



Master's research internship – Faculty of Veterinary Medicine –
Utrecht University & University of Pretoria

The Effectiveness of Veterinary Education on Antimicrobial Resistance in South Africa

A cross-sectional explorative study among
veterinary instructors, students and farmers

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ABSTRACT

Background South Africa is one of the fastest growing economies in the world and experiences a tremendous increase in meat consumption. Antimicrobial use in the livestock sector is prodigious. Combined with poor legislations and major health issues such as tuberculosis and HIV, antimicrobial resistance poses a serious threat to South African humanity. Education of all stakeholders could be an effective tool to tackle the problem. The aim of this explorative study is to investigate the effectiveness of AMR education of veterinary students of the University of Pretoria on creating awareness among the farmer community in South Africa and to identify potential points of improvement.

Methods In the period from November 2017 until May 2018 semi-structured individual and group interviews with 7 veterinary instructors, 28 students and 21 farmers of the Faculty of Veterinary Science in Onderstepoort, University of Pretoria, were organized.

Results The importance of AMR education is recognized by all instructor and student participants. Various courses include AMR related topics, although teaching tools, lack of time and absence of consistency throughout the study programme confine the effectiveness of AMR education. Nevertheless, AMR knowledge of the students seems to be decent. AMR knowledge of farmers seems to be lacking. Communication and cultural barriers are experienced by students and farmers as hurdles that need to be overcome.

Conclusions and recommendations AMR education at the Faculty of Veterinary Science in Onderstepoort is suboptimal. A consensus should be reached within the faculty in order to standardize AMR education throughout the study programme. Students should be prepared for prudent prescribing within the South African sociocultural context. By adopting an international One Health approach, forces could be joined in order to improve AMR education of veterinary and medical students worldwide.

KEYWORDS: antimicrobial resistance, antibiotics, stewardship, South Africa, Onderstepoort, veterinary education, curriculum

Introduction

Antimicrobial resistance is a worldwide problem that affects human as well as veterinary medicine. After the discovery of penicillin by Alexander Fleming in 1928, it took until the early 1940s before this “wonder drug” was widely used as a therapeutic agent against a wide variety of infections, including infections with bacteria that were already resistant to sulphonamides, the only other available antibiotic treatment at that time [1]. Soon the antibiotic era started and many other drugs were discovered to treat bacterial infections [2]–[4]. Nowadays, however, resistance to many of these drugs is widespread among pathogenic bacteria.

Antimicrobial resistance: global impact and interventions

Antimicrobial resistance (from now on AMR) is the genetic adaptation of bacteria that enables them to survive antimicrobial treatments. It is a natural phenomenon, intensified by misuse of antimicrobials [5]. The World Health Organization states that more antimicrobials are used in healthy food-producing animals as growth promoters and prophylaxis than in the treatment of disease in humans. This dominance of the animal side in antimicrobial use emphasizes the major responsibility of the veterinary profession [6]. Difficulties in treatment of bacterial infections in animals as well as humans arise due to the so-called ‘post-antibiotic’ era that we are approaching, causing increased morbidity and mortality and thereby creating an international public health problem [7], [8].

It was estimated that in 2050 drug resistant infections will cause 10 million deaths and financial costs of 100 trillion USD a year [9]. Compared to the current 700.000 people that die from multi-resistant infections each year, this would be an enormous increase, emphasizing the urge to undertake global actions. In May 2015 the World Health Assembly adopted a global action plan to tackle AMR. This plan consists of five objectives: 1) the awareness and understanding of AMR in policy-makers and professionals should be improved; 2) surveillance and research should be strengthened; 3) infections should be reduced; 4) rational use of antimicrobials in human and animal medicine should be encouraged and 5) investment in developing new medicines, diagnostics and vaccines should be increased. In order to reach these goals the need for a One Health approach was emphasized, in which human and veterinary medicine, agriculture, environment, finance and well-informed consumers should collaborate [10]. The World Organisation for Animal Health (OIE) also recognised the importance of the One Health approach and made a substantial contribution to the WHO global action plan [11], [12]. Finally, this multi-sectorial approach was discussed during the United Nations General Assembly in September 2016, where global leaders came together to commit to act on AMR nationally, regionally and internationally. This was only the fourth time a United Nations General Assembly was dedicated to a health issue, emphasizing the size of the global threat of AMR. In the same year, the Sustainable Development Goals were adopted in order to fight inequalities, end poverty and tackle climate change. H.E. Peter Thomson, President of this 71th session of the United Nations General Assembly: “Antimicrobial resistance threatens the achievement of the Sustainable Development Goals and requires a global response” [13].

Antimicrobial resistance in South Africa

South African context of public health

The WHO global national action plan stimulated all Member Nations to develop national action plans to meet the global objectives [10]. Although the goal was to have all national action plans in place by 2017, only 48 national action plans were publicly available in the Library of National Action Plans by the end of 2017 [14]. One of the nations that succeeded in developing a national action plan was South Africa. In 2010, South Africa was officially added to the

former BRIC countries Brazil, Russia, India and China, resulting in the BRICS. These are the fastest growing emerging economies in the world. Their increasing welfare is accompanied by increased meat consumption, resulting in a huge increase of antimicrobial use: the BRICS countries were responsible for 76% of the increase from 54 billion standard units antimicrobials used worldwide in 2000 to almost 74 billion in 2010 [15]. The BRICS are becoming more and more important in international development and global health policy making, although they still face their own health problems as well [16]. In South Africa the burden of infectious diseases in both humans and animals is high, especially in the areas where people live in poverty. These areas are more likely to experience a high burden of AMR as well, since the spread of resistant bacteria is facilitated by overcrowding, poor hygiene, malnutrition and high susceptibility as a result of the high HIV prevalence [17]. HIV and tuberculosis are huge problems in South Africa: in 2016 approximately 7.100.000 people were living with HIV and the incidence of tuberculosis was 438.000 [18], [19]. Combined with the growing AMR problem, this high burden of infectious diseases poses a serious threat to human health in South Africa [20]. Animal health is also affected by the problem of AMR in South Africa. A study in the academic veterinary hospital of the University of Pretoria showed that 63% of the *Staphylococcus* spp. that were found in cat samples, were resistant to one antimicrobial and 15,8% were multidrug resistant [21]. *Staphylococcus* spp. isolates from horse samples from that same veterinary hospital showed high levels of (multidrug) resistance as well [22]. However, generally more attention is paid to the influence of antimicrobial misuse in livestock on AMR development and the burden of AMR on human health.

The livestock sector and antimicrobial resistance in South Africa

Although it is beyond the scope of this report to elaborate on the role of human medicine, it is important to realise that the growing AMR problem in South Africa is a result of inappropriate antimicrobial usage in veterinary as well as human medicine. In this report the veterinary side will be discussed with a focus on food-producing animals.

Antimicrobial use in food-producing animals is intensive in South Africa. Poultry and pig farming have the largest share in this [23]. Recent data on the volume of antimicrobial consumption in livestock production in South Africa are scarce, but in 2012 Eager and his colleagues published their research on antimicrobial usage in livestock production in the period of 2002-2004 [24]. In this period the mean antimicrobial sales were 1 538 443 kilograms of active ingredients. 234 antimicrobial compounds are registered for food-producing animals, of which 72% are registered as stock remedies in the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947. 38% of the stock remedies are registered as in-feed antimicrobials. The other 28% of the antimicrobial compounds are registered in the Medicines and Related Substances Act 101 of 1965. One main difference between these two Acts is the availability of registered drugs: Act 36 of 1947 governs over-the-counter sale of antimicrobials to ensure that farmers have access to antimicrobials in order to enable them to control disease and improve food production, whereas the drugs that are registered in Act 101 of 1965 require veterinary prescription and administration in order to preserve drug quality and effectivity. Some older antimicrobials, such as tetracyclines, are registered in both Acts [25]–[27]. A study in the Northwest province of South Africa confirmed that veterinarians and animal health technicians are rarely involved with the sale of stock remedies, since these are mostly supplied by farmers' cooperatives [28].

By permitting over-the-counter sale of stock antimicrobials, the South African government favours the use of antimicrobials as growth promoters or prophylaxis. The growth promoters tylosin, spiramycin, bacitracin and virginiamycin are still authorised in South Africa. In the European Union, the veterinary use of these compounds was already forbidden in 1999,

because they are closely related to therapeutic antimicrobials used in human medicine and cause a threat for human health [24].

Besides the quantity of antimicrobial usage, drug quality also poses a problem in South Africa. Compulsory Good Manufacturing Practice (GMP) licenses ensure that Act 101 drugs are safe, efficacious and of good quality [27]. However, the quality of stock remedies is often not guaranteed: although inspections of stock remedies in order to control its quality are regularly conducted and stock remedies must be registered for sale, they are not subjected to GMP guidelines like the Act 101 drugs are [23]. Furthermore, since stock remedies are stored and sold by farmers' cooperatives and outlets and farmers are allowed to store these drugs themselves as well, drug quality can be negatively affected by adverse climate conditions and the absence of adequate storage facilities [29]. This results in unintentional subtherapeutic dosing by farmers, promoting development of resistant bacteria [30]. Subtherapeutic dosing can also be intentional: counterfeit is a well-known phenomenon within the African pharmaceutical industry [31]. No data on counterfeiting of antimicrobials in South Africa are available. However, a South African study on quality control in anthelmintics showed that one out of the three sampled commercial formulations was substandard and that the efficacy of different batches of active ingredients differ due to a lack of transparency of international brokers that supply these batches [32].

Concludingly, while some papers state that South Africa has the most active antimicrobial surveillance system of the whole of Africa, there are still different hurdles to overcome in order to tackle the problem of AMR [33].

National Strategy Framework to tackle antimicrobial resistance in South Africa

Fortunately, South Africa was one of the countries that published a National Strategy Framework on AMR in 2014. The National Department of Health recognized the gaps and weaknesses of the existing interventions and control systems, including the Global Antibiotic Resistance Partnership in South Africa (GARP-SA) and the South African Antibiotic Stewardship Programme (SAASP) [34]. Four key objectives were posed to provide a structure for managing AMR and preventing it from becoming worse: interdisciplinary efforts should be encouraged, surveillance systems should be improved, infection prevention and control should be enhanced and appropriate use of antimicrobials in human and animal health should be promoted. Education of health professionals as well as society was described as an important enabler of these objectives [25].

South African farmer community

A substantial part of the South African society consists of farmers. These farmers are part of the South African dual agricultural economy and can therefore be divided in commercial farmers and small scale or family farmers [35]. Commercial farmers are defined as “producers that farm primarily for market purposes” and that strive for profit maximization, whereas small scale or family farmers often have restricted access to food and labour markets and produce primarily to supply their own household by using family labour, although there is an enormous heterogeneity within this group [36]. Medium-scale or semi-commercial farmers are mainly subsistence, but sell their surpluses on the market when possible (55). These differences in access to markets lead to a relative advantage for commercial farmers and enable them to innovate and take more risks than other farmers [36], [37]. No data on the correlation between these differences and the farmers' attitudes towards AMR are available.

AMR education of veterinary students around the world

The WHO Global Action Plan addresses the importance of AMR education as part of undergraduate as well as postgraduate learning of health professionals: “Making AMR a core component of professional education, training, certification, continuing education and development in health and veterinary sectors and agricultural practice will help to ensure proper understanding and awareness among professionals [10].” The South African AMR National Strategy Framework elaborates on this by describing education as a strategic enabler to build expertise in AMR within the medical, nursing, pharmaceutical as well as veterinary and para-veterinary professions. Modules on AMR should be incorporated in undergraduate curricula as well as in continuous professional development (CPD) activities [25]. Antimicrobial stewardship programmes (ASPs) are popular postgraduate trainings, but these can only change existing prescribing behaviour [38]. Since knowledge, attitudes and prescribing behaviour are being shaped during undergraduate education, teaching students in different healthcare professions about AMR could decrease the need for and pressure on ASPs and effectively improve prescribing behaviour in the future generation [39], [40].

In contrast to the widely studied knowledge on AMR and attitudes towards AMR education of medical students, studies on AMR education in veterinary curricula are scarce. In the discussion of this thesis differences and similarities between medical curricula and the curriculum of the Faculty of Veterinary Science in Onderstepoort regarding AMR will be discussed. This paragraph focuses on veterinary curricula only.

Fanning and colleagues stated that, despite the hazard of food-borne AMR and therefore its relevance within the veterinary profession, AMR is not often discussed in an own course module nor in a risk management course within the crowded undergraduate veterinary curriculum [41]. A survey among veterinary instructors in the United States showed that almost 100% of the participants identified AMR as a very important subject in the core veterinary curriculum, but they often experienced a lack of time and sometimes a lack of expertise and information as limiting factors [42]. To date, no studies have been conducted to evaluate the knowledge and attitudes of South African veterinary students towards AMR, although the need for a structured veterinary curriculum regarding AMR is recognized (26).

According to Fanning and colleagues, a structured veterinary curriculum should enable the veterinary student to clearly understand how to design an appropriate antimicrobial treatment plan, how to evaluate its outcome and how to prevent infections by using non-selective mitigation strategies [41]. The OIE developed a “Veterinary Education Core Curriculum” guideline to serve as a basis for veterinary faculties in OIE Member Countries to which they can add their specific needs and contexts [43]. According to this guideline, prudent use of antimicrobials and the development of AMR by pathogens should at least be discussed during microbiology courses, complemented by appropriate laboratory or other hands-on experience. During pharmacology courses mechanisms of drug resistance and principles of therapeutic decision making should be discussed. Public health courses should provide students with information about food safety from a One Health point of view. Furthermore, the OIE acknowledges the importance of communication skills and state that these should be taught in relevant classes, such as clinical courses, epidemiology and microbiology. This guideline accompanies the OIEs recommendations on the Competencies of graduating veterinarians (‘Day One graduates’), which should ensure the quality of the veterinary profession in each OIE Member Country [44]. The Faculty of Veterinary Science of the University of Pretoria implemented these recommendations into their own Day One Competencies List, which can be found in Appendix 1 of this report.

AMR in the veterinary curriculum of the University of Pretoria

Curricular renewal

In 2016 the veterinary curriculum of the University of Pretoria was renewed [45]. This renewal resulted in a six years bachelor's degree with four and a half years of didactic teaching and one and a half year of clinical rotations and elective courses. The Day One Competencies, derived from the OIE recommendations, should be attained by integrating their theoretical knowledge, gained in their early years, in the practical modules later on. The effect of this approach on retention was investigated by the Faculty of Veterinary Science herself by setting students a test and giving them the same test three weeks later. Although these data have not been published yet, the results are shown in Figure 1: after four and a half years theoretical instruction is quickly substituted by practical instruction. This immensely increases the students' educational retention, since practical instruction that follows theoretical instruction results in a much higher retention rate than theoretical instruction only: practical instruction provides context. After six years the student graduates as a general veterinarian with knowledge of different disciplines and species [45]. In 2016 the compulsory community service for veterinary graduates was introduced. During this year, the young veterinarian provides veterinary services in rural or poor areas in order to improve animal and public health [45].

AMR related courses

The current macro curriculum consists of brief descriptions of each course that veterinary students will face during their study path and can be found in Appendix 2. At different places in the macro curriculum AMR related subjects are present, e.g. farm management, bacteriology, food safety and drug regulations. According to the macro curriculum four didactic courses stand out in terms of AMR education: Veterinary Microbiology (second year), Veterinary Pharmacology (third year), Veterinary Public Health (fifth year) and One Health (fifth year). The description of the Experimental Training in the fifth and sixth year also addresses AMR relevant subjects such as drug regulations and public health. However, the word "resistance" cannot be found in the entire macro curricular document. In Table 1 the Day One Competencies and AMR related topics according to the micro curricular documents are shown for each of the abovementioned courses. An extensive analysis of the micro curricular documents can be found in Appendix 3. The overview of the Faculty's Day One Competencies can be found in Appendix 1.

Communication related courses

Besides learning about AMR, students should learn how to communicate properly in order to effectively transfer AMR knowledge to clients. In the macro curriculum Veterinary Professional Life (VPL) is the main course that addresses communication related topics. This course is distributed over the first five years of the study programme. The micro curricular documents address topics like multidisciplinary communication, conflict management, the veterinary role in communities, cultural diversity and client communication. In Appendix 3 an extensive analysis of the micro curricular documents of VPL can be found. The micro curricula of Veterinary Public Health and One Health also contain communication related subjects, which can be found in Appendix 3 as well.

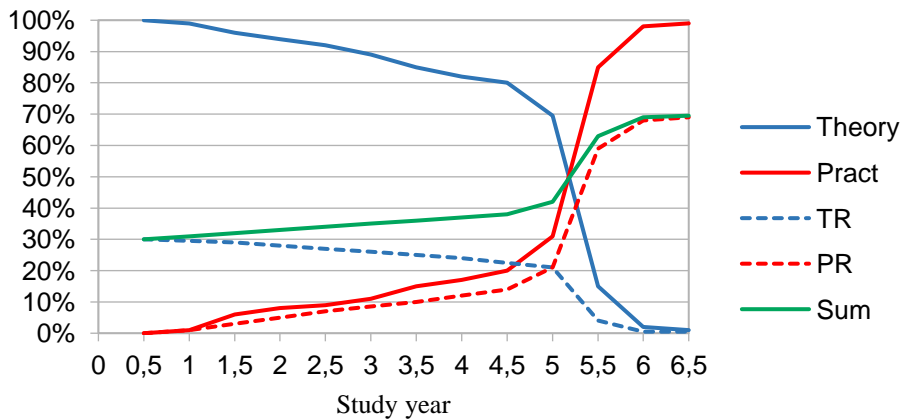


Figure 1: The efficiency of theoretical and practical instruction throughout the veterinary Bachelor's degree at the University of Pretoria (unpublished data from the Faculty of Veterinary Sciences). On the X axis the years of studying are shown. On the Y axis percentages of instruction and the students' retention are shown, respectively. Veterinary education starts with 100% of theoretical instruction (Theory), which is slowly substituted by practical instruction (Pract). After 4,5 years of studying, the amount of practical instruction suddenly increases enormously, while the amount of theoretical instruction quickly declines. The retention of theoretical instruction (TR) throughout the veterinary study programme is 20-30%, whereas the retention of practical instruction (PR) is 65-80%. The total retention (Sum) is maximal in the final year. Conclusion: the last 1,5 years seem to be most efficient in educating veterinary students (Sum).

Study objectives

No studies that evaluate the veterinary curriculum regarding AMR have been conducted at the University of Pretoria before. The aim of this explorative study was to investigate the effectiveness of AMR education of students of the Faculty of Veterinary Science in Onderstepoort on creating awareness about AMR among the farmer community in South Africa and to identify potential points of improvement. Four research questions were formulated in order to be answered:

1. What knowledge and skills on AMR and educating farmers are taught to students of the Faculty of Veterinary Science in Onderstepoort in the undergraduate curriculum?
2. To what extent do veterinary students already apply their learned knowledge and skills on AMR to educating farmers during their study programme?
3. What hurdles are being faced regarding AMR education of veterinary students and transfer of students' AMR knowledge to farmers?
4. What improvements concerning education on antimicrobial resistance could be made by the Faculty of Veterinary Science in Onderstepoort?

Veterinary instructors, veterinary students and farmers are all involved in this study in order to gain more insight in the academical contents regarding AMR and communication skills, the way students use this gained knowledge to educate farmers and the way farmers experience AMR education by students. At the end a comparison is made between the curriculum "on paper" and the curriculum "in action" in order to criticize the translation from theory to practice and to identify hidden curricular subjects: to what extent are the theoretical curricular documents translated by the veterinary instructors, and how do veterinary students perceive this AMR education? Finally, recommendations for improvement are made towards the Faculty of Veterinary Science of the University of Pretoria.

Table 1: Day One Competencies and AMR related subjects in the micro curricular documents of Veterinary Microbiology, Veterinary Pharmacology, Veterinary Public Health and One Health. In Appendix 1 the Day One Competencies are shown. In Appendix 3 an extensive analysis of these documents can be found.

