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Review

Distance Education in Veterinary Medicine: History, Current Situation, and Future Perspectives (a Systematic Review)

Educação a Distância em Medicina Veterinária: História, Situação Atual Revisões e Perspectivas Futuras (uma Revisão Sistemática)

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Abstract

Technology has revolutionized education making it more accessible, overcoming time and space barriers, and reducing costs for undergraduates and professionals. In veterinary medicine as well as in other knowledge areas, distance education has evolved, going to the forefront of technological advances. Today, many tools, courses, and on-line platforms are available to facilitate and enhance the teaching-learning process for institutions and students. However, because of the Covid-19 (Sars-CoV-2) pandemic, educational institutions and veterinary medicine students around the world were forced to use distance education tools, many of them without being prepared or knowing the tools available or not having the necessary tools. In this sense, seeking to offer students and educators information about the evolution of distance education in veterinary medicine, its current situation and available tools, it was made a systematic review using the databases Science Direct, Scopus and Google Scholar, gathering more than 244 journal articles, and finally 116 articles were selected. The selected articles were analyzed for the history, platforms, and resources available, difficulties, current situation, and future perspectives, as well as the advantages and need of distance education in the actual pandemic situation. We can conclude that distance education is currently an indispensable tool in veterinary medicine, complementing face-to-face courses and reducing costs. This has led to the development of several platforms, applications and on-line educational resources that facilitate and enhance the teaching-learning process for educational institutions, veterinary students, and professionals.

Keywords: On-line learning. E-learning. Distance learning. Digital tools. Veterinary education.

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Educação a Distância em Medicina Veterinária: História, situação atual e perspectivas futuras (uma revisão sistemática)

Resumo

A tecnologia revolucionou a educação, tornando-a mais acessível, superando as barreiras de tempo e espaço e reduzindo custos para graduandos e profissionais. Na medicina veterinária, assim como em outras áreas do conhecimento, a educação a distância tem evoluído, posicionando-se na vanguarda dos avanços tecnológicos. Hoje, muitas ferramentas, cursos e plataformas on-line estão disponíveis para facilitar e aprimorar o processo de ensino-aprendizagem de instituições e alunos. No entanto, decorrente da pandemia da Covid-19 (Sars-CoV-2), instituições de ensino e alunos de medicina veterinária ao redor do mundo ficaram obrigados a utilizar ferramentas de educação a distância, muitos destes sem estar preparados nem conhecendo as ferramentas disponíveis ou não contando com as ferramentas necessárias. Neste sentido, buscando oferecer aos alunos e educadores informações sobre a evolução da educação a distância na medicina veterinária, sua situação atual e as ferramentas disponíveis, foi realizada uma revisão sistemática usando as bases de dados Science Direct, Scopus e Google Scholar, reunindo mais de 244 artigos de revistas científicas, e finalmente 116 artigos foram selecionados. Os artigos selecionados foram analisados pela história, plataformas e recursos disponíveis, dificuldades, situação atual e perspectivas futuras, bem como as vantagens e necessidade da educação a distância na atual situação de pandemia. Podemos concluir que a educação a distância é atualmente uma ferramenta indispensável na medicina veterinária, complementando os cursos presenciais e reduzindo custos. Isso levou ao desenvolvimento de várias plataformas, aplicativos e recursos educacionais on-line que facilitam e aprimoram o processo de ensino-aprendizagem para instituições educativas, estudantes de veterinária e profissionais.

Keywords: *Aprendizagem on-line. E-learning. Aprendizagem a distância. Ferramentas digitais. Educação veterinária.*

1. Introduction

In education, as among other life fields, technology has brought enormous changes and adaptations to our lifestyles, and because of the modern world, and student and university demands, the usage of tools and on-line distance learning environments are increasingly common and necessary in higher education (GLEDHILL *et al*., 2017; PUTRA *et al*., 2021; SAADEH *et al*., 2021a). The wide popularization and access to computers, made easier the usage of distance education as a learning tool. Along with new information and communications technologies (ICTs), distance education (DE) is now an important and widespread way of teaching and learning, where the student and teacher are geographically distant and their personal interaction is replaced by different media resources making easier the education diffusion, access, and globalization (MAHDY, 2020; DAS *et al*., 2021; PUTRA *et al*., 2021).

Veterinary medicine (VM) has passed through several stages in the adoption of DE for the delivery of its curricula in universities worldwide. Currently the VM students have a large number and variety of electronic resources that complements and helps their learning process (GLEDHILL *et al*., 2017; STRUBE; RAUE; JANECEK, 2018; SAADEH *et al*., 2021a). Additionally, the current ICTs can be used by VM faculty to offer courses on subjects in which few faculties have expertise. Students may be reached even out of the institutions and continuing professional development may be provided faster, more efficiently, and less expensively (DHEIN, 2007a; MAHDY, 2020).

