an extended amount of time in practice and gain knowledge. This would not only assist veterinary educators in gauging student readiness for practice, but may also provide validation on whether the yearly DVM program outcomes and bench markers for clinical success are being met.

The relationship between self-confidence and clinical competence after extended exposure to learning strategies such as PBL or CBL modules should be explored. This would provide further evidence as to whether these learning strategies are appropriate methods to achieving yearly program outcomes as highlighted in the DVM curriculum. Implementation of PBL or CBL modules may be appropriate at various phases of the DVM program to assess their effectiveness over time.

Finally, further research should be done in veterinary pedagogy whether clinical performance and diagnostic skill development change when students are presented with the same case at two or more separate occasions (i.e., the start and end of each year in the program or course). A longitudinal study following one cohort or a small group of students given CBL modules at the start and end of a course or program benchmark (e.g., before and after their externships, fourth year clinical rotations) may provide insight into whether their self-confidence when approaching diagnostic reasoning changes as they gain knowledge and clinical experience. These CBL modules should be followed by semi-structured interviews with respondents to gain awareness into a process that is ubiquitous and yet unique to each clinician. This would also be an opportune time to assess what diagnostic reasoning tools are commonly used by veterinary students and graduates, and whether their use may impact their skill development. The specific use of data driven tools (e.g., POVMR, SOAP Records) is, in particular, an appropriate area for further study as it has received little attention in veterinary research, yet underlies how veterinary practitioners navigate information when problem-solving and can have extended implications in animal care, client satisfaction, and veterinary education.
Conclusion

To conclude, as a result of the research studies conducted herein, the recommendations provided in this chapter are intended to inform and support veterinary educators in their delivery and acquisition of skills and knowledge within the DVM program and ease veterinary graduates’ transition into clinical practice. Further study is needed on the success and impact of these approaches on the self-confidence of veterinary students, and in the development of their diagnostic reasoning, problem-solving, and clinical judgement skills.
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APPENDICES
Appendix A: Chapter Three Qualtrics E-Survey
SURVEY ON THE DEVELOPMENT OF DIAGNOSTIC REASONING SKILLS: PERCEPTIONS OF RECENT VETERINARY GRADUATES

This survey is being conducted by Dr. Tracey Chenier, from the Department of Population Medicine, Ontario Veterinary College at the University of Guelph. If you have any questions or concerns regarding this study, please feel free to contact Dr. Tracey Chenier at tchenier@uoguelph.ca or 519-824-4120 ext 54789. The purpose of this survey is to investigate recent DVM graduates’ perceptions of their diagnostic reasoning skills soon after graduation, how useful students found the approaches to diagnostic reasoning that were taught in veterinary school, and what tools new graduates utilize to help them solve clinical cases. This survey should take approximately 10 minutes to complete. People filling out the survey must be over 18 years of age and have graduated from veterinary school within the last 3 years. The REB protocol assigned to this survey is 1705016. You are free to participate in this survey, or not. You may quit the survey at any time and your data will not be stored if you do so. You are not waiving any legal claims, rights or remedies because of your participation in this research study. This study has been reviewed and received ethics clearance through the University of Guelph Research Ethics Board. If you have questions regarding your rights as a research participant, contact:

Director, Research Ethics
University of Guelph
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Fax: (519) 821-5236

Q1: Having read the above, I understand that by clicking the “Yes” button below, I agree to take part in this study under the terms and conditions outlined in the letter of information I received by email.
- Yes, I agree.
- No, I do not wish to take the survey.

Q2: What year did you graduate from your DVM program?
- 2014
- 2015
- 2016
- 2017
- 2018

Q3: When you first graduated, how challenging was it for you to solve clinical situations – to arrive at a diagnosis and plan for treatment?
- Extremely challenging
- Very challenging
- Moderately challenging
- Slightly challenging
- Not challenging at all

Q4: What aspect of diagnostic reasoning did you find most challenging when you first graduated?
- Making a Problem List
- Making a List of Differential Diagnoses
- Planning Initial Diagnostic Tests that were relevant and useful
- Refining the Differential Diagnostic List
- Making a Relevant Treatment Plan
- Other (please specify)
Q5: When you first graduated what tools did you use to help you problem solve? Check all that apply.
- Ask for help from a senior veterinarian in the practice
- Ask for help from a technician in the practice
- Textbooks and Course Notes
- VIN (Veterinary Information Network)
- Online resources (Plumb, Merck Manual etc.)
- Other (please specify)

Q6: In your first three (3) months in practice after graduating, how often did you need that help or use those resources that were available?
- Multiple times per day
- Once a day
- Multiple times per week
- Weekly
- Rarely

Q7: In your first three (3) months in practice after graduating, how often did you need that help or use those resources that were available?

Q8: What approaches to the diagnostic process did you learn in veterinary school? Check all that apply.
- POVMR (Problem Oriented Veterinary Medical Record)
- Exhaustive Approach to Differential List
- Comparison Tables or Flow Charts
- Hypothetico-Deductive Reasoning Method
- The Four Phases of Medical Problem-Solving
- DAMN-IT Mnemonic
- None
- Other (please specify)

Q9: Please indicate how useful you found the POVMR method was in helping you develop your diagnostic reasoning skills.
- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

Q10: Please indicate how useful you found the Four Phases of Medical Problem-Solving method was in helping you develop your diagnostic reasoning skills.
- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless
Q11: Please indicate how useful you found the Hypothetico-Deductive Reasoning Method was in helping you develop your diagnostic reasoning skills.

- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

Q12: Please indicate how useful you found the Exhaustive Differential Method was in helping you develop your diagnostic reasoning skills.

- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

Q13: Please indicate how useful you found comparison tables and flow charts were in helping you develop your diagnostic reasoning skills.

- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

Q14: Please indicate how useful you found the DAMN-IT method was in helping you develop your diagnostic reasoning skills.

- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless

Q15: Please indicate how useful this [other] method taught was in helping you develop your diagnostic reasoning skills.

- Extremely useful
- Moderately useful
- Slightly useful
- Neither useful nor useless
- Slightly useless
- Moderately useless
- Extremely useless
Q16: If you use online resources (e.g VIN, Plumb, etc) do you verify the accuracy of the information you find?
- Yes, I do verify the information I find online.
- No, I do not verify the information I find online.
- Not sure.

Q17: What method of diagnostic reasoning do you use now? Please specify below.

Thank you for participating in this survey and providing your feedback on Diagnostic Reasoning. If you are interested in entering into a draw to win a $25 Amazon Gift Card, please provide your contact information below.

If you have any questions, feel free to contact Dr. Tracey Chenier at tchenier@uoguelph.ca. If you are interested in participating in a one-on-one interview as part of this research project, please click here to provide your contact information.
Appendix B: Chapter Three Semi-Structured Interview Guide
Diagnostic Reasoning Skill Development: Perceptions of Recent Veterinary Graduates

Introduction

Thank you for taking the time to meet with me today for this one-on-one interview.

- My name is Dr. Tracey Chenier and I am researching how recent graduates’ approach clinical problem-solving when presented with a clinical case. I am interested in the methods you use and your thought processes towards assessing your veterinary patients.

Additionally, I am also interested in how your approach to clinical problem-solving may have evolved over time since graduation, and how your veterinary education (specifically, the approaches to diagnostic reasoning that you learned during vet school) may have helped prepare you for practice.

This information will be used to inform the way we teach clinical problem-solving to veterinary students throughout their DVM training.

As you can see, there is a microphone set up to record our conversation for data collection purposes. However, for confidentiality reasons you should know that your name will not be attached to any comments in our report. Verbatim comments from this interview may be used in the report, however no names or identifying information will be attached to those comments. You should also know that your participation is completely voluntary, and you can ask to withdraw from this interview at any point in time if you so wish. If you decide to withdraw, your responses will not be included in the final report and your data will be removed. You are also free to decline or skip answering any question during this interview.

Do you have any questions?

Ok, let’s begin.

Q1: Where and when did you graduate?

Q2: When you first graduated, how challenging was it for you to solve clinical problems – to arrive at a diagnosis and plan for treatment? Please rate your response on a scale of 1-10, with 1 being very easy and 10 being very hard.

Prompts:

- What is the reasoning or rationale behind your score?
- Has this [your score / feelings of being challenged] changed over time? Please explain.

Q3: What was it about diagnostic reasoning that was difficult for you when you first graduated?

Prompts:

- Following graduation when you were confronted with a case you had never seen before, what made it hard to work through that?

Q4: Did the approaches to the diagnostic process that you learned in vet school help you work your way through cases during school (exams, rotations)?
Q5: What method or approach to diagnostic reasoning did you use when you first graduated? Please provide the names of these tools or resources (approximately 1-2)

Prompts:

- Do you still use that method today? Why or why not?
- What was it about those tools that attracted you to using them?

Q6: Have you amended or altered that method in some way so that it works better for you?

Prompts:

- If yes, can you describe the amendment and its process?

Q7: Finally, can you take us through your typical approach to diagnosing a uncommon or unfamiliar problem.

To further understand and assess your approach within a clinical context we will go through a short example. The purpose of this example is to see how you work through a case and assess what approaches you use.

 Mrs. P., one of your regular clients, brings “Max” her 6-year-old Labrador Retriever in to your clinic. She says the dog has developed very bad breath. She also explains that her grandson has been visiting and playing with the dog a lot, and that “Max” has also been drinking more than usual recently and drooling a lot.

Prompts:

- How would you approach this case?
- How do you sort through the information provided by the owner and separate what information is important and what is not?
- Does your previous experience with a similar case impact how you approach a new patient? If yes how?
- What makes the process different the next time you see a similar case?

Concluding Remarks

Before ending the interview, I will be summarizing the key points made and then ask if any comments have been left out.

- We talked about several things that impact how you approach clinical problem-solving. For instance, … What I’ve heard from you is…
- Would you say that this is a good summary of the key things we’ve talked about today?
- Is there anything else that comes to mind in how you approach problem-solving in a clinical situation? Is there anything that should be included that we haven’t mentioned?

Thank you again for taking to participate in this study. Once again, your responses will be completely confidential, and if you withdraw from the study at any point your information and data provided will not
be used. Our study results will be published in a veterinary education journal, and if you are interested in the results, I am happy to provide you with a copy.

Thank you.