Study year	Course	AMR related Day One Competencies	AMR related topics
Two	Veterinary Microbiology	Major: B1.3, C1.8, C1.23	Bacterial genetics
			Bacterial mutations
			Sterilisation and disinfection
Three	Veterinary Pharmacology	Major: B1.6, B1.7 Minor: A1.4	Antibacterial drugs
			Sensitivity testing
			Drug registrations
			Stock remedies
			Counterfeit medicines
			Drug residues in food
			Pharmacovigilance
			Withdrawal periods
			Resistance development
			Limited antimicrobial use in food-producing animals
Five	Veterinary Public Health	Major: A1.3, A1.4, B1.6, B1.10, C1.11 Moderate: C1.10 Minor: B1.7	Meat and milk safety
			National and international legislation
			Food borne diseases
			Good Manufacturing Practices (GMP)
			Good Hygiene Practices (GHP)
			Good Agricultural Practices (GAP)
			Hazard Analysis Critical Control Points (HACCP)
	Risk assessment		
	Veterinary role in food control		
	One Health	Major: A1.3 Moderate: A1.4, B1.10, C1.11 Minor: A1.6, C1.10, C1.21	Links between animal, human and ecosystem health
			Impact drug residues in livestock (products) on animal, human and ecosystem health
			Collaboration with medical profession
			Legislation regarding drug residues

Materials & Methods

This cross-sectional study was conducted at the Faculty of Veterinary Science in Onderstepoort (from now on FVSO), University of Pretoria, South Africa, from the 30th of October 2017 until the 7th of May 2018. A qualitative phenomenological descriptive research method was chosen, since the main aim was to describe the participants' experiences with education regarding AMR. A descriptive method was chosen instead of an interpretive method in order to create an objective dataset. To get a complete view on veterinary AMR education in Onderstepoort, the study design was divided into three parts that represent the input, processor and output of AMR education, respectively: veterinary instructors, veterinary students and farmers (see Figure 2).

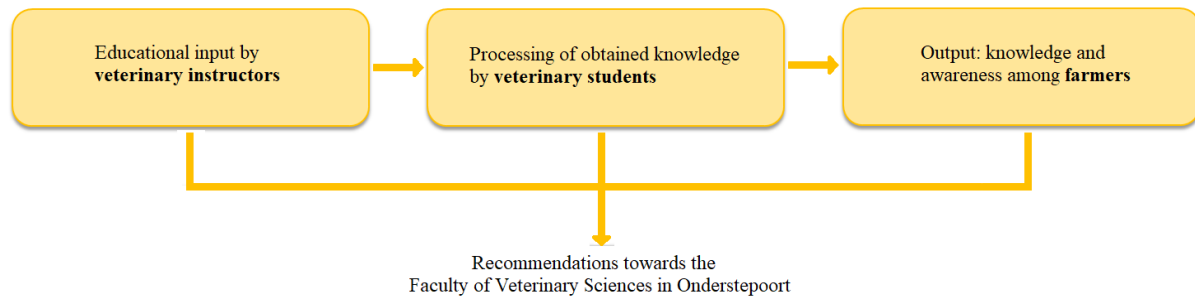


Figure 2: The study design consisted of three parts, that can be described as the input, processors and output of AMR education, respectively: veterinary instructors, veterinary students and farmers. The results were finally translated into recommendations towards the Faculty of Veterinary Sciences in Onderstepoort.

Part 1: Veterinary instructors

Experimental design

Semi-structured individual interviews with veterinary instructors of the FVSO were conducted in order to investigate the implementation of the curricular documents in the actual education and to identify hidden curricular aspects. The interviews were semi-structured in order to standardize the obtained dataset and to prevent information biases, since these interviews were conducted by two different researchers. This approach allowed participants' own inputs as well. The majority of the questions was open. Sometimes multiple answers were proposed by the researchers to clarify the question. The interviews were individual, since it was not possible to arrange focus groups within this short period of time. Two participants answered the questionnaire by e-mail, since it was not possible to arrange a face-to-face interview.

Participants

In total seven participants were included: five lecturers of the Veterinary Microbiology, General Veterinary Pharmacology, Veterinary Public Health, One Health and Veterinary Professional Life courses and two clinicians from the production clinics at Onderstepoort and the Hluvukani community clinic. The selection of these courses and clinics was based on the analysis of the curricular documents (Appendix 3) and informal conversations with veterinary students. The selection of the specific instructors was based on their role and relevance in terms of education on bacteriology, antimicrobials, resistance and communication within their course.

Data collection

From the 8th of November 2017 until the 16st of May 2018 five interviews were organized. The interviews took place at Onderstepoort. Researcher 1 interviewed one clinician and researcher 2 interviewed four lecturers. Two participants completed a digitalized questionnaire by e-mail. This questionnaire was the same as the questionnaire used for the semi-structured interviews.

The questionnaire used for the semi-structured interviews consisted of two parts. In the first part demographic information about the participant and his or her career path was gathered. The second part was not the same for all participants, since the discussed subjects differed between the participating courses. These differences were identified through analysis of the curricular documents. Topics that were discussed with lecturers of Veterinary Microbiology and Veterinary Pharmacology were: the importance of AMR education, the time they have available for this, the contents of their education, barriers they face, teaching tools they use and improvements they would like to suggest. These questions were based on the questionnaire that was used in a study among American veterinary instructors [42]. The interviews with the lecturers of Veterinary Public Health and One Health and clinicians were complemented with the same type of questions about education on communication. The lecturer of Veterinary Professional Life was asked questions about education on communication only. The questionnaires can be found in Appendix 4.

Data analysis

During the clinician interview, researcher 1 wrote down the participant's answers as complete as possible. These notes were digitalized by using Microsoft Word 2016. The two completed digital questionnaires were added to this dataset. Researcher 2 used a voice recorder to record four interviews. These records were transcribed and analysed after conducting all interviews. The digitalized notes and transcripts were analysed by using Colaizzi's thematic content analysis [46]. After intensively reading and re-reading the digitalized notes and transcripts, relevant statements about and opinions on the abovementioned topics were marked. These marked fragments were classified into themes and compared to the themed fragments of the other interviews. Ultimately, these themes were summarized in one document.

Part 2: Veterinary students

Experimental design

To gather information about the effect of current AMR education on the students' knowledge and their views on this, semi-structured focus groups were used for different reasons. In an explorative study focus groups yield more information compared to individual interviews, since participants complement each other's answers and stimulate each other to think deeper. To be able to approach data saturation, data collection by means of focus groups was most effective. Participants were easier to find by asking groups instead of individuals. By semi-structuring the group discussions a wide and clear dataset was yielded.

Participants

In total 29 students of the FVSO were selected. One participant of focus group two left after two minutes and was excluded from the dataset. Therefore, the research group consisted of 28 participants. Preferably, purposive sampling would have been used by randomly selecting students who are specifically interested in production animals and rural farming respectively. However, in this short period of time it was unrealistic to use purposive sampling. Therefore, convenience sampling has been used by approaching different groups of students during their rotations and asking who wanted to and had time to participate in this research. There was no selection on interests or electives. Students who were not on their clinical rotations or who were not full-time enrolled for the entire course in Onderstepoort were excluded from participation. In the original research proposal it was aimed to only use final year students. Since the final exams took place just before the research period, the students that just started their final twelve months of study were the most senior students available and were used as participants.

Data collection

From the 6th of November 2017 until the 27th of November 2017 six semi-structured focus groups were organized. Each focus group consisted of three to seven participants. A pilot study, referred to as focus group 1, was performed at the 6th of November. These data were already useful and were incorporated in the dataset. Focus groups 1, 2, 3 and 5 took place at the FVSO. Focus group 4 took place at the researcher's residence. Focus group 6 took place at the Hans Hoheisen Wildlife Research Station, where the participants and researcher were staying during that time. The length of the group discussions varied from 38 to 53 minutes with an average of 45 minutes. All group discussions were guided by the same researcher.

Before each focus group the participants were asked to fill out a demographic questionnaire and sign to give permission to record the discussion. The participants were anonymized by numbering them. The discussions were structured by using the following topics: top-of-mind aspects of antimicrobials, a case discussion, knowledge about AMR, curricular contents on AMR and its deficiencies, knowledge on didactics and communicating with farmers, curricular contents on didactics and communicating with farmers and its deficiencies and proposed curricular improvements. Various questions regarding these topics were prepared, but it depended on the discussion and the degree of active participation whether all questions were asked. The questionnaire can be found in Appendix 5. Member checking was implemented by repeating the answers and asking for confirmation before continuing to the next question.

Data analysis

The demographic questionnaires were digitalized and analysed by using Microsoft Excel 2016: the data were subsequently organized based on gender, age and elective to explore the dataset. Their motivations for studying veterinary science and their future career ideas were too diverse to organize by using Excel and were therefore organized by the researcher herself. Each focus group was recorded by using a voice recorder. In the days after each focus group the record was literally transcribed and analysed. Therefore, questions could be adjusted or added to optimize data collection during the next focus groups. The transcripts were analysed by using Colaizzi's thematic content analysis [46]. After intensively reading and re-reading the transcript, statements and opinions regarding AMR, education and communication were marked. Subsequently, these marked fragments were classified into themes. After analysing every focus group separately, the themes were mutually compared and integrated into higher themes. These themes were ultimately summarized in one document.

Part 3: Farmers

Experimental design

Semi-structured individual interviews with farmers, who were linked to the FVSO, were conducted in order to investigate the output of the veterinary curriculum in terms of the transfer of knowledge and awareness about AMR by students to farmers. The interviews were semi-structured to standardize the obtained dataset and to prevent information biases, since these interviews were conducted by two different researchers, and to save space for the participant's own input as well. The majority of the questions was open. Sometimes multiple answers were proposed by the researcher to clarify the question. Because of logistical reasons, farm visits and consultations at the Onderstepoort Veterinary Academic Hospital (OVAH) as well as phone calls were used to collect data.

Participants

The research group for this part consisted of 21 participants. Preferably, small scale farmers and commercial farmers would be equally represented in this dataset, but that was not possible. The reasons for that will be reviewed in the discussion. Multiple professional contact moments

with veterinary students from the FVSO in the past was the main inclusion criterium. All farmers spoke English or Afrikaans to optimize reciprocal understanding. Randomization was implemented by interviewing farmers that were already scheduled to be visited by researcher 2 for veterinary reproduction services. In order to complete the dataset, the research group was supplemented by farmers that were known and regularly visited by researcher 2, although they were not visited within the research period; these farmers were interviewed by phone. Finally, four farmers that visited OVAH were interviewed by clinicians, who were instructed by researcher 2.

Data collection

From the 14th of November 2017 until the 7th of May 2018 ten visits, seven phone calls and four consultations at OVAH were organized to complete the interviews. Researcher 1 interviewed one farmer during a visit. Researcher 2 interviewed nine farmers during visits and seven by phone calls. The four consultation interviews were conducted by clinicians of OVAH.

The questionnaire consisted of two parts and can be found in Appendix 6. In the first part the following demographic information about the participant and farm was gathered: gender, age, educational level, farmed species, farm size, years of experience as a farmer, fulltime or part-time farming (if part-time there was asked for other job) and the number of employees. In the second part open questions were asked to identify the top-of-mind aspects of antimicrobials and their knowledge about AMR, to reveal their attitudes towards the students' role in learning about AMR and communication with students and finally they were asked to come up with suggestions for the faculty to improve farmer-student contact about AMR. Member checking by phone calls was implemented in order to collect answers that were originally missing, incomplete or unreadable.

Data analysis

The demographic data were analysed by using Microsoft Excel 2016: the data were subsequently organized based on gender, age, farm size, years of experience as a farmer, fulltime or part-time farming and the number of employees. Educational levels, farmed species and jobs besides farming were too diverse to analyse by using Microsoft Excel 2016. Therefore, these data were analysed, organized and clustered into groups by the researcher herself. During the interviews the researchers wrote down the given answers in catchwords. These forms were digitalized in one document in Word2016 and analysed by using Colaizzi's thematic content analysis [46]. While reading, relevant statements and opinions were marked. Subsequently similarities in the answers of the different farmers were identified and clustered into themes. Ultimately, the important themes and statements were summarized.

Ethical justification

The study methods were approved by the Research Ethics Committee of the Faculty of Veterinary Science of the University of Pretoria (REC 001-18).

Results

In this section the results of the interviews, focus groups and questionnaires are described. The results are divided in three parts. In part 1 the veterinary instructors' ideas, views and suggestions on AMR education and education on communication are presented. In part 2 the data that were gathered during the six focus groups with students, are presented. Finally, in part 3 the farmers' AMR knowledge and experiences regarding AMR education are described.

Part 1: Veterinary instructors

In Table 2 the participant numbers are linked to the courses in which the participants were involved. In order to preserve the anonymity of the small number of veterinary instructor participants, derived from a small population of veterinary instructors at the FVSO, further demographic details are briefly summarized in this paragraph without linking specific details to specific participants, since that would make quotes and statements traceable to a specific instructor.

All participants had a Bachelor's Degree in Veterinary Science (BVSC). Four participants were educated in Pretoria, two in Zimbabwe and one participant was educated in Congo. The production animal clinics at Onderstepoort Veterinary Animal Hospital (OVAH) and the community clinic in Hluvukani provided the two clinical instructors, whereas the Veterinary Public Health, Pharmacology, Microbiology, One Health and Veterinary Professional Life courses were represented by the other participants. Table 2 shows which participant number belongs to which course. Common phases in the instructors' career paths were foreign work experiences in the United Kingdom and Canada, Master's programmes (e.g. MSc Public Health and MSc Veterinary Tropical Diseases) and experiences in private practises before joining the University of Pretoria. The time of experience as an instructor varied between two months and twenty years.

Table 2: Courses and clinics that were included in this study, linked to numbers of the representing participants

Participant	Course/clinic
1	Clinician Production Animal Clinics
2	Clinician Hluvukani community clinic
3	Lecturer Veterinary Public Health
4	Lecturer Veterinary Pharmacology
5	Lecturer Microbiology
6	Lecturer One Health
7	Lecturer Veterinary Professional Life

AMR education

All participants agreed on the major importance of AMR education in the veterinary curriculum. Participant 4: *"It is the central theme in terms of why we choose a certain antimicrobial: AMR and optimal therapy come together."* Participant 5: *"It is very important to educate them now so that they understand the mechanisms and they understand what an antibiogram exactly means, because in future this will become more and more important."* The time spent on AMR was difficult to grasp for most participants. Participant 3: *"I spend one to two hours on it, but I don't exactly know."* Participant 4: *"I use probably one hour for AMR."* The students' knowledge on AMR was described as variable. However, this question was not asked to all participants. Most instructors described their own knowledge on AMR as sufficient to teach students, although this question was not asked to all participants either.

Teaching tools

Both clinicians mentioned oral discussions about relevant cases as main teaching tool. Participant 1: *"We discuss it whenever it seems to be relevant from a clinical point of view, i.e. when you get an infected animal that is not responding to first line antibiotics. That is in like one out of thirty cases."* Participant 2: *"I discuss it in 3 out of 5 cases."* Formal lectures, mostly supported by Powerpoint, were mentioned by all AMR lecturers as commonly used tool to teach students about AMR, although there are no lectures specifically on AMR. Participant 3: *"We talk about it in class when I am talking about bacteria, but that is hidden in the curriculum. There is no formal lecture on AMR during my course."* Participant 4: *"It is a component of my lectures, but we do not necessarily test their AMR knowledge in exams."* Participant 3 uses examples from the human medical sector to get his AMR message across. Case studies and videos, such as Ted talks and explanations of bacterial mechanisms to acquire resistance, were also mentioned by participant 3 as part of the lectures or as self-study tools. Finally, group presentation assignments were used by participant 3: *"I let them do presentations: one group will make a presentation on antimicrobial promoters, another group presents on AMR in South Africa and internationally. I consider these presentations as a summary of all the things we have been talking about, so that students can internalize them, and they tell me that they like it, because it helps them."*

Discussed AMR topics

Participants 2, 4 and 5 include the biological mechanisms of requiring AMR in their teaching topics. Participants 1 and 4 mentioned that personal preferences are part of their way of teaching. Participant 1: *"I teach my students about trends in AMR, based on my personal experiences."* The veterinarian's role in AMR and the importance of prudent antimicrobial stewardship were mentioned by participants 1, 2, 3, and 4 as part of their teaching. Participant 4: *"I try to focus on principles of antimicrobial therapy that are going to help the students in decision making to reduce antimicrobial use and use it appropriately, like the first line, second line and restricted antibiotics. I briefly discuss antibiograms, but I think the majority of this is taught in clinics."* The South African context is discussed with the students by participants 3 and 4. Participant 3: *"I teach them about the South African regulations. For example, some antibiotics that are still being used in South Africa are already banned in Europe and to some extend in America."* Participant 4: *"The role of prophylactic use and growth promoters in animals is part of the story that I tell them."* Participant 3 mentioned alternatives for antimicrobial therapy as part of his teaching: *"I tell them that use of probiotics, such as yoghurt, can also help, just like bacteriophages."* Participants 1, 4 and 5 included One Health related topics in AMR education. Participant 1: *"I also talk to them about the medical practitioner's role in antimicrobial resistance."* Participant 4: *"Treating an individual patient with an antibiotic is affecting almost everybody around that patient. Students must be aware of that."* Participant 5: *"When you teach bacterial diseases, you do have to tell the students that certain diseases can infect them too, for their own safety. So automatically you go to a One Health kind of approach."* Participant 6 stated that AMR is not covered during the One Health course and that there is no involvement of the medical school in the current One Health course, although last year there was a lecture by a medical professional. Participant 6: *"But if I have to think where to place AMR, I think One Health would be suitable."*

Education on communication skills

The lecturers of Veterinary Professional Life and One Health and both clinicians agreed on the major importance of education on communication within the veterinary curriculum. Participant 1: *"Communication is a crucial aspect of the profession and is an important determinant of what makes a good vet."* Participant 7: *"For veterinarians to achieve their goal which is to*

firstly prevent and secondly treat disease, and help promote human health, they need buy-in from farmers for best practice in terms of animal management. To get buy-in they need to communicate effectively. Intercultural communication is very important in this: there is still much inequality in terms of access to veterinary services in South Africa and therefore, every effort must be made to communicate the veterinary message to all South African citizens.” Participants 1, 2 and 7 experience some variability in terms of the students’ communication skills and interest to learn about it. Participant 2: *“Some students miss knowledge about certain etiquettes which may inhibit a good flow of communication.”*

Teaching tools

Participant 6 mentioned the final assignment on interdisciplinary communication as an important tool to teach students about appropriate communication: *“They have to demonstrate collaboration and communication with another medical profession, so for example they do an interview with a medical person.”* Participant 7 uses different teaching tools to get the message about proper client communication across: *“We have a video assignment in which students do a simulated consultation and a community project in which they have to talk to a group of school learners or adults. In class we do role plays, show them videos and we invite guests, such as veterinarians, but also senior education students. These guest lectures are very successful and popular among students. Finally we have some sessions in which we ask students about their personal experiences with intercultural communication and let the others respond to that. This concept is extremely successful as well.”*

Discussed topics on communication

Participants 1 and 2 stated to discuss the basics with their students. Participant 1: *“I teach them the three Cs: communication should be courteous, clear and concise.”* Participant 2: *“I notice a need for communication skills relative to the type of client a student engages with, so I try to discuss that with them.”* Participant 7 discusses a variety of communication topics with the students: *“We teach them the principles and basics like eye contact and non-verbal communication, but also e-mail etiquette, consultation according to the Cambridge-Calgary model and conflict management. In the community engagement project they are encouraged to learn a few phrases of the language of their school/community.”* Participant 6 mentioned a theme on communication between different professions within multidisciplinary teams and a lecture on rural development as tools to teach students about communication.