The use of complementary study materials delivered via on-line has been reported as improving the veterinary students' outcomes when comparing to traditional methods as face-to-face lectures, textbook's study, and others (DUIJVESTIJN *et al*., 2021; FOSS *et al*., 2021; MCMICHAEL *et al*., 2021; NAVAS DE SOLIS *et al*., 2021; PILLAI, 2021; PUTRA *et al*., 2021; REINHARD; POWELL; WATSON, 2021).

Nowadays, DE is the main resource for providing effective and qualified education especially in difficult and social distancing times as in the current pandemic situation because of the Covid-19 (MAHDY, 2020; UNITED NATIONS, 2020; DAS *et al*., 2021; HUNT; ANDERSON, 2021). Facing this global problem that drastically affects VM students and institutions around the world and for which, not all universities and professors were prepared; it turns necessary for VM educators to understand and learn more about how DE in VM is carried out and how it has evolved over time, as well as the available resources for remote teaching. To provide more information about DE history, platforms available, difficulties, current situation, and future perspectives in VM, it was made a systematic review about these topics to help VM educators and students to cope better with these difficult times and better respond to this necessary and contemporary way of education.

2. Material and methods

A systematic review about distance education in VM was carried out, aiming to look at the existing literature to understand about its beginnings, developed platforms, tools and its status worldwide. For the systematic review, the authors conducted research during March 2020 and June 2021 using the keywords (MeSH) "on-line learning" or "on-line education" or "distance learning" or "distance education" or "e-learning" AND "veterinary". The research was made using the databases Science Direct, Scopus and Google Scholar, with no year exclusion criteria. Only articles in English, Portuguese and Spanish were included, articles in other languages were not considered. The exclusion criteria included: articles related to postgraduate education and articles not specifically reporting distance education experiences, methodologies, on-line platforms or other distance education technologies usage or development in VM undergraduate education. Those articles related to areas such as biology, animal science, biomedical sciences, or other but not specifically involving veterinary medicine were also excluded. Only research articles were included, not considering papers like conference proceedings, letters to editor, thesis, reviews, and news. Finally, the PRISMA checklist items were used when applicable (PAGE *et al*., 2021).

After a preliminary analysis based on the article's title and abstract, 244 journal articles that met the inclusion criteria were gathered, and after the 2 reviewers reading and analyzing the 244 articles, finally 116 articles specifically involving distance education experiences in VM were selected. Based on the selected articles, a compilation of the history of DE in VM was made. Other categories were created to discuss the different findings. The categories were created according to the dominant themes found on the selected articles and in order to create a broad logical line of reasoning discussing then about: the use of platforms and distance education tools, difficulties and challenges of DE, current situation, and future perspectives. Finally, how DE is used in VM during the current pandemic situation of the coronavirus (Covid-19) and social distancing time was analyzed.

3. Results and discussion

3.1 History of distance education in veterinary medicine

The first DE initiatives were developed as resources for veterinarians, and entities emerged like the Veterinary Information Network (VIN) in 1991, being the first to offer on-line courses for veterinarians, covering all the veterinary medicine specialties. (FERGUSER; PION, 1996).

In 1993, six renowned VM faculties from the United Kingdom (UK), formed a partnership to develop a Computer-Aided Learning Tool in Veterinary medicine (CLIVE). CLIVE attempted to provide study materials and open educational resources (OERs) among all undergraduate disciplines in VM (DALE *et al*., 2005). In 1994, the American Veterinary Medical Association (AVMA) developed an on-line computer-aided service called Network of Animal Health (NOAH). The service was like VIN, offering databases, continuing professional development and an on-line community for veterinarians (DHEIN, 2007a).

Among the first tools used for DE in VM was the videoconferencing and is still widely used. Already in 1999, the University of Tennessee started using videoconferencing in the VM program to make clinical rounds with students and faculty from multiple facilities with just one teacher (SIMS; HOWELL; HARBISON, 2007). The same year, Purdue University developed the first DE program for veterinary technicians, because of the need for technical staff in veterinary care and the lack of teaching staff to facilitate the courses on campus (BILL, 2007).