Barriers

Lack of time was mentioned by all participants as a major barrier of teaching their students about AMR or communication. Participant 5: *“Our lack of time limits us to the very basics.”* Participant 7: *“We have too many other responsibilities as well, and the practical application of the skills they learn can be very time consuming.”* Lack of information was mentioned by participants 1, 2, 3 and 4. Participant 3: *“There is a lack of information about how some antibiotics generate resistance to other antibiotics.”* Participant 4: *“There is no clear guideline about the South African situation regarding antibiotics.”* Participants 3 and 5 added that there is a lack of expertise at the FVSO. Participant 7 experienced a lack of facilities for group work and simulated consultation to practice client communication. The unsystematic and inconsistent approach of AMR education at the FVSO worried participants 3,4 and 5. Participant 4: *“There is no or a vague consensus in the hospital, so I teach them what my view is instead of teaching with more conviction and consensus about what is going to be taught further down the line. There is no consistent view: when they come to clinics, things quickly fall apart in terms of what antibiotics are recommended by us. They start to think the choice of antibiotics is quite random: it is just based on personal preferences.”* Participant 5: *“We teach*

our undergrads just loose bits of information.” Participant 3 and 4 felt impeded by the poor South African regulation and the pharmaceutical industry. Participant 3: *“We try to teach them about prudent antimicrobial use, although the legal framework does not favour it. The pharmaceutical industry is partly to blame in terms of education as well: they do not tell people about the disadvantages of antibiotics.”*

Suggestions

AMR education

Both clinicians would like to receive more information from the faculty to improve their own AMR knowledge in the South African context. Participant 1: *“They should organize special talks by bacteriologists and related personnel on current trends in AMR based on South African research.”* Participants 3, 4 and 5 mentioned the importance of laying a good foundation at an early stage in the study programme as a suggestion to improve AMR education. Participant 4: *“We have to build blocks first.”* Participant 5: *“It would be good to teach the basics first and then integrate it at a later stage.”* Participant 3 suggested to look at veterinary faculties overseas: *“We are still a bit back in the old science, so we could definitely learn from other veterinary faculties.”* Furthermore, participant 3 suggested to involve postgraduate students in AMR education. Participant 4 would like the faculty to fill the time gap between the didactic courses in the first years of the study programme and clinics: *“We should prevent the students’ knowledge from eroding. We should have some consensus in terms of what we should be recommending, based on scientific information that is available to us at the moment. We should have a document in which we say ‘this is the policy of this hospital’.”* Participant 6 thinks that the faculty should emphasize the seriousness of the AMR problem more: *“It is a serious concern. Students should know that.”*

Education on communication skills

Participant 2 would like the faculty to engage more with experienced veterinarians, who can give lectures from their personal point of view and experiences with client communication. Participant 7 would like better facilities to support the teaching tools. *“There should be better facilities for simulated consultations, such one-way glass between a ‘consulting room’ and an observation room, or video streaming equipment.* Furthermore, participant 7 suggested to use online tools more often: *“TrainTool, an online training system for communication skills, is very non labour-intensive for lecturers, since it involves peer assessment. Furthermore, it provides an opportunity for practical learning in a non-threatening environment.”*

Part 2: Veterinary students

In Table 3 a brief overview of demographic details of the 28 student participants is shown. The complete demographic table can be found in appendix 7 and is textually summarized here. Frequent motivations to study Veterinary Science were the student’s environment, the love and passion for animals and the idealism to help animals, people and the environment. All South African students chose to study at the FVSO, because it is the only veterinary faculty in the country. Two students from Zimbabwe and Swaziland were motivated by the good facilities and community engagement projects at Onderstepoort. The majority of the participants (N=15) attended the Small Animal and Exotic Practice elective, followed by Intensive Animal Production Practice (N=5), Equine Practice (N=3), Rural and Wildlife Practice (N=3) and Veterinary Public Health and State Veterinary Practice (N=2). The Veterinary Research Career elective was not represented. Future career ideas more or less coincided with elective choices, e.g. most students who attended the Small Animal and Exotic Practice elective would like to work in a mixed or small animal practice. Six participants explicitly mentioned to aspire a career in a rural area.

Knowledge on antimicrobial resistance

Each group discussion was started with a brainstorm about antimicrobials. In four out of six focus groups ‘resistance’ was brought forward as one of the top-of-mind aspects of antimicrobials. In two of those focus groups ‘post-antibiotic era’ was mentioned. In focus group 4 ‘resistance’ nor ‘post-antibiotic era’ were mentioned, although the students thought about misuse, overuse and abuse of antimicrobials. In focus group 1 nothing related to AMR was mentioned.

The rural case discussion was used to gain insight in the students’ knowledge on prudent antibiotic stewardship. In all focus groups management was mentioned as being the most important aspect to look at when encountering a bacterial problem. Vaccination was often mentioned as part of multifactorial management. Participant 28: *“It’s a dynamic approach, because there is a whole bunch of things you have to look at.”* When an antibiotic treatment is indicated after looking at the management, the majority of the participants would encourage an antibiogram and use a narrow spectrum antibiotic, although they were aware of potential money issues. A minority of the participants would start with a broad spectrum antibiotic and potentially evaluate this treatment with an antibiogram. According to most participants prescribing an antibiotic must be accompanied with advice about withdrawal periods, using the right doses and intervals and the urge to complete the course.

View on the South African situation

During the rural case discussion causes for the high burden of AMR in South Africa and the difficulties to decrease this burden were discussed. The communication barrier between veterinarian and client and the flexible legislation that enables over-the-counter sale of antibiotics were mentioned in the majority of the focus groups. According to focus group 3, 4 and 6 the government is the biggest stakeholder in the South African AMR problem, although they realise it is hard to change this situation. Participant 21: *“The reason that it is like this is the practicality for the big rural community that lives in the middle of nowhere. Vets can’t always get to them, because they have a wide area to cover. Over-the-counter sale enables these farmers to at least try to help their sick animals.”* Besides the wide area that veterinarians have to cover, the shortage of veterinarians and their lack of facilities were often recognized as South African problems. Strong cultural believes, poverty and habits of farmers as well as old veterinarians were also mentioned.

Table 3: Brief overview of demographic information of student participants, ordered per focus group. Explanation of abbreviations: 1) SA/EP = Small Animals and Exotic Practice, 2) IAPP = Intensive Animal Production Practice, 3) VPH/SVP = Veterinary Public Health and State Veterinary Practice, 4) EQP = Equine Practice and 5) RWP = Rural and Wildlife Practice. The complete demographics can be found in Appendix 7.

Focus group	Participant	Gender	Age	Elective
1	1	F	23	SA/EP
	2	F	25	SA/EP
	3	F	23	SA/EP
	4	F	23	IAPP
	5	M	32	VPH/SVP
2	6	M	23	SA/EP
	7	M	23	SA/EP
	8	M	23	SA/EP
	9	F	24	SA/EP
	10	F	22	SA/EP
	11	F	23	SA/EP
3	12	F	23	SA/EP
	13	F	23	SA/EP
	14	F	23	SA/EP
	15	F	24	VPH/SVP
	16	F	23	SA/EP
4	17	M	22	IAPP
	18	F	25	RWP
	19	F	23	RWP
	20	M	21	SA/EP
	21	F	23	IAPP
5	22	F	24	EQP
	23	F	24	EQP
	24	F	22	IAPP
6	25	F	24	RWP
	26	M	23	EQP
	27	M	23	IAPP
	28	M	23	SA/EP

In focus group 1 three participants mentioned medical doctors as being most responsible for the AMR problem, whereas the other focus groups concluded that it is a multidisciplinary problem in which the veterinary sector and the government are probably most responsible. Participant 6: *“As a production vet you treat animals that are used for human consumption: if we create resistance, the veterinary problem becomes a human problem as well.”* Participant 19: *“The human side is more regulated than the veterinary side.”* Participant 16: *“But farmers are actually the ones that work with the animals, that buy antibiotics over-the-counter and that don’t have the knowledge to make the right decisions.”* In most focus groups the farmers’ undereducation was recognized as a major problem, caused by the government. Participant 14: *“We can’t blame the farmers that are uneducated. We should blame the educational system and thus the government.”*

Importance of educating farmers

Most participants agreed that educating farmers is an important task of veterinarians as well as veterinary students. Participant 1: *“Farmers don’t have the same learning opportunities as people in the medical field, so it is our responsibility to teach them.”* Another argument was that the farmers’ habits should be changed. Participant 20: *“They are stuck in their ways, because it always worked perfectly and produced money for them.”* Participant 7: *“If you don’t mention antimicrobial resistance, he won’t have the motivation to stop the prophylactic use and misuse of antibiotics.”*

To the question how they would educate farmers, participants in all focus groups answered that it is very important to adapt the discussion about antimicrobial use and resistance to the client’s level. Participant 25: *“It is important to read your client.”* Some participants would mention the words ‘antimicrobial resistance’. Others would rather explain the concept in an understandable way. Most participants would go for a personal approach rather than a public health approach. Participant 17: *“I would emphasize the fact that his animals can become untreatable and that his costs will be higher when he gets resistance in his herd.”*

When the researcher turned the rural case into a commercial case, the importance of educating the farmer changed according to the majority of the participants. Participant 2: *“I think we should focus on commercial farmers, since they have the money and means to overuse, whereas rural farmers use less antibiotics because they don’t have the money for it.”* For most participants also the focus of the education would change. Participant 21: *“Assuming that the commercial farmer has had better education, you would use more terminology to prevent yourself from losing the message as you possibly will while educating rural farmers.”* Two participants declared that they would not have the discussion about AMR with a rural farmer nor a commercial farmer, because the rural farmers would not understand and the commercial farmers already know.

AMR education in the veterinary curriculum

Antimicrobial resistance

The majority of the participants mentioned 10th or 11th grade in high school as the first moment they learnt about AMR at a basic level, although some participants heard about it for the first time during their veterinary degree. Participant 25: *“In South Africa the standard education is not uniform: it depends on the area you grew up in and the school you were on whether you were taught about antibiotics and resistance or not.”* A few participants mentioned extracurricular events as their introduction to AMR. Participant 12: *“My sister and my parents already had conversations about it at the dining table when I was still in primary school”.* Participant 16: *“When I went to the doctor and he prescribed antibiotics, he explained to me why I should finish the course.”*

When the participants were asked which courses during their veterinary degree focused on AMR, Veterinary Pharmacology was mentioned in all focus groups. The different mechanisms of antibiotics and the importance of antibiograms and narrow spectrum, first line antibiotics were emphasized during this course, according to focus group 4. However, the effectiveness of this course was doubted by many participants. Participant 21: *Pharmacology is such a packed subject; I feel like I forgot everything.* Participant 23: *“We have a thousand other drugs to remember, so we have to filter some things out.”* Focus group 2 and 6 mentioned Veterinary Microbiology, in which the morphology and genetics of bacteria were discussed. Veterinary Public Health was mentioned in focus groups 2 and 3, after the researcher asked her question two times. Participant 7: *“In our fifth year the Public Health course was really good. My group had to do a presentation specific on antimicrobial resistance about how it happens, the public’s awareness, what would happen if it continues and how we can prevent it in the future, so everything was covered.”* Participant 15: *“My public health presentation was about antimicrobial resistance, so that’s why I remember it, but when you were just sitting there, you won’t remember.”* The One Health course was mentioned in focus group 1 and 5. Participant 4: *“During the One Health course medical doctors, vets and epidemiologists come together to discuss things, like who is actually causing antimicrobial resistance.”* Participant 22: *“A human doctor gave a passionate lecture and briefly discussed antimicrobial resistance.”* In focus groups 3 and 4 the researcher mentioned the One Health course. In focus group 3 only one participant was able to remember this course. The other participants were not able to recall the contents of the One Health course. In focus group 4 it was said that AMR was not widely discussed during the One Health course.

Focus group 6 added the second year Animal Sciences course as a course that discusses AMR.

The clinical rotations in fifth and sixth year were mentioned by all focus groups as an important educational moment regarding AMR. The dairy week and the outpatient rotation were often explicitly mentioned as clinics that discuss AMR. Also the production clinics, the community clinic in Hluvukani, beef herd health and equines were mentioned to do well as antimicrobial prescribers. Small animal surgery, anaesthesiology and the feedlot challenge were mentioned as rotations that negatively contribute to AMR education. Participant 19: *“During the feedlot challenge, prophylactic use of antibiotics was even recommended.”* This lack of uniformity in AMR education by different clinics as well as different clinicians was mentioned by most participants. Participant 7: *“Not in all clinics we do those plenary discussions.”* Participant 23: *“During the clinical rotations education on antimicrobial resistance is not in a concerted fashion and depends on the cases you get and the clinicians you work with.”* Finally, the external internship at a private veterinary practice often came up negatively in the discussion. Participant 6: *“I think private vets are not as well educated as we are regarding antimicrobial resistance.”* Participant 11: *“In private practice they will tell you that this is not the way that it is taught to you, but this is the way that works.”*

Communication

Veterinary Professional Life was often mentioned as a course that theoretically taught the students about communicating with clients and communities. Participant 1: *“In our VPL classes we learn acronyms about how to approach a community, how to bring your message across: who is your subject? Who is the messenger? What is the topic? What material are you going to use to convey the message? What is the result? Communication is a life skill, but here they try to teach it to us.”* In focus group 3 and 6 the community engagement project in their third year was emphasized as being helpful to learn about communication with communities. Focus group 2 did not mention Veterinary Professional Life, but One Health as a useful course regarding communication education. Participant 11: *“In the One Health course they tell a lot about speaking to a community, how you get them engaged and how to can deal with cultural*

differences.” Participant 8: *“But that was the first time in five years.”* Also in focus group 5 the One Health course came up. Participant 24: *“During the One Health course there was a topic about a community and tuberculosis and we had to keep the multi-resistant variant in mind when thinking about the treatment.”*

The clinical rotations were often seen as the place where students can practically learn and experience communication with clients. Most participants mentioned the clinical rotations in general, but beef herd health and the community clinic in Hluvukani were explicitly mentioned by focus group 4 and focus group 6 respectively. Participant 20: *“On beef herd health we went to rural farmers, where we had a translator and asked him questions about his management and tried to give feedback. This was really beneficial to get a better understanding.”* Participant 27: *“Here in Hluvukani we are really exposed to rural, uneducated farmers and really experience communication with them.”* Focus group 6 was asked about the responsibilities they get in the clinics regarding communication with clients. Participant 27: *“We are responsible for client communication every day.”* Participant 28: *“That is one thing that is really good in Onderstepoort: doctors want students to get involved in formulating diagnostic and treatment protocols and communicating this to the client.”* This question was not asked in other focus groups.

In focus group 4 the compulsory community service, a year in which newly graduated veterinarians serve a community, came up as being beneficial to improve their communication skills. Participant 19: *“Although it is not part of the curriculum, our compulsory community service helps: we are getting exposed to different cultures, languages and believes. It is still a learning curve.”*

Teaching tools

The majority of the participants recognized lectures as being the most used teaching tools to teach students about AMR. Also PowerPoint handouts, peer discussions and plenary as well as individual discussions with lecturers or clinicians were often mentioned. Participant 25: *“We are encouraged to have discussions about antimicrobial resistance with each other and with our teachers.”* Less often mentioned were videos, textbooks, research articles, practicals, presentations and specific assignments, such as the community engagement project during Veterinary Professional Life and the community project during the One Health course. During the clinical rotations experience based learning was the most used teaching tool regarding different participants.

Opinions about faculty’s efforts

Half of the focus groups believed that the theoretical AMR education is abundant at the FVSO. Participant 2: *“The common message in Onderstepoort is “Don’t use broad spectrum, wait for the antibiogram results”.”* Participant 27: *“The faculty has done everything she can and can’t give us a bigger scope. The concepts are explained very well.”* Some participants felt that AMR became more emphasized in the curriculum in the last few years. Participant 3: *“Every year they are emphasizing more and more, because the problem is actually getting worse.”* However, exact details about the size and emergence of the AMR problem are scarce, according to some participants. Participant 14: *“It feels like far away, something there, but not already here.”* Participant 20: *“Sometimes it feels like somebody else’s problem.”* The lack of education about how to resolve the problem and what alternatives can be used was mentioned in four focus groups. Regarding AMR education during the clinical rotations, five focus groups mentioned imprudent use of antimicrobials in the clinics in OVAH. Participant 1: *“They inject cephalosporin in every patient that is going into surgery, regardless of the type of surgery. It’s just an automatic protocol here.”* Participant 15: *“All clinicians are talking about it, but nobody actually does something about it.”* Participant 22: *“Antimicrobial resistance is a thing*

that is easily being forgotten, especially in the hospital setting: the clinicians just give antibiotics and we are just like "Okay!"."

Most participants believed that the preparation in terms of client communication is sufficient. Participant 9: *"They teach us a lot about communication."* Participant 19: *"Communication is something that can't really be taught, but you have to get experienced. So as far as possible, they are doing good here."* Participant 22: *"In the first years we get enough talks about communication and how to deal with difficult clients."* However, the lack of education on coping with language barriers was mentioned in four focus groups. Some participants indicated education on communication as chaotic, because there is no specific course on it.

Finally, in focus groups 1, 4 and 5 the lack of engagement with medical faculties was discussed. Participant 4: *"There is no communication between vets and medical doctors nor between veterinary and medical students."* Participant 21: *"We actually never engage with medical students at all."*

Suggestions

All three focus groups that mentioned the lack of engagement with medical faculties suggested to establish more interaction and exchange of knowledge between medical and veterinary students. Participant 21: *"I think One Health is an important concept. It would be nice to organise a big outreach with medical and veterinary students at the same time."* Participant 26: *"They used to do this during the Hluvukani rotation, but this is getting less. They should bring this back."* In all focus groups it was suggested to make AMR education more practical where possible. Participant 6: *"Academics are doing research and are more in the microbiology part of it. They will say you shouldn't treat with antibiotics, but they don't think practically."* It was often suggested to incorporate more practicals and outreaches earlier in the study programme to experience client communication as well as to get more insight in antimicrobial treatments before the students get to their clinical rotations. Participant 13: *"Maybe we could spend just one day or two afternoons a week in the clinics, just like the medical faculty does, or do more compulsory outreaches to 1) expose students and 2) educate farmers already in our third year."* Participant 25: *"More rural exposure in our early years would decrease false expectations and make the resistance problem real to us. In our second and third year we are not as stressed as in the other years and we often have free afternoons, so they could give us this exposure in those years."* Also smaller practical experiences were suggested. Participant 12: *"Let us be involved in making antibiograms for example, to make it more real to us and make us more aware of the importance of it."* Not all participants agreed on the introduction of more practical AMR education in the early years of their study programme. Participant 27: *"I think this should not happen before third year, because you need the background of the Pharmacology course to understand what antimicrobial resistance is and how antimicrobials work before you can do this practically. However, fourth year is already the year of death in Onderstepoort and in fifth year we already start with clinics, so..."*

Regarding didactic teaching participants were positive about lectures as a teaching tool, but more interactive components were suggested. Participant 15: *"It would be nice if they incorporate more case reports about real experiences with antimicrobial resistance from the field to make it more relevant."* Participant 18: *"A debate would be great, like giving us a case, splitting us up in groups and then letting each group defend the use of a specific type of antibiotic and tell the others how to apply it, what the resistance rate is and that kind of stuff."* In two focus groups it was mentioned that the provided PowerPoint handouts are not very effective. Participant 3: *"Nobody ever looks back at those handouts."* Participant 6: *"So when you join the lectures, it is fine, but in clinics you won't have anything to refer back to. I would like to have a detailed hard copy instead of just the summary on a handout."*

Nearly all participants would like to see more emphasis on AMR during the current clinical rotations. Participant 19: *“The doctor should force you to look up which antibiotics you could administer, why you would choose one and thus motivate what you are doing.”* Regarding the lack of uniformity in prudent antimicrobial stewardship between the different clinics and clinicians, some participants suggested to provide compulsory trainings to all educational staff.

Regarding contents of AMR education, some participants would like to get more details about the size of the problem and the mechanisms and resistance rates of the different antimicrobial drugs. Participant 20: *“We learn about it in Pharmacology, but since that is such a packed course, it may be better to do this during the clinical rotations.”* In four focus groups more education about alternatives for antimicrobial treatment was suggested. Participant 11: *“They tell us about management, but they should also tell us about other treatment options.”* Participant 13: *“It is all theory, but nobody tells us what we need to do.”*

Although most participants were satisfied with their education on communication, many of them would like to learn more about how to cope with language barriers and cultural differences. In two focus groups it was suggested to provide a language course in the second or third year. Participant 16: *“The medical students, but also dentists and some other health students, can choose between Zulu and other African languages. Since we are working with farmers a lot and we don’t always have a translator, this would be good for us as well.”* Some participants suggest to make this a compulsory course. Participant 13: *“I think everybody has to do it, because even though you might want to do small animals, you can end up liking cows.”* Other participants would make it optional. Participant 21: *“A lot of people would be interested to learn the basic speaking of an African language like “where is your cow?”, since we all have our compulsory community service here.”* In focus group 4 it was also suggested to introduce a specific communication course and a cultural course, provided by a sociologist or somebody that works in a rural area, to learn about cultural differences in South Africa. Some participants suggested to make it more the students’ responsibility to communicate with clients during the clinical rotations, whereas other participants this is already sufficient in the current clinical rotations. Participant 27: *“The faculty can do so much, but if you are not willing to take a case in the hospital and communicate with the client, that’s on yourself.”*

Many participants recognized imprudent antimicrobial stewardship not only in the clinics in OVAH, but also in veterinary private practices, that are important to shape their behaviour. Participant 24: *“A big part of our practice and career is what we learn from the old vets. You end up doing what that vet does.”* In focus group 5, education of private vets was suggested by assigning a stimulating amount of points for continued professional development (CPD) courses on AMR. Participant 23: *“There are like twenty courses and each vet has to do five of them in a year to get their points. Let’s say that one of them has to be on antimicrobial resistance.”*

Besides curricular suggestions, some participants recommended the FVSO to get more involved in policy making and legislation. Participant 28: *“Put pressure on governmental legislation through the state vets that are working at the faculty and that are also somehow involved in the government.”* A few participants would like the FVSO to do more research on AMR and share the findings with the students.

Part 3: Farmers

In Table 4 a brief overview of demographic details of the 21 farmer participants is shown. The complete demographic table can be found in Appendix 8 and is textually summarized here. Mixed farmers as well as one species farmers, situated in four South African provinces, were represented. The ages varied from 27 to 71 years and the years of experience as a farmer varied from 5 to 40. The smallest farmer herded 10 animals, whereas the biggest farmer kept 2500

animals. Twenty farmers kept more than 100 animals. The mean herd size was 400,4. All participants employed at least one person. The mean number of employees was 8,33 with a range from 1 to 30. Sheep and goat farmers represented the majority, while six farmers kept cattle. All participants attended secondary school and most of them finished this. Eight participants accomplished a Bachelor's degree. Two participants possessed a National Diploma (completion of a three year course at a technical university). One participant accomplished a Master's degree. For eight participants farming was their fulltime job. Part-time farmers were attending jobs in diverse sectors, including two veterinarians.

Knowledge on antimicrobials and AMR

Each interview was started with a brainstorm about antimicrobials. All participants mentioned the treatment of infections or diseases as an application of antimicrobials. Participants 4, 5 and 13 mentioned the expensiveness of antimicrobial treatment. Terramycin and penicillin were often mentioned as examples of antimicrobials. Participants 1, 6 and 10 explicitly mentioned AMR. Participant 1: *"We should avoid using antimicrobials. We are running out of antibiotics quickly, because there is much resistance."* Participants 7, 15 and 18 linked

antimicrobials to preventing diseases in animals. Participant 11 and 19 already emphasized the importance of dose, duration and withdrawal periods during this brainstorm. Participant 11: *"We cannot eat the meat of the animal if you have just treated it with antimicrobials."*

When the researcher introduced the term "antimicrobial resistance", participants 15 and 17 said that they have never heard about AMR before. Participants 2 and 5 heard about AMR for the first time when they were visited by a doctor from the Faculty of Veterinary Science in Onderstepoort. Participant 5: *"When prof *** visited me five years ago to test my bulls, he told me about it."* Participant 18 was introduced to AMR by advertisements at the clinic in Onderstepoort. Participants 3, 7, 9, 12, 14, 19 and 21 said that publicly available media like radio, TV, magazines and newspapers introduced them to the AMR concept. Daily work, scientific papers and farmers information days played a role in the introduction of the AMR concept to participant 1, 6, 8 and 16. Participants 4, 11, 13 and 20 mentioned that their human doctor told them about AMR for the first time. Participant 4: *"My doctor told me about it when I was not getting better from a pneumonia two years ago."* Participant 20: *"When I broke my leg my doctor told me about resistance."*

Table 4: Brief overview of demographic information of farmer participants. The complete demographics can be found in Appendix 8.

Participant	Gender	Age	Farmed species	Number of animals
1	M	41	Sheep	1000
2	M	63	Goats	150
3	M	71	Goats	100
4	F	59	Sheep	350
5	M	61	Cattle	450
6	F	55	Sheep	200
7	F	27	Goats, sheep	200 600
8	M	58	Sheep, cattle, game	2500
9	M	47	Goats	150
10	M	66	Sheep, cattle, horses	120 40 10
11	M	27	Sheep	100
12	M	60	Sheep	250
13	M	50	Goats, sheep	150 200
14	M	54	Sheep	400
15	M	55	Goats, sheep, cattle	118 3 8
16	M	35	Goats	100
17	M	50	Cattle	10
18	M	65	Cattle	300
19	M	57	Sheep	400
20	M	48	Goats	150
21	F	34	Cattle, goats	350

Participants 2, 4, 6, 7, 8, 10, 12, 13, 14, 16, 19, 20 and 21 recognized AMR as a big problem for public health. Participant 13: *"It is a huge problem for people with tuberculosis: the new TB is stronger, so old drugs do not work anymore."* Participant 21: *"It is a major problem in the food chain, hospitals, water etc."* Overuse and/or incorrect use of antimicrobials were mentioned by participants 2, 7, 8, 9, 10, 12 and 14 as causes of AMR. Participant 9: *"We should only use antimicrobials when really necessary such as for valuable animals or life-threatening diseases."* Finishing antimicrobial courses, minimizing antimicrobial use, using only newer antimicrobials and prevention by hygiene measurements were mentioned as means to fight AMR. Participants 3 and 5 admitted having limited knowledge about AMR. Participant 5: *"I don't know that much. I should ask the vet for guidelines on antibiotic use."*

Participants 3, 4 and 12 would like more information about the AMR problem itself, now and in the future. Participant 4: *"Is it really true? Is it not just people overreacting?"* Participants 5, 8, 10 and 13 would like to learn more about alternative ways to prevent AMR. Participant 8: *"What is being done to develop drug that are "immune" to resistance development?"* Participants 2, 7, 9, 14 and 16 would like to have more practical information on how they could avoid AMR on their farm. Participant 2: *"What drugs can I use best? Which ones have less resistance?"* Participants 11, 18, 19 and 20 did not want to learn more about AMR because of their lack of interest and/or sense of responsibility. Participant 11: *"I don't really want to learn more, because it is the vet's job."*

Farmers' perceptions regarding AMR education by veterinary students

Communication in general

The first question of this part of the interview was how often the veterinary professor communicates with the farmer while students are listening. Participants 4, 6, 7, 9, 12 and 17 answered "very often", participants 1, 3, 8, 11, 15, 18, 19, 20 and 21 answered "often" and participants 2, 5, 10, 13, 14 and 16 answered "sometimes".

Participants 3, 11, 15, 16 and 21 were positive about the communication with the students themselves. Participant 3: *"They are enthusiastic, full of life and treat us with respect."* Participant 15: *"I like to talk to them and they teach me many things about diseases".* Participants 2, 5 and 14 were moderately positive, but added that the students lack practical knowledge. Participant 14: *"They know a lot, but sometimes they are not really practical. I don't think they know or care about money and costs."* Participants 6, 7, 8, 9, 10, 19 and 20 perceived a wide variety in communication skills between students with a lack of interest as main reason. Participant 6: *"Many are not interested in farm animals. They just talk because they have to impress the prof and get marks."* Participant 10: *"Some students are excellent and some are not so good. Those that are not interested are the biggest problem."* Participants 8 and 9 stated that the students seem unsure when talking with them. Participants 1, 4, 12, 17 and 18 perceived the communication with students as negative. Participant 18: *"Students communicate rarely. They struggle to understand me."* Participant 4: *"I know they are learning, but I do not benefit from communicating with them. They ask the prof anyway."*

Participants 4, 7, 8, 9, 10, 17, 18 and 19 doubted the value of communicating with students and therefore think there is enough communication with students. Participant 17: *"I don't always feel like students know what they are talking about."* Participants 4, 8, 9, 10 and 19 would rather communicate with the prof. Participant 8: *"They are still learning so they should not talk too much. I would rather have real information, so it is better if the prof talks."* Participants 2, 11, 13, 14, 16, 20 and 21 were positively satisfied by the amount of communication with students. Participant 20: *"They already talk and tell me stuff, sometimes even more when the prof is not there."* Participant 15 also answered that he experienced enough communication with students, but he did not explain why. Participants 1, 3, 6 and 12 wished

for more communication with students. Participant 3: *“They are being trained very well. They always have new ideas and I like that.”* Participant 12: *“They are there to learn, so I can teach them more about farming, but not about diseases.”*

When the researcher asked the participants to mention barriers or challenges that they face when communicating with students, participants 5 and 11 answered that they do not experience any barriers. Participants 1, 2, 7, 14, 15, 19 and 20 experienced the lack of practical knowledge and advices as the main barrier of students’ communication. Participant 15: *“They know a lot about diseases, but not so much about animals and how to handle them.”* Participant 19: *“Students have a lack of context. They make impractical suggestions, because most of them just have book knowledge.”* Participants 8, 9, 13, 16, 17 and 18 had difficulties to understand the technical language of students. Participant 16: *“They use terms that I don’t always understand. Their knowledge is a lot and can intimidate me.”* Participants 3, 10 and 17 mentioned local languages of local languages as a barrier. Participant 10: *“I don’t like it when they talk with a mix of languages.”* Participant 17: *“They talk Afrikaans or English, but very little Tswana.”* Participants 4, 8, 12 and 15 faced challenges with trusting students’ knowledge.

Transfer of antimicrobial and AMR knowledge

After asking questions about the participants’ perception on communication with students in general, the quality and quantity of education about antimicrobials and AMR were discussed. Participants 1, 2, 4 and 6 answered that the prof talks about antimicrobial treatments with them instead of the students. Participant 4: *“The prof talks to me about the treatment plan. He tells me everything: how much, for how long and how I will know if it is not working.”* Participants 3, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20 and 21 all answered that the students tell them about the dose and duration of the antimicrobial treatment. Participant 5: *“I usually use 20 ml for small and 40 ml for big cattle, so I probably learnt that from the students.”* Participant 21: *“Some almost recite the label!”* Participants 5, 15, 19 and 20 mentioned that indications for antimicrobial treatment are subject of the conversations with students. Participant 5: *“Terramycin is for redwater and heartwater, penicillin is for everything else.”* However, participant 3 said that *“they don’t tell much about indications.”* Participants 3 and 19 answered that students give them information about how to inject. Participant 8 said that students give warnings about how to store medication, but according to participant 14 they do not.

Participants 1, 2, 6, 11, 12, 13, 15, 16, 17, 19 and 20 would like students to tell them more about antimicrobial treatments. Participant 6: *“They should be able to practice how to give this information to an owner.”* Participant 16: *“We always learn from each other.”* Participant 19: *“They should also talk about withdrawals and other alternatives.”* Participants 3, 4, 5, 7, 8, 9, 10, 14 and 21 did not wish for more information from students about antibiotic treatments. Participants 5 and 21 argued that they do not use much antibiotics, so extra information from students would be unnecessary. Participants 4, 9 and 14 would like to get more information about antimicrobial treatments from the professor instead of the students. Participant 4: *“When the students are involved, it takes a long time and I am very busy.”* Participant 14: *“The prof should handle that, because it is so important.”* Participants 7 and 8 rather use other sources to learn about antimicrobial treatments. Participant 7: *“I mostly read what I have to do myself.”*

Participants 1, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16, 17, 18, 19, 20 and 21 said that students have never explicitly told them about AMR. Participant 9: *“I have heard the prof and students talk about it, but they have never spoken to me about it.”* Participants 8, 11, 13 mentioned occasional AMR discussions with students. Participant 8: *“One student talked to me about it. She was just saying that for Pasteurella penicillin is not working anymore and that I should try a different antibiotic.”* Participant 13: *“When an ewe had mastitis they told me that antibiotics would not work because of resistance. Then I changed to another antibiotic and it got better.”*

Suggestions

In order to improve the communication between students and farmers, participants 3, 5, 7, 14, 19 and 21 recommended to give students more practical experience with farming. Participant 14: *“They should work more hands on so that they know what their advice implies.”* Participant 21: *“They should spend more time on farms. They must become confident around farmers and farm animals.”* Participants 1, 6 and 9 suggested to select students that are interested in farm animals to visit farms. Participant 9: *“I feel like many students do not seem to want to be a food animal vet. I don’t think those students should come to farms.”* Participants 10, 13 and 18 suggested to teach students to use an appropriate type of language. Participant 13: *“They should learn more common names for diseases and treatments.”* Participants 2, 8 and 10 would like the students to improve their report writing. Participant 2: *“Students talk fast and I need more time to read and refer back to something, so the information about antibiotic treatments should be written down.”* Participant 8 and 10 would like to receive the written reports quicker after the visit. Participant 10 added that *“the reports often contain too much information.”* Participant 6 recommended more oral examinations to improve the students’ verbal communication. Participants 13, 16 and 17 suggested that students should learn relevant terms in an indigenous language. Participant 13: *“Sometimes a little bit of Tswana would help.”* Participant 18 suggested to use translators.

Participants 10, 14 and 19 were concerned about the amount of veterinary students that want to work with food animals and suggested to focus more on food animal training. Participant 14: *“We need more students with farming interests and backgrounds. We should not just train dog and cat vets.”* Participant 1 added to that that he needs *“independent vets that can help with AMR management and think in alternatives like probiotics. The faculty should fill this gap.”*

Participants 1, 3, 4, 7, 8, 10, 13, 17, 18 and 21 would like to receive more information from the FVSO herself as well. Participant 4: *“The faculty does not have much information for farmers. I get information from Veeplaas. That is more informative!”* Participants 1, 7, 8 and 10 suggested regular emails or newsletters to inform farmers. Participant 1: *“It would be nice to receive an email from Onderstepoort once in a while with information about currently important topics, such as antimicrobial resistance.”* Participants 1, 13, 17 and 21 suggested courses or seminars for this purpose. Pamphlets and information booklets were suggested as educational tools by participants 3, 13 and 21. Participants 10, 12, 14 and 19 recommended to use more promotion material to gain more publicity. Participant 14: *“There should be more exposure for farmers to Onderstepoort, because people don’t know about the services they offer.”* Participant 19: *“They are not visible.”* Participants 5 and 12 questioned the responsibility of the FVSO and would like more involvement of medical professionals. Participant 12: *“It should also be the job of medical professionals.”* Participants 1 and 13 would like to see more faculty activities in rural areas. Participant 13: *“The community must benefit from their expertise.”*

Discussion

The aim of this study is to investigate the effectiveness of veterinary education on antimicrobial resistance (AMR) at the Faculty of Veterinary Science in Onderstepoort, University of Pretoria, South Africa. How well are the future South African veterinary prescribers prepared for prudent antimicrobial use and what hurdles have to be overcome according to veterinary instructors, students and farmers? In the discussion all data from three participant groups are integrated before providing a list of recommendations to improve veterinary AMR education at the FVSO. By our knowledge no studies investigating any veterinary curriculum regarding AMR education by involving instructors as well as students and clients have been published

before. Since tackling the AMR problem, in which veterinarians play a major role, is high on the priority list of major health organisations such as the World Health Organization (WHO), World Organization for Animal Health (OIE) and Food and Agriculture Organization (FAO), this study could be an inspiration for other veterinary faculties to evaluate their curricula in order to improve veterinary AMR education worldwide.

AMR in the FVSO's curriculum

The importance of prudent use of antimicrobials and education on AMR was recognized by all veterinary instructors and students that participated in this study. Of course this is the only desirable answer they could give, but similar results were found in different studies among South African medical and pharmacy students [47], [48]. The overall AMR knowledge of veterinary students seems to be decent: multifactorial management, basing antimicrobial choices on antibiograms, using narrow spectrum antibiotics when possible and the importance of advising clients about withdrawal periods, right dosing and completing the course are topics that come to mind when students talk about AMR. Some cautiousness is needed when attributing the students' level of knowledge directly to the veterinary curriculum: extracurricular events, e.g. doctor visits and high school, should be taken into account as well.

According to the curricular documents as well as students' attitudes, Veterinary Pharmacology is the leading course in discussing AMR and prudent antimicrobial stewardship and seems to meet the OIE "Veterinary Education Core Curriculum" guideline [43]. However, a discrepancy seems to exist between curricular documents and the attitudes of instructors of the other AMR related courses on the one hand and the students' perceptions on the other hand: although all instructors confirmed the micro curricular contents, only a minority of the students did so. This discrepancy could be explained by evaluating the teaching tools that are being used when teaching about AMR. AMR seems to be interwoven in lectures, discussions and assignments. Lectures or other tools specifically on AMR do not exist. In clinics it depends on presented cases whether students are exposed to AMR discussions with clinicians or not. Furthermore, during Veterinary Public Health and One Health AMR is being discussed by means of peer-to-peer group presentations. Although group projects are active learning methods that enhance the students' ability to collaborate – an important skill in order to tackle the AMR problem together – group presentations are not always an effective way to teach students about a certain topic. In their meta-analysis Tomcho and Foels (2012) concluded that students perform better without a group accountability component such as a group presentation that allows group members to divide the work instead of learning all of the material [49]. The problem of social loafing facilitated by group projects, should also be taken into account [50]. Furthermore, the results of this study show that students that prepare a presentation about AMR topics feel that they are better informed about AMR than students who prepare another subject and just listen to their peers. Concludingly, the degree of exposure to AMR education differs between students and the use of teaching tools is suboptimal.

Additional to factual knowledge on AMR, communication skills are essential in order to get a message across and to educate the actual users of antimicrobials: clients. The instructors' and students' perceptions seem to coincide with the curricular documents regarding education on communication: during Veterinary Professional Life a theoretical framework on communication skills and coping with cultural diversity is provided, which is extended with community projects, education on interdisciplinary risk communication and practical experience during One Health and the clinical rotations. In general students seem to be satisfied with their education on communication. Moreover, the results of this study show that extracurricular activities can enhance communication skills as well.

Application to the farmer community

Now the curricular contents have been discussed from various points of view, the next question needs to be answered: to what extent do veterinary students apply these communicative skills and transfer their AMR knowledge when visiting farmers? Although students are aware of the fact that educating farmers about AMR is an important task of the veterinary professional, their own contribution seems to be insufficient. In principle, students seem to know how to effectively educate farmers about AMR: they would use a personal approach, discuss practical topics and adapt their use of language to the client's level. However, due to the way of asking (i.e. discussing a fictional case) it is not clear whether the students were talking about the hypothetical approach they would use as a veterinarian or the approach they actually apply when visiting farmers during their clinical rotations. The results of the farmer interviews tend to confirm the first option. AMR, antimicrobial misuse and other AMR related topics do not seem to be top-of-mind subjects for South African farmers. Although students talk to their farmer clients about dose and duration of antimicrobial treatments, they hardly ever explicitly mention AMR. More often the professor seems to do the talking, while students are listening. Although we did not explicitly ask the farmer participants if they would like to have more discussions with students about AMR, half of them would like students to teach more about antimicrobial treatments. Other farmers were satisfied by the professor doing the talking, since they doubted the students' expertise, experienced a lack of interest and practical knowledge and/or had trouble understanding the students' technical language. In our view this creates a vicious circle: as long as students are not exposed to communicating with clients, their lack of practical knowledge and use of too technical language are maintained and transfer of AMR knowledge remains ineffective. Therefore, the major conclusion regarding student-farmer AMR education that can be drawn from this study is that a proper student-farmer relationship is key in effectively transferring AMR knowledge.

Hurdles to be overcome

Before making recommendations on how to improve the curriculum, hurdles that interfere with AMR education at the FVSO should be identified. These hurdles can be subdivided in those encountered within and those encountered outside the FVSO.

The results of this study show different factors from the South African context as major impeders of the effectiveness of veterinary AMR education. More background information about this context can be found in the introduction of this thesis. Firstly, a lack of data about antimicrobial use and the size of the AMR problem in South Africa concerns instructors as well as students. This is confirmed when searching literature databases: by our knowledge the only data on antimicrobial use in the South African livestock sector originate from 2002-2004 and although consumption and resistance data in the human health sector are more abundant, surveillance systems remain a challenge [24], [51]. This lack of data makes students perceive AMR as a theoretical problem that is far removed from their personal lives. This perception could potentially impede their sense of responsibility and commitment.

A second contextual factor that becomes apparent from the results is the lack of legislation regarding antimicrobial use in South Africa. The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947 favours the use of certain antimicrobial compounds as prophylactic stock remedies without veterinary intervention [24], [26]. The FVSO could be fully committed to optimizing their AMR education, but as long as the South African law does not promote prudent antimicrobial use, the effectiveness of AMR education will remain insufficient.

Finally, instructors, students as well as farmers sometimes face a communication barrier when communicating with each other. After all, South Africa is a multilingual country that houses many different cultures. Various studies show that the South African medical profession also faces this barrier, which impedes effective healthcare delivery [52], [53]. Additionally, the educational system is not standardized and poverty prevents a major part of the population from attending school. This educational gap enlarges the communication barrier between veterinarians and their clients even more, impeding effective transfer of AMR knowledge.

The results of this study indicate three major hurdles within the FVSO. Firstly, lack of time is experienced by instructors as well as students. It is a common phenomenon that veterinary curricula are crowded [42]. Hardly any veterinary curriculum around the world contains a course specifically dedicated to antimicrobial use within a sociological context [41]. Especially Veterinary Pharmacology (VP) was described as a packed course from which students “have to filter some things out.” Combined with the instructor’s statement that students are taught about AMR during VP, but not tested on AMR knowledge, presumably AMR is one of the topics that students ignore. Similar results were reported in studies among medical students in different high income countries: AMR education is perceived as inadequate and rigid curricular policies seem to cause a lack of time to prioritize antimicrobial principles in the medical curriculum [54]–[57]. South African medical and pharmacy students ask for more attention for prudent antimicrobial use and AMR in their curriculum as well [47], [48].