In 2000, the International Veterinary Information Service (IVIS) created its website with the main purpose of providing information, resources and courses for veterinarians and students. In 2001, the University of Edinburgh created an electronic veterinary curriculum as an alternative to its veterinary medicine presential program (ELLAWAY *et al*., 2005). In 2002, the drug manufacturer, Merck created the free website of his famous Merck Veterinary Manual. The manual was first published in 1995, and it is still an important reference book in veterinary medicine. The Merck Veterinary Manual website has free study material in all VM specialties.

Later in 2007, one of the biggest DE platforms in VM called WikiVet was developed by 7 UK VM faculties. The aim of creating a virtual learning environment was to complement and enhance the VM students learning. WikiVet has e-content addressing all VM areas through resources such as videos, slides, podcasts, books and more (BROWN; QUENTIN-BAXTER; BELSHAW, 2010). A survey developed by Dhein (2007b) with VM faculties along United States, showed that in that time most of the faculties already had DE in their curriculum via videoconferencing in courses like dermatology, ophthalmology, pharmacology, orthopedics, internal medicine, neurology, embryology, and anatomy. Afterwards in 2010, because of a partnership between 5 veterinary schools in different European countries, the Network of Veterinarians in Continuing Education (NOVICE) was formed. NOVICE is a virtual learning platform still available that serves as a network for veterinarians and VM students to find and share information (BAILLIE *et al*., 2011).

In 2012, the first On-line Veterinary Anatomy Museum (OVAM), was created by a 20 institutions consortium worldwide looking to provide on-line OERs in the field of veterinary anatomy, histology, and embryology (GAITSKELL-PHILLIPS; SHORT; STANIKOVA, 2012). Later in 2014, the International Veterinary Students Association (IVSA), through its standing committee, created an educative on-line tool called EDU+ Platform. The tool has a collection of several OERs and educational platforms available in VM, classified by species and knowledge area (IVSA, 2020). The Royal College of Veterinary Surgeons (RCVS) developed a free learning on-line platform in 2015 for training in Evidence-based Veterinary Medicine (EBVM). The platform was created for all kinds of veterinary practitioners, nurses, educators, and students. In 2019, they made an assessment about the platform usefulness and found out it had been used by more than 20 thousand students worldwide and was very well received and recommended by most of the surveyed

users (SELLERS *et al*., 2021). More recently in 2016, IVSA, in cooperation with WikiVet, developed an initiative called VET Talks, which aimed to provide e-lectures on different topics for veterinarians and VM students; the videos are delivered via YouTube and are still available (IVSA, 2016).

Finally, in the last years the development of DE tools and platforms in VM are mainly focused on 3D software that allows a student greater interaction and understanding and permit the simulation of different realistic situations. These developments were mainly in the fields of anatomy, virtual/augmented reality, virtual clinic environments and patients (RAFFAN *et al*., 2017; ESPITIA *et al*., 2019; NOLAN; BALOGH; WALTMAN, 2019; VOGT *et al*., 2019; LITTLE *et al*., 2021; MCCAW *et al*., 2021). Besides highlighting these main initiatives in the DE literature in VM, there have been several other successful experiences in many veterinary areas as shown in the Table 1.