Another major hurdle is the inconsistent approach of AMR education in different phases of the study programme, caused by a lack of consensus within the FVSO. It seems that clinicians do not always comply with the rules that students learn during theoretical courses. They seem to prescribe based on personal or practical preferences instead of scientific research. Some clinics appear to do better regarding prudent antimicrobial prescribing compared to others. Private veterinarians, who are indirectly involved in AMR education by the FVSO, deserve attention as well. Students described their external internship as valuable in terms of learning practical knowledge and skills, but they felt like they are better educated regarding AMR than private veterinarians, who are again impeded by South African contextual factors as described earlier. Similar results were found in a study among Dutch veterinarians, that found that years of experience were related to a less concerned attitude towards the contribution of antimicrobial use to the development of AMR [58].

Finally, the FVSO’s visibility and information for farmers seems to be insufficient. In our view this is an important problem that needs to be solved: the FVSO is the only veterinary faculty in South Africa and is therefore authority in the field of educating students as well as the community about issues such as AMR. The FVSO needs to reach out to the community and share her knowledge with them.

Recommendations towards the FVSO

Although half of the student participants believed that theoretical AMR education is sufficient and the majority was satisfied with the amount and contents of education on communication at the FVSO, the curriculum could be strengthened at various points. In this paragraph recommendations towards the FVSO are proposed. Table 5 shows a brief overview of the recommendations. Some recommendations were brought up by participants, other recommendations are based on literature.

Table 5 Brief overview of recommendations towards the Faculty of Veterinary Science in Onderstepoort (FVSO)

	Recommendation	Aim
Curricular	Training on intercultural communication	Tackle linguistic/cultural barriers
	More practical experience earlier in the study programme	- Make AMR less abstract - Improved student-farmer relationship
	E-modules on AMR	- Interactive education - Less time-consuming - Horizontal connections between courses
	Document with FVSO's policy regarding antimicrobials	Standardisation of AMR education
	AMR course for private veterinarians	
Contextual	Put pressure on the government	Law amendment that prevents over-the-counter sales and use of antimicrobials as stock remedies
	More scientific research on AMR and antimicrobial use in South Africa	- Fill the data gap - Make AMR less abstract
	Use publicly available media to reach the community	- Education of the community - More publicity

Most medical schools in South Africa already provide basic training in local African languages and cultures [59]. The results of our study show that students and farmers would like such trainings to be implemented in the veterinary curriculum as well in order to cross linguistic and cultural barriers. Abundant international literature on training strategies and frameworks within the medical profession is available, that could inspire the FVSO [60]–[62]. However, these strategies do not exactly fit the South African situation: in their systematic review Chipps et al. state that the main challenge in South Africa is providing a training that bridges the gap between the worldview of the African people and the Western way of thinking that is taught to health care professionals [63]. Our recommendation to the FVSO is to offer students a course on intercultural communication that includes cultural values and the basic concepts of local languages. In order to develop a South African specific course, collaboration with South African medical schools and consulting the Department of Anthropology of the University of Pretoria could be useful. We are aware of the fact that the veterinary curriculum is already crowded and that such course must not be at the expense of other important curricular contents. Therefore, we would recommend an elective course or even an e-module that enables students to earn an extra certification on intercultural communication.

This lack of time poses a problem on AMR education as well. Ideally, students would get practical experience in an early stage of their study programme in order to give context to theoretical AMR education, to make AMR less abstract and to create a proper student-farmer relationship that enables effective transfer of AMR knowledge. However, practical instruction is an intensive and time-consuming way of teaching. Therefore, the FVSO could explore the opportunities that e-learning modules could offer. Massive open online courses (MOOCs) on AMR have already been proven to be effective in modern medical education [64]. MOOCs facilitate independent learning and learning fragmentation and are therefore promising additions to crowded curricula [65]. Implementation of a MOOC on AMR could kill various birds with one stone: it could fulfil the students' wish for more active and practical education, e.g. by including fictional cases, and by dividing the MOOC in submodules within existing courses, horizontal connections between these courses will arise and AMR education will

become more efficient [41]. In 2011, Michigan State University and the University of Minnesota (United States) collaborated and developed the Antimicrobial Resistance Learning Site (AMRLS) with the aim to help veterinary students understand the AMR concept [66]. The current website consists of seven modules: Microbiology, Pharmacology, Dairy Cattle, Beef Cattle, Pet Animals, Equine and Swine. Besides classical lectures and reading parts more practical and interactive teaching tools are used, such as case presentations, animations, videos and quizzes. All modules are publicly accessible at <https://ccaps.umn.edu/amrls>. It should be taken into account that this website does not perfectly suit the South African context because of differences in farming methods, prevalent diseases, legislation et cetera. Despite that, this website could be used as foundation. Since the website is publicly available, no major investment is needed initially. When evaluations among students demonstrate its success, the FVSO could potentially invest in developing similar modules adjusted to the South African context. Collaboration with medical faculties is then recommended in order to accomplish a One Health approach, profit from each other's expertise and support medical students, who could profit from more active educational tools as well [47].

Although a MOOC on AMR could positively contribute to integrative learning, it will not be able to solve the problem of inconsistency in AMR education at the FVSO. A consensus should be reached in order to standardize AMR education in different phases of the study programme. We advise the FVSO board members to sit together with experts from the veterinary as well as the medical field and representatives of lecturers, clinicians and students in order to develop a policy document about antimicrobial use. This document should be based on scientific research, although the practical feasibility should also be taken into account in order to make it work. All educational staff members, including private veterinarians that coach students during their external internship, should be educated about this policy document. This document could be summarized on posters at different places inside the faculty building in order to inform students and clients about the policy as well. Students could function as valuable inspectors of the policy's practical implementation, since they are the ones who are exposed to the complete study programme and would notice discrepancies between theoretical and clinical education on AMR and prescribing.

Finally, in our opinion the FVSO should not only revise her own curriculum regarding AMR. The FVSO is the only veterinary faculty in South Africa and therefore a major authority that possesses the expertise to tackle the AMR problem from a veterinary point of view. On a large scale we encourage the FVSO to collaborate with the South African Veterinary Council (SAVC) and other stakeholders to put pressure on the government in order to address the legal issues that were described earlier. Furthermore, more scientific research on antimicrobial use and the size of the AMR problem in South Africa should be facilitated in order to be able to teach students as well as the community about the seriousness of the problem.

On a smaller scale we would advise the FVSO to include targeting farmers and private veterinarians in their revision plan as well. In order to meet the farmers' wish for more information about AMR, antimicrobial use and alternatives and to gain more publicity at the same time, the FVSO could explore the opportunities of using media such as newspapers, TV and e-mail. In order to reach the rural community as well, information booklets could be spread and seminars could be organized by the FVSO.

A tool that was recommended by students in order to improve prescribing behaviour of private veterinarians, was organizing a continued professional development (CPD) course on AMR and prudent antimicrobial use. The AMR National Strategy Framework encourages this idea [25]. Potentially, a MOOC could be used in order to make it easily accessible for all South African veterinarians.

Limitations

Like every other study, this thesis has its limitations. Firstly, the participant groups were not fully balanced and representative. Due to lack of time, all students who were in their clinical rotations and willing to participate, were accepted. This could have created a selection bias by selecting enthusiastic, critical students instead of “the average student”. Moreover, there was no selection on electives, resulting in an overrepresentation of Small Animals and Exotic Practice. Even though all students get exposed to farm consultations, selecting more students with a specific interest in production animals or rural farming would have suited the study aim better. Furthermore, small scale farmers were strongly underrepresented. Two farmers were originally veterinarians and no pig or poultry farmers were included, while they are the largest antimicrobial users [23]. Therefore, some cautiousness is needed when extrapolating the data to the South African farmer community. However, veterinary students of the FVSO are mainly exposed to commercial farmers in the area around Pretoria. Therefore, this slightly biased participant group was sufficient in order to meet the aim of this study. Selection of instructor participants was based on the appearance of AMR related topics in the curricular documents of their courses. Consequently, hidden curricular contents were possibly not identified.

Secondly, not all questions were asked to all participants due to using semi-structured interviews and focus groups. This method could also have created a confirmation bias: although we aimed to minimise our own input and to prevent ourselves from provoking certain answers, sometimes guidance was needed to revive the discussion. Therefore, it is questionable whether all information and opinions purely originate from the participants themselves.

Another limitation of this study is the fact that the farmer interviews were conducted by different researchers. As a consequence, not all interviews were conducted in the same way. The clinicians who were asked to interview one or a few farmers possibly did not feel as involved and responsible as the researchers themselves, making the completeness of their notes doubtful. This poses another limitation: not all interviews were recorded, making it impossible to verify the completeness of all answers.

Finally, the scope of this thesis was too broad for the time we had in order to be able to provide a comprehensive overview of the gathered data. It would have been better to focus on veterinary students alone. However, AMR education is a broad topic with many parties involved that were not even all covered by this thesis.

Follow-up research

This thesis serves as an explorative study. In order to draw more definite conclusions about the effectiveness of AMR education at the FVSO, a quantitative study that includes larger participants groups in which all variables (e.g. student electives, undergraduate courses, clinicians from different departments, farm sizes, farm species etc.) are evenly represented, is needed. The Hluvukani Animal Clinic could be approached in order to include rural farmers as well. A cross-sectional electronic survey could be used, from which differences between groups and correlations between variables can be demonstrated after conducting a statistical analysis. This survey could be inspired by similar studies among medical students and instructors [47], [54], [57].

Furthermore, it would be interesting to extend the client group with pet owners. In this study only farmers were included as educational output parameter, because of their major contribution to antimicrobial use in animals. However, due to the close relationship between humans and pets and the occurrence of resistant bacteria in pets, antimicrobial use in pets also contributes to AMR development and poses a risk for public health [21], [22]. Therefore, veterinary AMR education should not only pay attention to antimicrobial use in livestock, but antimicrobial use in pets and how to constructively inform pet owners about AMR should be addressed within the curriculum as well.

It is also important to realise that educational effectiveness proves itself not only during the study programme, but even more during the consecutive career of students. After all, veterinarians are the ones that actually have to take responsibility for their prescribing behaviour. In a follow-up study young veterinarians (e.g. two years after graduation) and their clients could be involved in order to evaluate the direct result of AMR education at the FVSO. Experienced veterinarians would not suit this aim, since their study programme is outdated and their prescribing behaviour is shaped by many external influences and experiences. On the other hand, it would actually be interesting to investigate these external influences that are encountered before and after attending Veterinary Science in order to identify and intervene in extracurricular events that affect AMR knowledge and prescribing behaviour.

Last but not least, hopefully this study can be an inspiration for other veterinary faculties to evaluate their curricula in order to improve veterinary AMR education worldwide.

Conclusion

Antimicrobial resistance (AMR) is a worldwide problem that affects human as well as veterinary medicine. Combined with the high burden of infectious diseases such as HIV and tuberculosis, AMR poses a serious threat to South African humanity. Education could be an important tool to tackle the problem. This explorative study aimed to investigate the effectiveness of AMR education of veterinary students of the Faculty of Veterinary Science in Onderstepoort (FVSO), University of Pretoria, South Africa. The importance of AMR education is recognised by veterinary instructors as well as students and AMR related topics are discussed at various moments within the study programme. However, AMR education at the FVSO seems to be suboptimal. The curriculum is crowded and instructors are teaching loose bits of information due to the absence of a clear consensus within the FVSO. As a result, a discrepancy exists between theoretical and clinical AMR education. The South African context impedes the practical applicability of taught AMR related topics even more due to cultural, economic and legal issues. The FVSO should prepare her students for prudent antimicrobial prescribing and educating clients within this sociocultural context. Various recommendations were made to accomplish this. Offering a course on intercultural communication and getting them more practically involved in communication with farmers could result in a win-win situation for students as well as farmers, who now often experience communication barriers when talking to students. Since the curriculum is already crowded, the FVSO should explore the promising opportunities that online AMR modules could offer. Medical schools and veterinary schools all over the world seem to experience similar difficulties regarding AMR education. By choosing an international One Health approach, joining forces and benefiting from each other's expertise, AMR education of veterinarians and health professionals worldwide could efficiently be improved. Finally, since the FVSO is the only South African veterinary faculty and thus a major authority in the field of AMR, the FVSO should collaborate with other South African veterinary and medical stakeholders in order to put pressure on the government to address the legal issues and shape an environment that favours prudent antimicrobial use by our future prescribers.

Acknowledgements

“Start where you are. Use what you have. Do what you can.” – *Arthur Ashe (tennis player)*

Even though I am the worst tennis player ever, this advice helped me through my intensive research project. It was more than just writing a thesis. I developed myself professionally and personally: a new country, a new culture, new people and all the challenges that I faced. I learnt to be flexible and responsible, patient and assertive. And above all, I had a great time.

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Appendix 1 Day One Competencies List of the Faculty of Veterinary Science (University of Pretoria)

UNIVERSITY OF PRETORIA
FACULTY OF VETERINARY SCIENCE
2009-07-02

ESSENTIAL COMPETENCIES REQUIRED OF THE NEW VETERINARY GRADUATE

“DAY ONE COMPETENCIES”

Veterinarian – a person with professional skills, attributes, knowledge and understanding who is able to provide comprehensive services ranging from individual clinical services to a full spectrum of preventive/regulatory/control services through which an individual, communities and the country as a whole may also benefit

Common domestic species – implies cattle, horses, small stock (sheep and goats), pigs, poultry, dogs and cats in the context of this document

A 1 - GENERAL PROFESSIONAL SKILLS AND ATTRIBUTES

The new veterinary graduate should be able to:

A1.1 Recognise and comply with all legal and statutory requirements and obligations pertaining to veterinary activities

A 1.2 Communicate effectively, both verbally and in writing, with clients, the lay public, professional colleagues and responsible authorities; listen to, understand and respond empathetically to clients, use language in a form appropriate to the audience and the context (a diversity of cultures, customs, value systems and means)

A 1.3 Work as a member of a multi-disciplinary team and/or collaboratively with professional colleagues, support staff and clients

A 1.4 Recognise the ethical responsibilities of the veterinarian to the community in relation to their possible impact on the environment and society as a whole, taking into account the diversity of cultures, customs, value systems and means of the various communities (see A 1.9)

A 1.5 Recognise the economic and emotional climate in which the veterinarian operates and respond appropriately to the influence of such pressures

A 1.6 Demonstrate willingness to use his/her professional capabilities to contribute as far as possible to the advancement of veterinary knowledge in order to improve the quality of animal care and public health

A 1.7 Manage a veterinary practice through application of basic principles of:

- human resource management,
- financial management,
- health, safety, biosecurity and labour legislation,

- use of information technology,
- public liability, and
- compliance with regulatory requirements (fees, record-keeping, advertising) as determined by the SAVC

A 1.8 Understand the need and professional obligation for a commitment to continuing education, training and professional development throughout one's professional life

A 1.9 Conduct him/herself in a professional manner with regard to the veterinarian's professional, legal and ethical responsibilities in relation to individual patient care and client relations, demonstrate a mature personality, integrity, tolerance and patience and understand and apply the Code of Conduct and Practice of the SAVC (see A1.4)

A 1.10 Demonstrate and apply skills that enable him/her to competently undertake the functions expected of a veterinarian including

- literacy and numeracy,
- relevant computer skills and utilisation of modern information technology,
- critical and analytical thought,
- logical reasoning,
- problem-solving,
- finding, utilising and managing information,
- well-developed observational skills,
- adaptation to change, and
- make valid judgments and deductions on the basis of available evidence and information.

A 1.11 Develop a capacity for intellectual curiosity and desire for life-long learning, self-audit and willingness to participate in the peer-review process

A1.12 Demonstrate understanding of the scientific method and the scientific basis of modern veterinary medicine and the ability to utilise scientific principles in the practice of veterinary science and medicine

A 1.13 Recognise own professional/technical limitations and demonstrate awareness of when and from where to seek professional advice, assistance and support

(Commentary: This last item is considered to be one of the most important, and should guide all new veterinary graduates when undertaking their professional duties)

B1- UNDERPINNING KNOWLEDGE AND UNDERSTANDING

The new veterinary graduate shall have a thorough knowledge and understanding of the following:

B 1.1 Basic subjects in chemistry, molecular cell biology and physics as well as animal science (husbandry, nutrition and production) and veterinary science subjects on which everyday veterinary activities are based

B 1.2 A basic foundation in research methodology and the contribution of basic and applied research to all aspects of veterinary science

B 1.3 How to evaluate evidence including the interpretation of clinical/diagnostic test results

B 1.4 The structure and functions of healthy animals and all aspects of their husbandry

B 1.5 The aetiology, pathogenesis, clinical signs, diagnosis, pathology, treatment, epidemiology and control/eradication of the common diseases (infectious, parasitic, non-infectious and toxicities) and other disorders that occur in the common domestic species and selected non-domestic species in South Africa and the immediate surrounding southern African region

B 1.6 Relevant South African legislation applicable to the veterinary and paraveterinary professions, animal welfare, meat safety, animal improvement, medicines and related substances, hazardous substances, environment, animal diseases and notifiable/controlled diseases

B 1.7 Relevant South African legislation and guidelines on responsible sale, use, dispensing, storage and disposal of medicines and related substances in animals

B 1.8 Environmental aspects including farming practices, social and economic factors, climate and weather, water supply, conservation practices, etc.

B 1.9 The principles of disease prevention (immunisation, parasite control, housing, nutrition, management and medication) and the promotion of health and welfare, including public health and zoonoses

B 1.10 Veterinary public health principles related to food hygiene and safety, health certification of food, HACCP and zoonotic diseases

C1 - PRACTICAL COMPETENCIES/SKILLS

The new veterinary graduate should be able to:

C1.1 Obtain an accurate history of the individual animal/group of animals including relevant aspects related to the immediate environment of the animal(s)

C1.2 Approach, handle and restrain animals in ways that are effective, safe, humane, ethical and appropriate to the circumstances and instruct others in performing these techniques

C1.3 Investigate a disease outbreak, applying basic epidemiological principles

C1.4 Perform a complete clinical examination and distinguish between normal and abnormal

C1.5 Derive a well-considered diagnosis and list of differential diagnoses

C1.6 Attend to all animals in an emergency and perform basic first aid

(Commentary: problems to be handled for any species include first aid management of haemorrhage, wounds, breathing difficulties, eye & ear injuries, unconsciousness, clinical deterioration, burns, tissue damage, internal organ damage and cardiac arrest. First aid to be applied includes bandaging, cleaning, immobilising limbs, resuscitation procedures, haemorrhage control.)

C1.7 Correctly assess the nutritional status of an animal and advise the client on principles of husbandry and feeding

(Commentary: this applies to commonly presented cases and would not, for example, be expected to include advanced nutritional advice for complex cases, eg. high performance horses, high yielding dairy cows, certain exotic or zoological species.)

C1.8 Where appropriate, carry out routine diagnostic tests and procedures (such as haematology, basic clinical pathology, basic imaging) and request more advanced tests as are needed to make a diagnosis. Ensure proper collection, preservation, identification, and handling of samples, keep accurate records, interpret the results, ensure any diagnostic equipment is used safely and maintained in accordance with current regulations, while applying appropriate quality control

(Commentary: new graduates are expected to have a working knowledge of tests to be undertaken including conditions relating to infectious & contagious diseases; alimentary system; respiratory system; circulatory system; urinary system; nervous system; endocrine system; mucocutaneous system; musculoskeletal system; trauma; poisoning; obstetrics; paediatrics; parturition; reproduction)

C1.9 Use radiographic, ultrasonic, and other technical equipment which can be used as a diagnostic aid, safely and in accordance with current regulations

C1.10 Adhere to and implement the requirements of regulatory/state veterinary medicine in relation to controlled/notifiable diseases, food safety and certification of animals and animal products

C1.11 Promote and maintain human health through the application of veterinary public health principles in the provision of safe, sound and wholesome foodstuffs of animal origin, the control of zoonoses and the appropriate handling and disposal of biological waste and contaminated materials/substances

C1.12 Know and apply the requirements for veterinary certificates as contained in the Code of Conduct and Practice and Rule 5 of the Rules relating to the practicing of veterinary professions, correctly

C1.13 Access the appropriate sources of data on registered medicines; store, administer, prescribe and dispense appropriate pharmacological agents or medicines correctly and responsibly in accordance with relevant legislation, including disposal of waste and unused/expired medicines

C1.14 Carry out common surgical procedures using appropriate techniques and procedures before, during and after surgery, including correct application of the principles of sterilisation of surgical equipment and aseptic surgery

C1.15 Recognise when analgesia and/or anaesthesia are required, implement chemical methods of restraint, assess and control pain, safely induce, maintain and monitor analgesia, sedation, general and regional anaesthesia and take steps to ensure safe and humane recovery

C1.16 Assess the need for therapeutic or other intervention, advise the client accordingly (rationale, options, outcomes, human safety, costs, ethical considerations) and administer appropriate treatment with due cognisance of one's own professional/technical limitations

(Commentary: the new veterinarian must always seek professional advice and support if presented with a case beyond his or her immediate capability - see item A1.14)

C1.17 Evaluate the need for euthanasia and, where required, carry it out safely and humanely with due consideration of the owner's consent and the feelings of owners and others. Advise on disposal of the carcass

C1.18 Carry out a routine post-mortem examination of common domestic animals, record and interpret gross post-mortem findings, and initiate further diagnostic procedures where appropriate. Derive a well-considered morphological diagnosis and a list of aetiological diagnoses

C1.19 Perform ante mortem inspection of animals destined for the food chain and correctly identify conditions affecting the quality and safety of products of animal origin

C1.20 Interpret basic health and welfare records (including production records where necessary) and implement appropriate record-keeping systems

C1.21 Advise on, and carry out basic preventive and prophylactic programmes to promote health, well-being, productivity and performance (immunisation, feeding, housing, management, training, parasite control, treatment) appropriate to the species and commensurate with accepted animal health, welfare and public health standards

C1.22 Promote animal welfare

C1.23 Apply principles of bio-security to minimise the risk of contamination, cross infection and accumulation of pathogens in the veterinary premises and in the field

Appendix 2 Macro curriculum for the core-elective veterinary programme of the University of Pretoria

April 2015

FIRST YEAR: Natural Sciences		
Academic information management AIM 101		
Academic organisation: School of Information Technology	Language of tuition: Both Afr and Eng	
Contact time: 2 lpw	Period of presentation: Semester 1 or Semester 2	Credits: 6
Module content: Find, evaluate, process, manage and present information resources for academic purposes using appropriate technology. Apply effective search strategies in different technological environments. Demonstrate the ethical and fair use of information resources. Integrate 21st-century communications into the management of academic information.		
LST 110 Language and study skills 110		
Academic organisation: Unit for Academic Literacy	Language of tuition: English	
Contact time: 2 lpw	Period of presentation: Semester 1	Credits: 6
Module content: The module aims to equip students with the ability to cope with the reading and writing demands of mainstream modules. LST 110 comprises two components: A flexible learning component that requires individual engagement with the online computer program, MyFoundationsLab; and a formal taught component utilising the scheduled contact periods.		
Biometry BME 120		
Academic organisation: Statistics	Language of tuition: Both Afr and Eng	
Prerequisite: At least 4 (50-59%) in Mathematics in the Grade 12 examination, or at least 50% in both Statistics 113, 123		
Contact time: 1 ppw 4 lpw	Period of presentation: Semester 2	Credits: 16
Module content: Simple statistical analysis: Data collection and analysis: Samples, tabulation, graphical representation, describing location, spread and skewness. Introductory probability and distribution theory. Sampling distributions and the central limit theorem. Statistical inference: Basic principles, estimation and testing in the one- and two-sample cases (parametric and non-parametric). Introduction to experimental design. One- and two-way designs, randomised blocks. Multiple statistical analysis: Bivariate data sets: Curve fitting (linear and non-linear), growth curves. Statistical inference in the simple regression case. Categorical analysis: Testing goodness of fit and contingency tables. Multiple regression and correlation: Fitting and testing of models. Residual analysis. Computer literacy: Use of computer packages in data analysis and report writing.		
Chemistry CMY 117		
Academic organisation: Chemistry	Language of tuition: Both Afr and Eng	
Prerequisite: Refer to Regulation 1.2: A candidate must have obtained at least 50% for Mathematics and Physical Science in the Grade 12 examination		
Contact time: 1 ppw 4 lpw	Period of presentation: Semester 1	Credits: 16
Module content: Theory: General introduction to inorganic and analytical chemistry. Nomenclature of inorganic ions and compounds, stoichiometric calculations concerning chemical reactions, redox reactions, solubilities, atomic structure, periodicity. Inorganic and physical chemistry. Molecular structure and chemical bonding using the VSEPR models. Chemical equilibrium, acids and bases, buffers, precipitation.		
Chemistry CMY 127		
Academic organisation: Chemistry	Language of tuition: Both Afr and Eng	
Prerequisite: Natural and Agricultural Sciences students: CMY 117 GS or CMY 154 GS Health Sciences students: none		
Contact time: 1 ppw 4 lpw	Period of presentation: Semester 2	Credits: 16
Module content: Theory: General physical-analytical chemistry: Physical behaviour of gases, liquids and solids, intermolecular forces, solutions. Principles of reactivity: energy and chemical reactions, entropy and free energy, electrochemistry. Organic chemistry: Structure (bonding), nomenclature, isomerism, introductory stereochemistry, introduction to chemical reactions and chemical properties of organic compounds and biological compounds, ie carbohydrates, lipids and aminoacids. Practical: Molecular structure (model building), synthesis and properties of simple organic compounds.		
Mathematics WTW 134		
Academic organisation: Mathematics and Applied Mathematics	Language of tuition: Both Afr and Eng	
Prerequisite: A candidate must have passed Mathematics with at least 50% in the Grade 12 examination		
Contact time: 1 tpw 4 lpw	Period of presentation: Semester 1 or Semester 2	Credits: 16
Module content: *Students will not be credited for more than one of the following modules for their degree: WTW 134, WTW 114, WTW 158. WTW 134 does not lead to admission to Mathematics at 200 level and is intended for students who require Mathematics at 100 level only. WTW 134 can also be taken in the second semester. Functions, derivatives, interpretation of the derivative, rules of differentiation, applications of differentiation, integration, interpretation of the definite integral, applications of integration. Matrices, solutions of systems of equations. All topics are studied in the context of applications.		
Physics PHY 131		
Academic organisation: Physics	Language of tuition: Both Afr and Eng	
Prerequisite: Refer to Regulation 1.2: A candidate must have obtained at least 50% for Mathematics Grade 12 examination		
Contact time: 1 dpw 1 ppw 4 lpw	Period of presentation: Semester 1	Credits: 16
Module content: Units, vectors, one dimensional kinematics, dynamics, work, equilibrium, sound, liquids, heat, thermodynamic processes, electric potential and capacitance, direct current and alternating current, optics, modern physics, radio activity.		
Molecular and cell biology MLB 111		
Academic organisation: Genetics	Language of tuition: Both Afr and Eng	

<p>Prerequisite: Refer to Regulation 1.2(c): A candidate who has passed Mathematics with at least 50% in the Grade 12 examination Contact time: 1 ppw 4 lpw Period of presentation: Semester 1 Credits: 16</p> <p>Module content: Introductory study of the ultra structure, function and composition of representative cells and cell components. General principles of cell metabolism, molecular genetics, cell growth, cell division and differentiation.</p>
<p>Medical Terminology MTL 180 Academic organisation: Ancient Languages and Cultures Language of tuition: Both Afr and Eng Contact time: 2 lpw Period of presentation: Semester 1 and Semester 2 Credits: 12</p> <p>Module content: The acquisition of a basic medical orientated vocabulary compiled from Latin and Greek stem forms combined with prefixes and suffixes derived from those languages. The manner in which the meanings of medical terms can be determined by analysing the terms into their recognisable meaningful constituent parts, is taught and exercised. The functional use of medical terms in context as practical outcome of terminological application is continually attended to.</p>
<p>Animal Diversity ZEN 161 Academic organisation: Zoology and Entomology Language of tuition: Both Afr and Eng Prerequisite: MLB111 GS or TDH Contact time: 2lpw fortnightly practicals Period of presentation: Semester 2 Credits: 8</p> <p>Module Content: Animal classification, phylogeny, organisation and terminology. Evolution of the various animal phyla, morphological characteristics and life cycles of parasitic and non-parasitic animals. Structure and function of reproductive, respiratory, excretory, circulatory and digestive systems</p>
<p>Introductory Genetics GTS 161 Academic organisation: Genetics Language of tuition: Both Afr and Eng Prerequisite: MLB 111 GS Contact time: 2 lpw fortnightly practicals Period of presentation: Semester 2 Credits: 8</p> <p>Module content: Chromosomes and cell division. Principles of Mendelian inheritance: locus and alleles, dominance interactions and epistasis. Probability studies. Sex determination and sex linked traits. Pedigree analysis. Extranuclear inheritance. Genetic linkage and chromosome mapping. Chromosome variation.</p>
<p>Veterinary professional life VPL 120 Academic organisation: Veterinary Tropical Diseases Language of tuition: English Contact time: 2 lpw Period of presentation: Semester 2 Credits: 3</p> <p>Module content: The focus of the five-year programme on veterinary professional life is on professional and competency development. It also aims to contribute to the development of competencies to enable veterinarians to be consummate professionals capable of dealing with the diverse challenges of professional and everyday life. The VPL 120 module specifically aims to expose students to the diversity of opportunities and career paths in the veterinary profession.</p>

Total credits: 139

SECOND YEAR : Basic Veterinary Disciplines			
<p>Veterinary comparative anatomy VCA 200 Academic organisation: Anatomy and Physiology Language of tuition: English Contact time: Semester 1: 9 lpw Semester 2: 11 lpw Period of presentation: Year Credits: 38</p> <p>Module content: Anatomical terminology, early embryonic development, central and autonomic nervous systems, cutaneous appendages and musculature, thoracic limb, pelvis, pelvic limb and the head of the major domestic species. Basic avian anatomy.</p>			
<p>Veterinary physiology and histology VPH 200 Academic organisation: Anatomy and Physiology Language of tuition: English Contact time: Semester 1: 8 lpw Semester 2: 9 lpw Period of presentation: Year Credits: 33</p> <p>Module content: The light microscope, structure and function of cells and tissues, the endocrine system, the nervous system, the integument, muscle structure and function, haematology, the cardiovascular system, the respiratory system, metabolic pathways and the digestive system, the urinary system, the reproductive system, basic avian physiology and thermo-regulation.</p>			
<p>Veterinary Ethology & Genetics VET 200 Academic organisation : Production Animal Studies Language of tuition: English Contact time: 3 lpw 4 ppw Period of presentation: Year Credits:</p> <p>Module Content: The impact of genetics on function and management of key domestic species, husbandry of and common procedures performed on key domestic species, behavioural principles of key domestic species, handling skills for key domestic animals. Animal welfare and animal welfare legislation.</p>			
<p>Introduction to Animal Nutrition VKU 222 Academic organisation: Animal and Wildlife Sciences Language of tuition: English Prerequisite: None, exemption to be given to students who have completed VKU122 Contact time: 2 lpw Period of presentation: Semester 1 Credits: 8</p> <p>Module content: The chemical composition of animal feedstuffs and fodder. Digestive processes and the digestibility of animal feed and fodder. Basic principles of the nutrition and nutritional requirements of companion animals and livestock. Basic composition of rations. Intensive and extensive feeding.</p>			
<p>Animal Science VKU 210 Academic organisation: Animal and Wildlife Sciences Language of tuition: English Contact time: 2 lpw 1 ppw Period of presentation: Quarter 1 Credits: 12</p> <p>Module content: Origin and domestication of farm and companion animals. The ecological environment in which animal production and development is</p>			

<p>practised. Animal ecological factors that influence regional classification. Livestock species, breeds and breed characterisation and genetic variation. Basic principles of nutrition, physiology, breeding and production-Organisation of the livestock industry and relevant legislation. Practical work includes identification and classification of different breeds of livestock, as well as the general care and handling of farm stock.</p>		
<p>Animal Science VKU 220 Academic organisation: Animal and Wildlife Sciences Prerequisite: VKU 210 GS or TDH Contact time: 2 lpw 1 ppw Module content: Livestock ecology, interaction between genotype and environment. Production regions and systems. Animal ecological factors to be considered in production factors, planning and management of different livestock production systems. Applied principles of livestock production, production management and systems (large livestock, small stock, pigs and poultry). Conservation farming and adapted farming and management systems; environmental conservation. Practical work will consist of compulsory farm practical during vacation after the 1st year and or during the 2nd year of study in order to understand different animal production systems as well as the general care and handling of farm stock.</p>	<p>Language of tuition: English Period of presentation: Quarter 2</p>	<p>Credits: 12</p>
<p>Veterinary Microbiology VEM 210 Academic organisation: Veterinary Tropical Diseases Contact time: 3 lpw Module content: General introduction to microbiology, bacteriology and mycoplasmaology, pathogenesis of bacterial and mycoplasmal infections, rickettsiales and pathogenesis of infection, chlamydiales and pathogenesis of infection, general introduction to fungi and patho-genesis of infection, general introduction to viruses and pathogenesis of infection, laboratory diagnosis of infectious diseases, normal flora of selected organ systems in domestic animals, sterilisation and disinfection.</p>	<p>Language of tuition: English Period of presentation: Quarter 1</p>	<p>Credits: 5</p>
<p>Veterinary Immunology VIM 220 Academic organisation: Veterinary Tropical Diseases Contact time: 3 lpw Module content: Overview of the immune system, structure of antibodies, biosynthesis of immuno-globulins, antigen-receptor interaction, complement, the immune response, cellular immune responses, selected immunodiagnostic techniques, vaccinology , basic principles of immunity to infectious and parasitic diseases.</p>	<p>Language of tuition: English Period of presentation: Semester 2</p>	<p>Credits: 5</p>
<p>Basic Principles of Pasture Science WDE 253 Academic organisation: Plant Production and Soil Science Contact time: 1 lpw Module content: The influence of biotic and abiotic factors on the productivity of different strata and components of natural and planted pastures. This will enable the student to understand the management, production, appropriate and optimal utilisation as well as the animal production and health.</p>	<p>Language of tuition: English Period of presentation: Semester 1</p>	<p>Credits: 4</p>
<p>Veterinary Professional Life VPL 200 Academic organisation: Veterinary Tropical Diseases Contact time: 2 lpw Module content: Information management, societal roles and responsibilities of veterinarians, cultural diversity and group skills, leadership, stress management.</p>	<p>Language of tuition: English Period of presentation: Year</p>	<p>Credits: 7</p>

Total credits: **147**

THIRD YEAR : Causes and Effects of Disease		
<p>Veterinary Infectious Diseases VIP 300 Academic organisation: Veterinary Tropical Diseases Contact time: 3 lpw Module content: Veterinary infectious diseases is a module aimed at providing the student with in-depth knowledge of all aspects of diseases of food-producing and companion animals caused by viruses, bacteria, fungi and prions. The module is structured to enable students to discern which infectious diseases of animals are high impact diseases and which are of lesser significance in order of importance. The module covers the morphological and physico-chemical characteristics of the causative organisms and the epidemiology and pathogenesis of the diseases caused by them. Course candidates will also learn how to diagnose these diseases in both the living and dead animal, and the control strategies applicable, including control at the livestock/wildlife/human interface. Finally, course candidates will learn about the socioeconomic importance of infectious diseases of animals with special reference to transboundary spread.</p>	<p>Language of tuition: English Period of presentation: Year</p>	<p>Credits: 14</p>
<p>Veterinary Parasitology VTP 300 Academic organisation: Veterinary Tropical Diseases Contact time: 5 lpw Module content: The objective of the module is to provide fundamentals of applied veterinary helminthology, ectoparasitology and protozoology as required by veterinarians. The module covers the life cycles, relevant morphological features, epidemiology and pathogenesis of important parasites of domestic animals. Candidates will also learn how to diagnose infections/infestations and diseases in life and dead animals as well as how to treat and control them. Where applicable, emphasis is also given on zoonotic implications.</p>	<p>Language of tuition: English Period of presentation: Year</p>	<p>Credits: 22</p>
<p>Veterinary Toxicology TOX 300 Academic organisation: Paraclinical Sciences Contact time: 3 lpw Module content: General principles of veterinary toxicology, with emphasis on the relevant factors and circumstances contributing to poisoning; advanced toxicology with regard to inorganic and organic compounds, fungi, cyanobacteria, plants, rodenticides, zootoxins, etc. Plant poisonings, mycotoxicoses and inorganic and organic poisonings are discussed under the following headings: epidemiology and species affected, description, identification, distribution and poisonous principle (if applicable), mechanism of action, toxicity, clinical signs, pathology</p>	<p>Language of tuition: English Period of presentation: Year</p>	<p>Credits: 14</p>

(limited to the most important lesions); diagnosis, differential diagnosis, treatment and control of prevention. A pressed plant collection or a poisonous plant collection in digital format has to be submitted.		
General Veterinary Pharmacology VPH 300 Academic organisation: Paraclinical Sciences Contact time: 3 lpw Module content: General principles of pharmaceuticals, pharmacokinetics, pharmacodynamics and pharmacotherapeutics. Regulatory control of veterinary medicines and dispensing requirements. A study of groups of functional, systemic and chemotherapeutic drugs utilised in general veterinary practice with emphasis on their pharmacological effects, general indication, safety and side effects.	Language of tuition: English Period of presentation: Year	Credits: 14
General and Organ Pathology GOP 300 Academic organisation: Paraclinical Sciences Contact time: 7 lpw Module content: Definitions and common causes of basic lesions in tissues and organs. Pathogenesis of basic lesions including, reversible cell injury, pigmentations, necrosis, apoptosis, circulatory disturbances, inflammation, immunopathology, growth disturbances and neo-plasia. Organ pathology (with the emphasis on macroscopic changes and pathogenesis) of the various organ systems of the body.	Language of tuition: English Period of presentation: Year	Credits: 30
Introductory Veterinary Diagnostics IVD 300 Academic organisation: Production Animal Studies Contact time: S1: 3 lpw 5 pps; S2: 2 lpw Module content: Diagnostic focus: Introduction to common diagnostic procedures used in key domestic animals including clinical examination, clinical pathology, pain assessment and sedation in relation to clinical examination, basic epidemiological concepts, basic diagnostic imaging modalities and radiation safety. Clinical physiology focus: Using clinical cases, the integrated homeostatic responses to disease/insult involving all the body systems. The aim of this section of IVD 300 is therefore to build on basic physiological principles and to explain changes under abnormal situations. Veterinary research focus: IVD 300 also includes a section on the role of research in veterinary science, literature reviews, research design, the role of laboratory animals in veterinary research and examples of research.	Language of tuition: English Period of presentation: Year	Credits: 28
General Surgery GNS 320 Academic organisation: Companion Animal Clinical Studies Contact time: 1 ppw 3 lpw 7 Module content: General principles of surgery, applicable to all species. Principles of surgical asepsis, disinfection and sterilisation, suture materials and patterns, surgical haemostasis, traumatology, wound healing, wound infection, wound management, small animal bandages and surgical instrumentation.	Language of tuition: English Period of presentation: Semester 2	Credits:
Veterinary Professional Life VPL 300 Academic organisation: Veterinary Tropical Diseases Contact time: 1 dpw 2 lpw 10 Module content: This module continues with aspects of leadership and diverse personality types and builds on the framework presented earlier in the modules VPL 120 and VPL 200. The aim is to evaluate personal growth during the preceding two years and formulate personal goals for the next two years. Emotional intelligence (EQ) is included in the module and deals with the core skills of self-awareness, self-management, social awareness and relationship management. The module also deals with communication-, conflict management- and negotiation skills with particular reference to the veterinary profession. The module is concluded with basic concepts of financial skills (personal financial fitness), e.g. budgeting (personal and organisational), balance sheets and financial statements (basic understanding) as a precursor to the teaching of more detailed business management principles in the module VPL 510.	Language of tuition: English Period of presentation: Year	Credits:

Total credits:139

FOURTH YEAR : Veterinary Diagnostics and Therapeutics		
Small Animal Medicine and Surgery SAS 400 Academic organisation: Companion Animal Clinical Studies Contact time: S1: 9 lpw 8 pps; S2: 13 lpw 7 pps Module content: Patient assessment; therapeutic and monitoring plans for selected key critical situations; identification, diagnosis and treatment of important cardiovascular, respiratory, gastrointestinal, liver, pancreas, peritoneal, kidney, urogenital, skin, endocrine, musculoskeletal, nervous system and eye conditions/diseases; multi-systemic conditions; dentistry; oncology; behaviour-related disorders and treatment, critical care and traumatology in dogs and cats; selected aspects of the handling, housing, nutrition, husbandry and diseases of cage birds, reptiles, small mammals, rabbits and chinchillas.	Language of tuition: English Period of presentation: Year	Credits: 50
Porcine Health and Production PHP 420 Academic organisation: Production Animal Studies Contact time: 2 lpw Module content: The pig industry; breeding and husbandry; nutrition and related disorders; important diseases; biosecurity; miscellaneous conditions.	Language of tuition: English Period of presentation: Semester 2	Credits: 5
Poultry Health and Production PLY 420 Academic organisation: Production Animal Studies Contact time: 2 lpw Module content: The poultry industry; breeding and husbandry; nutrition and related disorders; important diseases; biosecurity; miscellaneous conditions; zoonosis.	Language of tuition: English Period of presentation: Semester 2	Credits: 5
Equine Medicine and Surgery EQM 410 Academic organisation: Companion Animal Clinical Studies Contact time: 7 lpw Module content:	Language of tuition: English Period of presentation: Semester 1	Credits: 14

Lameness: disorders of the front and hind limb; disorders of the spine; fractures and emergencies; muscular disorders; insurance examinations; identification, diagnosis and treatment of important cardiovascular, gastrointestinal, nervous system, urinary, skin, multi-systemic and respiratory disorders/diseases; hydration status and correction of fluid imbalances; the equine neonate: clinical examination, diagnostic tests and selected disorders.		
Veterinary Reproduction VRP 400 Academic organisation: Production Animal Studies Contact time: 4 lpw 20 ppy Module content: The female reproductive cycle; parturition and puerperium; control of reproduction; identification, diagnosis and treatment of important diseases or malfunctions of the female reproductive system; identification, diagnosis and treatment of conditions of the neonate; male reproductive processes; identification, diagnosis and treatment of important diseases or malfunctions of the male reproductive system; venereal diseases in domestic animals; optimisation of breeding; investigation of infertility; the Animal Improvement Act.	Language of tuition: English Period of presentation: Year	Credits: 17
Diagnostic Imaging DIM 400 Academic organisation: Companion Animal Clinical Studies Contact time: 27 ppy 3 lpw (Sem1) 2 lpw (Sem2) Module content: Principles of diagnostic imaging; diagnostic imaging of the abdomen, thorax, head, appendicular system and vertebral column in dogs and cats; diagnostic imaging of the appendicular system in horses and production animals.	Language of tuition: English Period of presentation: Year	Credits: 17
Anaesthesiology ANV 420 Academic organisation: Companion Animal Clinical Studies Contact time: 3 lpw 3pps Module content: Prepare for safe general anaesthesia; premedication; trachea intubation; induction and maintenance of intravenous and inhalation anaesthesia; recovery from anaesthesia; local anaesthesia and pain management; anaesthetic complications.	Language of tuition: English Period of presentation: Semester 2	Credits: 8
Clinical Pathology CLP 410 Academic organisation: Companion Animal Clinical Studies Contact time: 3 lpw Module content: Diagnosis and treatment of anaemia, polycythemia, leukocyte kinetics, lymphohaemo-poietic neoplasia; diagnosis and treatment of haemostatic abnormalities; diagnostic use of serum biochemistry, faecal and blood tests, urinalysis; cytology.	Language of tuition: English Period of presentation: Semester 1	Credits: 7
Diagnostic Pathology DPT 400 Academic organisation: Paraclinical Sciences Contact time: 2 lpw S1 2 lpw S2 30 ppy Module content: Planning and conducting necropsies; making a diagnosis; fatal conditions and diseases of dogs, cats, pigs, poultry and horses.	Language of tuition: English Period of presentation: Year	Credits: 16
Veterinary Professional Life VPL 400 Academic organisation: Veterinary Tropical Diseases Contact time: 2 lpw Module content: The veterinarian in context: political roles and responsibilities; collegiality and professional associations; veterinary law and ethics; stressors and stress management.	Language of tuition: English Period of presentation: Year	Credits: 11

Total credits:150

FIFTH YEAR : FIRST SEMESTER: Veterinary Community Interaction		
Veterinary Public Health VPH 510 Academic organisation: Paraclinical Sciences Contact time: S1: 6 lpw 14 Module content: The role of the veterinary surgeon in veterinary public health. Veterinary food hygiene and nutrition-related diseases of importance regarding food of animal origin. Meat and milk hygiene; all necessary measures, including legislation, to ensure that food of animal origin is safe, sound and wholesome at all stages of production and manufacture, up to the consumer. Veterinary aspects of environmental health. Zoonoses in veterinary science. Introduction of the use of laboratory animals in biomedical research and relevant aspects relating to animal welfare. Introduction to the social aspects of the human-animal interaction by protecting and promoting human health in communities, veterinary extension and risk communication.	Language of tuition: English Period of presentation: Semester 1	Credits:
Veterinary Business Management VPL 510 (Veterinary Professional Life) Academic organisation: Veterinary Tropical Diseases Contact time: 3 ppy Module content: This module will deal with business management including basic financial reporting and development of a business plan. Marketing, promotion and sales will be studied in terms of marketing oneself and one's business. Human resources management will be approached from the perspective of staff recruitment and retention, work place discipline, as well as recognition and rewards for good work performance and application of the Labour Law in the work place. The module will be concluded with strategic client service and management that will focus on client satisfaction and dissatisfaction, approaches to deal with different categories of clients and compassion fatigue and its components.	Language of tuition: English Period of presentation: Semester 1	Credits: 10
One Health VOH 510 Academic organisation: Veterinary Tropical Diseases Contact time: 2 lpw Module content:	Language of tuition: English Period of presentation: Semester 1	Credits: 7

Introduction to the One Health concept; emerging and endemic infectious diseases at human/animal interfaces; veterinary issues at human/wildlife interfaces in southern Africa; One Health approaches at human/animal/ecosystem interfaces; animal health, conservation and rural development at interfaces in southern Africa; communication and collaboration between multiple disciplines.		
Veterinary Epidemiology EPL 510	Academic organisation: Production Animal Studies	Language of tuition: English
Contact time: 3 lpw	Period of presentation: Semester 1	Credits: 10
Module content: Topics presented within an evidence-based medicine and clinical decision making framework: basic concepts of epidemiology and disease transmission, measures of disease in populations, precision and bias, causal inference, measures of association, epidemiological study design, sampling methods, disease outbreak investigation, principles of diagnostic tests.		
Bovine Health and Production BPH 510	Academic organisation: Production Animal Studies	Language of tuition: English
Contact time: 9 lpw	Period of presentation: Semester 1	Credits: 25
Module content: The pathophysiology, diagnosis, prognosis, treatment and control of diseases in cattle. Aspects of clinical veterinary science, including components of clinical diagnosis, therapeutics, medicine, surgery and introductory herd health.		
Small Stock Health and Production SSH 510	Academic organisation: Production Animal Studies	Language of tuition: English
Contact time: 6 lpw 1ppw 25	Period of presentation: Semester 1	Credits:
Module content: An encompassing approach including case studies, peer instruction and practical group work will enable the student to acquire, understand and apply knowledge regarding small stock production systems. Nutrition, parasite management, disease management, technology and economics will be dealt with.		

Total credits: **91**

FIFTH YEAR : SECOND SEMESTER and SIXTH YEAR: Experiential and Elective Training		
Veterinary Core Practice VCP 600	Academic organisation: Production Animal Studies	Language of tuition: English
Prerequisite/s: All modules up to and including the 9 th semester of the BVSc curriculum	Period of presentation: 72 weeks during the 10 th , 11 th and 12 th semesters of the BVSc programme	Credits: 160
Module content: Practical application of the theoretical aspects of small animal, production animal, equine and state veterinary practice covered in the core curriculum of the BVSc programme. Topics include medicine, surgery, reproduction, diagnostic imaging, pathology and clinical pathology, ophthalmology, dentistry and anaesthesiology of cats, dogs, cattle, small stock and horses, herd/flock health, epidemiology, economics, drug regulations, certification, animal health- and import/export regulations, veterinary public health, veterinary business management and veterinary professional life skills. The emphasis of practical exposure will be on attaining of the Day One Competencies for graduating veterinary professionals.		
Veterinary elective practice VEP 600	Academic organisation: Companion Animal Clinical Studies	Language of tuition: English
Period of presentation: The module will be presented over a period of 72 weeks during the 10 th , 11 th and 12 th semesters of the BVSc course		Credits: 120
Module content: The purpose of this module is to give students additional exposure in a practice area of interest. The aim is to provide the graduate with theoretical and practical exposure to strengthen Day 1 competencies in those components of veterinary science needed for him/her to enter the particular career path with confidence. The scope of the module is expansion, integration and practical application of knowledge established through the core component of the BVSc programme. Students will complete one of the following six practice areas: Small Animal and Exotic Practice, Rural and Wildlife Practice, Veterinary Public Health and State Veterinary Practice, Equine Practice, Intensive Animal Production Practice, and Veterinary Research Career.		

Total credits: **280**

Appendix 3 Extensive analysis of the macro curriculum and micro curricula of Veterinary Microbiology (VEM210), Veterinary Pharmacology (VPH300), Veterinary Public Health (PHE510), One Health (VOH510) and Veterinary Professional Life (VPL)

Method of analysis

The macro curriculum was first intensively read while marking relevant words and phrases. Then the search function of Word2016 was used to specifically search for the following words: antimicrobial, bacterial, resistance, sensitivity, antibiotics, stewardship, antibiogram, management, communication, communicating, communicate, social, education, educating, didactics and competencies. Hits were marked.

Based on the macro curriculum analysis and informal conversations with veterinary students and the researcher's supervisor, the micro curricula from the following core courses were analysed: Veterinary Microbiology (second year), General Veterinary Pharmacology (third year), Veterinary Public Health (fifth year), One Health (fifth year) and Veterinary Professional Life (first five years: VPL120, VPL200, VPL300, VPL400 and VPL500). The same method of analysis as used for the macro curriculum was used to analyse the micro curricular documents. After globally reading it was decided to exclude the study guides of this study, since their contents was mostly similar to the content of the micro curricula.

Antimicrobial resistance

In the macro curriculum the description of the second year's course Animal Science VKU 220 was the first course description that yielded a hit on "*planning and **management** of different livestock production systems*". The description of Veterinary Microbiology, also a second year course, yielded a hit on "*pathogenesis of **bacterial** and **mycoplasmal** infections*" and included some other relevant words regarding AMR education: "*bacteriology*", "*laboratory diagnosis*" and "*sterilisation and disinfection*". The description of the third year's course Veterinary Pharmacology included "*pharmacotherapeutics*", "*regulatory control of veterinary medicines and dispensing requirements*", "*pharmacological effects*" and "*side effects*" as relevant words. In the descriptions of the fourth year's courses no hits nor other relevant words were found. In the fifth year many relevant words were found. In the Veterinary Public Health course description "*meat and milk hygiene; all necessary measures, including legislation, to ensure that food of animal origin is safe*" and "*introduction to the social aspects of the human-animal interaction by protecting and promoting human health in communities*" were relevant regarding AMR. In the One Health course description "*One Health approaches at human/animal/ecosystem interfaces*" and "*rural development*" were mentioned. In the Bovine Health and Production course description "*treatment and control of diseases in cattle*" was mentioned. The course description of Small Stock Health and Production yielded a hit on "*disease **management***". "*Herd/flock health*", "*drug regulations*" and "*veterinary public health*" were relevant subjects mentioned in the description of the Experiential Training in fifth and sixth year.

In the micro curricula the Day One Competencies that are addressed in that module were described. The complete Day One Competencies List can be found in Appendix 1. The rest of the micro curricula were divided in outcomes and themes. The micro curriculum of Veterinary Microbiology included Day One Competencies B1.3, C1.8 and C1.23 as being

related to AMR. The contribution to all these competencies was major according to the micro curriculum. Relevant themes in the Veterinary Microbiology micro curriculum were Theme 2 General Introduction to Bacteriology Including Mycoplasma and Theme 14 Sterilisation and Disinfection. Theme 2 Subtheme 2.6 Bacterial Genetics included two relevant learning objectives: “2.6.1. Explain the central dogma of molecular biology and define basic terms such as mutation, plasmid, episome and transposons” and “2.6.2. Describe the possible causes and results of bacterial mutations”. Theme 14 included one relevant learning objective: “14.5. Explain the factors influencing the antimicrobial activity of both physical and chemical methods of sterilisation/disinfection”.

The micro curriculum of Veterinary Pharmacology included the relevant Day One Competencies A1.4, B1.6 and B1.7. The contribution to A1.4 was minor, the contributions to B1.6 and B1.7 major. Outcome 5 Demonstrate Knowledge of Chemotherapeutic Drugs yielded hits on “5.2 Demonstrate knowledge of **antibacterial** drugs”, “5.3 Select the most appropriate **antibacterial** drug based on bacterial culture and **sensitivity** testing” and “5.3.1. The laboratory report on culture results and **sensitivity** testing is interpreted in order to select the most appropriate **antibacterial** drug”. Another relevant outcome was “Demonstrate knowledge of Act 101 of 1965 and Act 36 of 1947 as it pertains to veterinarians”. Theme 1 Veterinary Drug Control and Management included the following relevant learning objectives: “1.1.1. Explain the basic differences between drugs registered as Medicines (Act 101) and Stock remedies (Act 36) with regards to storing, handling, selling and advertising”, “1.2.3. Briefly discuss the requirements for using stock remedies”, “1.2.5. Briefly discuss the dangers of counterfeit medicines”, “1.3.1. Briefly discuss the responsibility of the veterinarian in preventing drug residues in foodstuffs” and “1.5.1. Define pharmacovigilance and list all the parties responsible for pharmacovigilance”. Theme 2 Fundamental Pharmacology included the relevant learning objective “2.5.2. Define/explain the pharmacotherapeutic concept of withdrawal periods”. Theme 5 Chemotherapy of Infectious Agents yielded hits on learning objectives “5.1.4. Discuss empirical use of **antimicrobials** vs. **sensitivity** testing; include advantages and limitations”, “5.1.7. Define constitutive **resistance**”, “5.1.8. Give a general overview of how acquired **resistance** develops against chemotherapeutic agents” and “5.2.9. Explain why certain **antibiotics** like rifampin and vancomycin are not commonly used in veterinary science”. Another relevant learning objectives in Theme 5 was “5.2.6. Appraise the banning of chloramphenicol in food-producing animals”.

The micro curriculum of Veterinary Public Health included the relevant Day One Competencies A1.3, A1.4, B1.6, B1.7, B1.10, C1.10 and C1.11. The contributions to A1.3, A1.4, B1.6, B1.10 and C1.11 were major, whereas the contribution to C1.10 was moderate and the contribution to B1.7 was minor. Relevant outcomes were Outcome 2 Demonstrate Knowledge of Meat Safety, Outcome 3 Demonstrate Knowledge of Milk Hygiene and Outcome 5 Demonstrate Knowledge of Farm to Fork Approach to Food Safety and Risk Mitigation. Relevant specific outcomes were “2.1 Demonstrate knowledge of legislation relevant to meat safety in South Africa and the role of the veterinarian in meat safety”, “3.1 Demonstrate knowledge of national and international legislation pertaining to production and sale of milk and milk products”, “3.4 Identify problem areas on a farm” with assessment criteria “3.4.1 Problem areas on the farm that increases transmission of food borne diseases associated with milk and milk production are identified according to given criteria”, “5.1 Demonstrate knowledge of food security, food control and one health” and “5.3 Demonstrate knowledge of general principles of Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP), Good Veterinary Practices (GVP), Hazard Analysis Critical Control Points (HACCP) and risk assessment of hazards in food of animal origin”. Theme 2 Meat Safety included the following relevant learning objectives: “2.1 List the legislation relevant to meat safety in South Africa”, “2.2 List the responsibilities of veterinarians concerning meat safety

in South Africa” and “2.3 Discuss the role of the private veterinary practitioner in ensuring that meat presented for sale in South Africa is fit for human consumption”. Theme 3 Milk Hygiene included the following relevant learning objectives: “3.1 List national and international legislation pertaining to production and sale of milk and milk products”, “3.2 Give examples of a hazard associated with milk and milk products in each of the following categories: biological, physical and chemical hazards”, “3.3 Discuss control and management of the most common food safety hazards associated with milk and milk products”, “3.6 Discuss the role of a veterinarian in ensuring healthy animals and herds (cattle and small stock) are used for production of good quality and safe milk” and “3.8 Discuss how feed, veterinary drugs and pests should be controlled to minimize the contamination of milk”. Theme 5 included relevant learning objectives “5.1 Discuss food security, food control and one health”, “5.2 Discuss the role of the veterinarian in the food chain through control of hazards on the farm” and “5.3 Discuss the general principles of Good Manufacturing Practices, Good Hygiene Practices and Good Agricultural Practices and HACCP”.

The micro curriculum of One Health included the relevant Day One Competencies A1.3, A1.4, A1.6, B1.10, C1.10, C1.11 and C1.21. The contributions to A1.6, C1.10 and C1.21 were minor, the contributions to A1.4, B1.10 and C1.11 moderate and the contribution to A1.3 was major. Outcome 1 Demonstrate Understanding of the One Health Concept included two relevant specific outcomes: “1.3 Demonstrate knowledge of the links between animal health, human health and livelihoods, and ecosystem health” and “1.4 Apply knowledge of One Health principles to address complex health-related issues at interfaces in South Africa”. Outcome 4 Apply Knowledge of One Health Approaches at the Human/Animal/Ecosystem interface included three relevant specific outcomes: “4.4 Demonstrate knowledge of the impact of drug residues in livestock/livestock products on animal health”, “4.5 Demonstrate knowledge of the impact of drug residues in livestock/livestock products on human health” and “4.6 Apply knowledge of One Health principles to address the issue of drug residues in livestock/livestock products in Southern Africa” with assessment criteria “4.6.1 Relevant examples of the impact of drug residues in livestock/livestock products on human health and ecosystem health in southern Africa are given and discussed” and “4.6.2 A One Health approach to address the issue of drug residues in livestock/livestock products in southern Africa is applied to a given scenario, in a written assignment or oral presentation”. Outcome 6 Apply Effective Communication and Collaboration Skills in Multiple Disciplinary Groups included one relevant specific outcome: “6.1. Work effectively in teams with colleagues from medical profession to address a complex health related problem at a human/animal interface”. In Theme 4 Subtheme 4.2 Impact of Drug Residues on Human and Animal Health was relevant with learning objectives “4.2.1 Describe how current South African legislation attempts to protect the public from harmful residues”, “4.2.3 Discuss the impact of residues of veterinary antimicrobials on human health” and “4.2.5 Discuss the role of the veterinarian in ensuring that persons consuming animal protein in South Africa are not exposed to harmful drug residues in the food”.

VPL120, VPL200 and VPL400 included a major contribution to Day One Competency A1.4. No hits were yielded in the VPL micro curricula, but relevant outcomes in the micro curriculum of VPL200 were “2.2 Demonstrate knowledge of the role of the veterinarian as guardian of animal welfare and food safety”, “2.3 Demonstrate knowledge of the role of the veterinarian in contributing to a safe and healthy natural environment” and “2.4 Demonstrate knowledge of the different areas in public life where veterinarians can play leadership roles”. A relevant learning objective in VPL200 was mentioned in Theme 8 The Role of the Veterinarian In Animal Welfare and Food Safety: “Discuss the economic importance of food safety and the role that the veterinarian plays herein”. The micro curriculum of VPL500 included relevant outcome “1.6 Demonstrate knowledge of stock management”. Two relevant

learning objectives were mentioned in Subtheme 1.5 Stock Management: “1.5.2 Name the commonly occurring reasons for stock losses and the prevention thereof”, “1.5.3 Describe the processes to be followed to ensure optimal stock management” and “1.5.7 Describe the correct stock control and storage for scheduled, unscheduled and over the counter medicines, healthcare products and merchandise”. No relevant outcomes were mentioned in the micro curricula of VPL120, VPL300 and VPL400.

Communication

The veterinary macro curriculum contained communication related topics in different modules throughout the study programme. Veterinary Professional Life (VPL) could be found in the first five years in the macro curriculum. In the description of VPL in the second year “*societal roles and responsibilities of veterinarians*” was mentioned. The description of VPL in the third year yielded a hit on “**communication-**, conflict management- and negotiation skills with particular reference to the veterinary profession.” In the description of VPL in the fourth year “*political roles and responsibilities*” were mentioned. The fifth year’s Veterinary Public Health course description yielded two hits on “*introduction to the **social** aspects of the human-animal interaction by protecting and promoting human health in communities*” and “**risk communication**”. The description of the fifth year’s One Health course yielded a hit on “**communication** and collaboration between multiple disciplines” and mentioned “*rural development*”. “*Veterinary professional life skills*” was a relevant subject mentioned in the description of the Experiential Training in fifth and sixth year.

All five Veterinary Professional Life micro curricula included a minor contribution to Day One Competency A1.2. VPL120, VPL200 and VPL400 included a major contribution to Day One Competency A1.4. The outcomes in VPL120 did not yield any hits, nor were they relevant regarding communication. The outcomes in VPL200 did not yield any hits, but relevant outcomes regarding communication were “2.1 Demonstrate knowledge of the role of the veterinarian in communities”, “3.1 Demonstrate knowledge of the elements of cultural diversity” and “3.3 Demonstrate knowledge of the effect of cultural diversity on morality and interaction with the environment”. The outcomes in VPL300 yielded hits on “2.1 Demonstrate knowledge of the importance of **communication** skills”, “2.5 Demonstrate knowledge of relevant **communication** skills when dealing with clients”, “2.6 Demonstrate knowledge of relevant **communication** skills when dealing with veterinary and medical professionals” and “2.7 Demonstrate knowledge of relevant **communication** skills when dealing with a wider audience”. Learning objectives in Theme 2 The Importance of Communication Skills, Theme 6 Communicating With Clients and Theme 7 Professional Communication yielded hits on “List the benefits associated with good communication skills”, “Describe situations in the veterinary profession where good **communication** skills would be needed”, “List **communication** skills that will lead to effective transfer of knowledge”, “Explain how the effectiveness of **communication** can be assessed” and “List the different areas where a veterinarian will **communicate** with other professionals”. Theme 4 Verbal Communication included the relevant learning objectives “Identify which type of questions would be best suited to different situations” and “Identify which type of listening would be best suited to different situations”. In the micro curriculum of VPL400 no relevant outcomes or learning objectives regarding communication were mentioned. One relevant outcome in the micro curriculum of VPL500 was “4.3 Demonstrate knowledge of effective approaches to deal professionally with various categories of difficult and/or challenging client interactions”.

Although the course descriptions of the Veterinary Pharmacology, Veterinary Public Health and One Health did not contain topics that were related to communication in the macro curriculum, the micro curricula respectively included a minor, moderate and major contribution to Day One Competency A1.2 and a minor, major and moderate contribution to Day One Competency A1.4. The outcomes in the Veterinary Public Health micro curricula yielded hits

on “4.1 Demonstrate knowledge of the principles of risk **communication**”, “4.2 Demonstrate knowledge of risk **communication** in management and control of food borne and zoonotic diseases”, “4.3 Demonstrate knowledge of **communication** tools and channels that can be used during risk **communication**”, “4.4 Demonstrate knowledge of challenges and barriers related to risk **communication**”, “4.5 Assess a food safety or zoonotic diseases **communication** strategy” and “4.6 Formulate a **communication** strategy using the Sender, Message, Channel, Receiver and Effects” with assessment criterium “4.6.1. An appropriate **communication** strategy is formulated based on the characteristics of the target group from a case study”. In Theme 4 Veterinary Risk Communication the following learning objectives yielded hits: “4.1 Define risk **communication**”, “4.2 Discuss the principles of risk **communication**”, “4.3 Discuss risk **communication** in the context of food safety and zoonotic diseases”, “4.4 Discuss the tools and channels that can be used during risk **communication**” and “4.5 Discuss challenges and barriers related to risk **communication**”. In the micro curriculum of One Health, Outcome 6 Apply Effective Communication and Collaboration Skills in Multiple Disciplinary Groups yielded a hit on specific outcome “6.1. Work effectively in teams with colleagues from medical profession to address a complex health related problem at a human/animal interface” with assessment criterium “6.1.1. Initiative, **communication**, teamwork and problem solving ability are demonstrated according to applicable criteria in a problem-based learning exercise that requires a multiple disciplinary approach.”

Appendix 4 Questionnaires interviews with instructors

Introduction by researcher

Topics

- Importance AMR / communication in the curriculum
- Time available for AMR education / education on communication
- Contents
- Barriers
- Teaching tools
- Improvements

Questions part 1: Demographics

- Sex
- Age
- Education
- Degree
- Department
- Career: previous jobs, current job, year of experience as instructor/lecturer

Questions for lecturers Microbiology, Pharmacology, Public Health and One Health

- How important do you think education on AMR is in the veterinary curriculum if you have to choose between very important, important, neutral, unimportant and very unimportant? Why?
- How many hours do you present antibiotics in general during the course?
- How many hours do you present AMR during the course?
- How many hours would you wish to spend on antibiotics in general?
- How many hours would you wish to spend on AMR?
- What subtopics of AMR do you discuss?
 - First ask as an open question, then possibly give the following suggestions
 - Biological mechanisms
 - Risks/epidemiology
 - Veterinarians' role in AMR problem
 - Antimicrobial stewardship / prudent prescription behaviour
- What barriers to teaching AMR do you face?
 - First ask as an open question, then give the following suggestions:
 - Lack of time
 - Lack of faculty expertise
 - Lack of faculty interest
 - Lack of information
 - Lack of teaching tools
 - Lack of student interest
- What teaching tools do you use to teach students about AMR?
- What teaching tools would you like to use if possible? Please explain why.
- What could the faculty do to improve AMR education?
- Is there anything else you want to mention about AMR education in Onderstepoort?

Questions for lecturers in Veterinary Professional Life and One Health

- How important do you think education about communication with farmers is in the veterinary curriculum if you have to choose between very important, important, neutral, unimportant and very unimportant? Why?
- How many hours do you discuss these communication and didactic skills during this course?
- How many hours would you wish to spend on this subject?
- What subtopics about communication and didactic skills do you discuss?
- What barriers to teaching communication skills do you face?
 - First ask as an open question, then give the following suggestions:
 - Lack of time
 - Lack of faculty expertise
 - Lack of faculty interest
 - Lack of information
 - Lack of teaching tools
 - Lack of student interest
- What teaching tools do you use for this purpose?
- What teaching tools would you like to use if possible? Why?
- What could the faculty do to improve education on communication and didactics?
- Is there anything else you want to mention about education on communication and didactics in Onderstepoort?

Questions for clinicians

- How important do you think education on AMR is in the veterinary curriculum?
- How important do you think education on communication skills is?
- What do you think about the students' knowledge on AMR and antimicrobial stewardship when they start their clinical rotations?
- What do you think about the students' communication skills with farmers when they start their clinical rotations?
- What do you think about your own knowledge on AMR and antimicrobial stewardship?
- Do you think this knowledge is sufficient to educate students about it?
 - If not, what would you like to learn more about AMR and antimicrobial stewardship?
 - And how?
- During what occasions do you discuss AMR with the students?
- How often do you discuss AMR with the students? Please be specific (one out of ... cases or something like that)
- What subtopics of AMR do you discuss then?
 - First ask as an open question, then possibly give the following suggestions
 - Biological mechanisms
 - Epidemiology
 - Risks of specific antimicrobials
 - Veterinarians' role in AMR problem
 - Antimicrobial stewardship / prudent prescription behaviour
- What do you teach the students about communication with farmers?
- To what extent do you think students educate farmers about AMR?
- What teaching tools do you use to teach students about AMR and communication? (orally during cases, literature, peer learning, plenary discussions, etc.)

- What barriers to teaching AMR do you face?
 - First ask as an open question, then give the following suggestions:
 - Lack of time
 - Lack of faculty expertise
 - Lack of faculty interest
 - Lack of information
 - Lack of teaching tools
 - Lack of student interest
- What could the faculty do to improve AMR education?
- Is there anything else you want to mention about AMR education in Onderstepoort?

Appendix 5 Guideline focus groups with students

Introduction (10 minutes)

- I am Dian, a Dutch vet student and I am in my 4th year now. In the Netherlands we have to do a three month research internship somewhere in our 4th, 5th or 6th year, so here I am! My research is about the usage of antimicrobials in South Africa. I am not telling you the specific topic now, because then I already ruin my first question, but I am sure you will find out in our discussion.
- The discussion will take max one hour. I have prepared some questions, but there is also enough time for your suggestions and ideas, because ultimately I am interested in those.
- Firstly, I will give you all a short questionnaire to gain some demographic data. As you can see I will just use a participant number, so you will remain anonymous. I would like to record the discussion so that I can analyse it later. If that's okay with you, I would like you to sign this questionnaire.
- Thanks you all for answering the first questions, that wasn't so hard right? Does anybody of you have questions about the next hour? ... Let's start then!

Questionnaire Demographics (individually provided on paper)

- Participant number
- Sex
- Age
- Origin (country and province)
- Place of growing up (farm, city, village, elsewhere)
- Previous education
- Motivation for Veterinary Science
- Motivation for Faculty of Veterinary Science in Onderstepoort
- Elective
- Current idea of career path

Prior to the focus group discussion, the researcher informed me about the discussion being recorded. With this signature I give my permission to do so.

Signature participant:

Topics

- Top-of-mind aspects of antimicrobials
- Case discussion
- Knowledge on AMR
 - Information sources
 - Definition
 - Problem size (worldwide and in SA)
 - Cause AMR problem in SA
 - Stakeholders
 - Reducing strategies
- Knowledge on educating farmers
- Deficiencies in veterinary education regarding AMR and educating farmers
- Proposed curricular improvements

Questions (45 minutes)

- Let's start with a brainstorm about antimicrobials: what do you think of when you hear "antibiotics"?
- Now I would like to discuss a case with you. During your production weeks you visit a cattle farmer in a rural area, who has big problems with Clostridia.
 - What would you advise him to do?
 - Would you tell him about AMR? Why/why not?
 - Would this be different when you are a graduated vet?
 - What would you tell him about AMR? Why?
 - What would you do if it was a commercial farmer regarding AMR? Why?
- When did you hear about AMR for the first time?
- What sources do you use to learn more about AMR?
- What more things do you know about AMR?
 - What is the problem? > One Health?
 - How big is the problem, worldwide and in SA?
 - Who are the stakeholders and which of them is most important? Rate government, doctor, vet, farmers, human patients. Why?
 - What do you know about potential reducing strategies? (prescription guidelines, National Action Plan, ...)
- Who thinks that you know enough about AM stewardship and AMR? And who wants to learn more about it?
- What have you learnt about educating farmers?
 - What part of your job consists of educating farmers when you are a vet?
 - How are didactic skills incorporated in your curriculum?
- What are the challenges regarding educating commercial and communal farmers?
- What do you think should be more emphasized in your curriculum regarding AMR?
- And regarding didactics?
- How could they do that, suggestions? What would you think of formal lectures, e-learning, problem-based / case learning, peer learning, preparing seminars, etc.?
- Do you have anything else you want to mention that could help my research?

Close: evaluation (5 minutes)

Appendix 6 Guideline interviews with farmers

Introduction by researcher

Thank you in advance for completing this questionnaire. Your answers will be used by a Dutch veterinary student for her research internship. The aim of this research is to investigate the effectiveness of the veterinary education in Onderstepoort on creating awareness for antimicrobial resistance among the farmer community. Your opinion is very important to help the Faculty of Veterinary Sciences to optimise their way of educating their students and creating the best veterinarians in future.

This questionnaire consists two parts. In part one you will be asked for some demographic information about you and your farm. Part two focuses on your knowledge on antimicrobial resistance, the communication with veterinary students from Onderstepoort and your suggestions to improve both of these themes. At the end of this questionnaire you can write down everything you want to help the Veterinary Faculty in Onderstepoort to optimize their curriculum.

Therefore, it is very important that you feel free to answer honestly. Your answers will stay anonymous and will only be available for the researcher.

Questionnaire demographics

- Age
- Gender
- Origin (country and province)
- Place of growing up (city, suburb, farm, village, elsewhere)
- Farm data: species, amount of animals, location
- Highest level of education
- Years of experience as a farmer
- Residence
- Full-time or part-time farmer → other profession?
- Amount of employees

Topics

- Demographics
- Top-of-mind aspects of antimicrobials
- Knowledge on AMR
- Students' role in learning about AMR
- Communication with students
- Suggestions for improvement

Questions

1) What do you think of when you hear the word “antibiotics”? Please write down as much as you can.

2) Have you ever heard of antimicrobial resistance? *Explanation: antimicrobial resistance is the problem that occurs when we use too many antibiotics or when we don't use antibiotics in a proper way, causing bacteria to get used to these treatments and enable them to survive the treatments. This will make certain bacterial infections in animals as well as humans untreatable.*

If yes, please answer questions a t/m c below. If no, you can continue at question 3.

- a) Who told you about antimicrobial resistance and during what occasion?
- b) What do you know about antimicrobial resistance in terms of the cause of the problem, the size of the problem and what you can do to prevent it?
- c) What would you like to learn more about antimicrobial resistance?

3) Have you been visited by veterinary students from Onderstepoort before?

If yes, please answer the questions a t/m g below. If no, you can continue with question 4.

- a) How often does the veterinarian or professor communicate with you while the students are listening?
 - Very often
 - Often
 - Sometimes
 - Rarely
 - Never
- b) What do you think of the communication with the students themselves?
- c) Do you think there is enough communication with the students? Why / why not?
- d) What challenges/barriers regarding communication with the students do you face?
- e) What would you suggest to improve the communication between you and the students?
- f) What do the students tell you about antibiotic treatments? (e.g. indications, doses, duration, warnings etc.)
- g) Would you like to get more information from the students about antibiotic treatments? Why / why not?
- h) Do the students tell you specifically about antimicrobial resistance? If yes, what do they tell you?

4) How could the Veterinary Faculty and her students help you to learn more about antimicrobial resistance?

5) Is there anything else you would like to mention about antimicrobial resistance, communication with students, suggestions for the Veterinary Faculty or another topic?

Close: evaluation

Appendix 7 Demographic information of student participants

Explanation of abbreviations: 1) SA/EP = Small Animals and Exotic Practice, 2) IAPP = Intensive Animal Production Practice, 3) VPH/SVP = Veterinary Public Health and State Veterinary Practice, 4) EQP = Equine Practice and 5) RWP = Rural and Wildlife Practice.

Focus group	Participant	Gender	Age	Origin (province or country)	Place of growing up	Previous education	Elective	Motivation Veterinary Science	Motivation Onderstepoort	Future career path
1	1	F	23	Gauteng	City	Matric	SA/EP	Love for animals, fulfilling, helping others	Only faculty	Small animal private practice, outreaches and community work
	2	F	25	Not answered	Farm	Matric	SA/EP	Love for animals	Only faculty	Small animal practice
	3	F	23	Not answered	City	Matric	SA/EP	Love for animals, love for surgery, don't like working with people	Only faculty + high level	Small animal practice and surgery
	4	F	23	Gauteng	City	Matric	IAPP	Love for animals	Only faculty	Mixed practice, work with state to educate people in rural areas
	5	M	32	Swaziland	Village	BSc Animal Health	VPH/SVP	Grew up with livestock with a lack of veterinary assistance	High level	Livestock, dentistry, exotics
2	6	M	23	Western Cape	City	Matric	SA/EP	Love for animals, challenging	Only faculty	Work hard
	7	M	23	Gauteng	City	Matric	SA/EP	Love for animals	Only faculty	Small animal practice
	8	M	23	Eastern Cape	Village	Matric	SA/EP	Family member	Only faculty	Mixed practice
	9	F	24	KwaZulu-Natal	Suburb	BSc Animal Health	SA/EP	Love for animals	Only faculty	Mixed or small animal practice
	10	F	22	KwaZulu-Natal	Township	Matric	SA/EP	Love for animals instead of people	Only faculty	Exotics and sealife
	11	F	23	Gauteng	City	Matric	SA/EP	Love for animals	Only faculty	Small animal and equine practice
3	12	F	23	KwaZulu-Natal	City	Matric	SA/EP	Love for animals, helping people, animals and environment simultaneously	Only faculty	Small animal practice

	13	F	23	Gauteng	City	Matric	SA/EP	Love for animals, interest in medicines, solving problems	Only faculty	Small animal specialist
	14	F	23	Western Cape	Village	Matric	SA/EP	Love for animals and science	Only faculty	Practice in rural town or overseas
	15	F	24	Gauteng	City	Matric	VPH/SVP	Interesting, lots of advances to make in industry	Only faculty	Public health, pathology, research
	16	F	23	KwaZulu-Natal	City	Matric	SA/EP	Love for animals, care about animal welfare	Only faculty	Unsure
4	17	M	22	Eastern Cape	Farm	Matric	IAPP	Love for animals	Only faculty + high level	State vet, intensive industry
	18	F	25	Gauteng	City	Matric	RWP	Love for animals, passion for conservation and rehabilitation	Only faculty	Mixed practice, rehabilitation, One Health, wildlife research
	19	F	23	Zimbabwe	Farm	Matric	RWP	No vets in my area	Only faculty	Work with human-wildlife conflict and rural farmers
	20	M	21	Western Cape	City	BSc Stellenbosch	SA/EP	Make the world better for animals, humans and the environment	Only faculty	Conservation, NGO animal welfare
	21	F	23	Eastern Cape	City	Matric	IAPP	Love for animals, helping people in rural areas	High level	Mixed practice in rural area
5	22	F	24	Western Cape	Suburb	Matric	EQP	Love for animals	Only faculty	Mixed practice
	23	F	24	Gauteng	Suburb	Matric	EQP	Love for animals and science	Only faculty	Equine practice
	24	F	22	Limpopo	Village	Matric	IAPP	Parents made me to	Only faculty + high level	Unsure
6	25	F	24	Gauteng	City	Matric	RWP	Love for animals and surgery	Only faculty	Specialising in surgery or wildlife
	26	M	23	KwaZulu-Natal	Farm	Matric	EQP	Love for animals	Only faculty	Sport horse veterinarian
	27	M	23	Western Cape	City	Matric	IAPP	Lifelong dream	Only faculty	Small animal practice
	28	M	23	Mpumalanga	Farm	Matric	SA/EP	Love for animals	Only faculty	Equine veterinarian

Appendix 8 Demographic information of farmer participants

Participant	Gender	Age	Origin	Place of growing up	Location farm	Farmed species	Number of animals	Educational level	Years of farmer experience	Fulltime/ Part-time	Number of employees
1	M	41	Mpumalanga	Farm	Gauteng	Sheep	1000	BSc Agri	15	Fulltime + abattoir	10
2	M	63	Limpopo	Suburb	Gauteng	Goats	150	B. Ed	13	Part-time	7
3	M	71	Eastern Cape	Farm	Gauteng	Goats	100	Matric	40	Fulltime	3
4	F	59	Mpumalanga	City	Gauteng	Sheep	350	Matric	15	Part-time Businesswoman	4
5	M	61	Zimbabwe	Farm	Gauteng	Cattle	450	National Diploma	35	Fulltime	20
6	F	55	Gauteng	Suburb	Gauteng	Sheep	200	BVSc	8	Part-time Veterinarian	6
7	F	27	Free State	Farm	Gauteng	Goats, sheep	200 600	BSc Agri	10	Fulltime	10
8	M	58	North West	<i>Not answered</i>	North West	Sheep, cattle, game	2500 in total	B Eng (chem)	20	Part-time Chemical engineer	30
9	M	47	North West	Farm	Gauteng	Goats	150	Matric	24	Part-time Panel beater	6
10	M	66	Eastern Cape	Suburb	Gauteng	Sheep, cattle, horses	120 40 10	BVSc	16	Part-time Veterinarian	8
11	M	27	Free State	Suburb	Gauteng	Sheep	100	Matric	5	Part time Pilot to be	5
12	M	60	North West	Suburb	Mpumalanga	Sheep	250	Matric	20	Part-time Shop keeper	4
13	M	50	North West	Village	North West	Goats, sheep	150 200	BSc	20	Part-time Businessman	2
14	M	54	Mpumalanga	Farm	North West	Sheep	400	Matric	40	Part-time Auctioneer	10
15	M	55	Limpopo	Village	Gauteng	Goats, sheep, cattle	118 3 8	Matric grade 11	10	Fulltime	1

16	M	35	<i>Not answered</i>	City	Gauteng	Goats	100	Matric	15	Part-time Director	20
17	M	50	North West	Village	North West	Cattle	10	Matric grade 12	35	Part-time Police officer	2
18	M	65	<i>Not answered</i>	City	Gauteng	Cattle	300	<i>Not answered</i>	10	Part-time Construction and Security	5
19	M	57	Gauteng	Suburb	North West	Sheep	400	National Diploma	20	Fulltime	6
20	M	48	Northern Cape	Farm	Gauteng	Goats	150	BSc	30	Fulltime	4
21	F	34	Gauteng	City	Limpopo	Cattle, goats	350 in total	Masters (agriculture)	8	Fulltime	12