Table 1: Distance education experiences in veterinary medicine

Veterinary area	References
Physiology and biochemistry	(KLEINSORGEN *et al*., 2017; ARAUZ *et al*., 2021; SAADEH *et al*., 2021a; WASHBURN; COOK; TAYCE, 2021)
Farm animals' health, production, and reproduction	(ALLORE *et al*., 2001; BERNKOPF; FRANZ; BAUMGARTNER, 2010; KLUPIEC *et al*., 2014; WINDER *et al*., 2017; CALSAMIGLIA *et al*., 2020; JONKER, 2020; MOLLER KLIT; KIRKETERP NIELSEN; STEGE, 2020; RUSTON *et al*., 2020; ZHITNITSKIY, 2020)
Radiology and imagenology	(VANDEWEERD *et al*., 2007; FLORES DUEÑAS *et al*., 2021; NAVAS DE SOLIS *et al*., 2021; SUKUT *et al*., 2021; WILLIAMS; SAGE; VALBERG, 2021)
Internal medicine and medical specialties	(ACOR, 2005; DHEIN; NOXON; DEYKIN, 2005; HAINES *et al*., 2020; FOSS *et al*., 2021; MCCAW *et al*., 2021; PUTRA *et al*., 2021; REINHARD; POWELL; WATSON, 2021; SAADEH *et al*., 2021b)
Case-based learning and simulation	(DHEIN, 2005; ALLENSPACH; BELL; WHITTLESTONE, 2008; STEELE *et al*., 2013; CREEVY *et al*., 2018; VOGT *et al*., 2019; ESPITIA *et al*., 2019; ALVAREZ; REINHART, 2020; RONG *et al*., 2020; SAWRAS *et al*., 2020; DUCKWITZ *et al*., 2021a; ROSS-ESTRADA; SNYDER, 2021)
Epidemiology and public health	(LIPMAN; BARNIER; DE BALOGH, 2003; CONRAD *et al*., 2007; POZZA *et al*., 2010; VALERA. *et al*., 2010; RAMÍREZ; ANTÚNEZ; RODRÍGUEZ, 2013; SEGUINO *et al*., 2014; DUCKWITZ *et al*., 2021a, 2021b)
Pathology	(MCCONNELL; CALVER, 1997; POSPISCHIL *et al*., 2007)
Anatomy	(THEODOROPOULOS; LOUMOS; ANTONOPOULOS, 1994; EL SHARABY; ALSAFY; EL-GENDY, 2015; HANNON, 2017; OSORIO ECHEVERRI *et al*., 2019; MOHAMED, 2020; SCALLA VULCANI *et al*., 2020; LITTLE *et al*., 2021)
Histology and embryology	(GARCÍA-IGLESIAS *et al*., 2018; EVANS *et al*., 2019; SCALLA VULCANI *et al*., 2020; BATISTA DE ASSUNÇÃO; VELÁSQUEZ; MIGLINO, 2021)
Surgery and anesthesia	(STEAGALL *et al*., 2017; DECLOEDT *et al*., 2020; HUNT; ANDERSON, 2021; THIEMAN MANKIN *et al*., 2021)
Parasitology	(STRUBE; RAUE; JANECEK, 2018; PFEIFFER; JABBAR, 2019; FERREIRA *et al*., 2020; JABBAR; GAUCI; ANSTEAD, 2021)

3.2 Platforms and distance education tools

As internet access is now available worldwide, it is an increasingly common way of learning. Among the tools that may be used via the internet are the Open Educational Resources (OERs). The OERs are free on-line teaching materials and are constantly increasing in quantity and quality. Currently, video platforms like YouTube are viewed as OERs because of the large amount of free educational content available, and the ease of finding and sharing educational videos. YouTube is especially helpful to faculty and students in the health fields and have been successfully used in VM (MÜLLER *et al*., 2019; MOHAMED, 2020; SAADEH

et al., 2021a). For example, the University of Veterinary Medicine Hannover, Foundation (Tio) in Germany, developed a YouTube channel as a complement tool for veterinary students to prepare and study the practical procedures at home before going into the clinical skills lab (MÜLLER *et al*., 2019).

There are multiple delivery modalities for DE in VM that are synchronous events i.e., videoconferencing to offer what is commonly known as webinar. There can be asynchronous events where videos are recorded and made available so the student can access them whenever and as often as desired (MÜLLER *et al*., 2019; FOSS *et al*., 2021; REINHARD; POWELL; WATSON, 2021). For example, MacKay *et al*. (2021) reported the usage of recorded lectures as a study aid for veterinary students with positive outcomes. The students expressed they were more likely to use the recorded lectures as the exams approached and when the topics were more difficult to comprehend. On the other hand, Schoenfeld-Tacher and Dorman (2021) reported no significant difference on the students' learning outcomes when comparing synchronous versus asynchronous teaching-learning.

More recently, the Massive Open On-line Courses (MOOCs), that are free on-line courses available for anyone, have become popular. Although there are a limited number of MOOCs in VM, these are increasing and some have been created and made available on popular course platforms with good results (ROOT KUSTRITZ, 2014; MACKAY; LANGFORD; WARAN, 2016; GLEDHILL *et al*., 2017; PATERSON *et al*., 2017).

At the institutional level, there are the Learning Management Systems (LMS), which are learning platforms with different tools that provide a teaching-learning virtual environment where institutions can offer and manage their distance courses. LMS have been widely used in VM (EDITH *et al*., 2017; VALERO; CÁRDENAS, 2017; DOOLEY *et al*., 2018; DOOLEY, 2020; ELSAID; EMAM; ABUZEID, 2020; SCALLA VULCANI *et al*., 2020; MCMICHAEL *et al*., 2021). Social media has also been used as a DE tool and delivery method, allowing sharing educational material, study cases discussion and interaction between students and faculty. Facebook, Twitter, and Instagram have been the most social media used in VM (TENHAVEN *et al*., 2013; WHITING; KINNISON; MOSSOP, 2016; OBER, 2019; SCALLA VULCANI *et al*., 2020; DO NASCIMENTO SENA *et al*., 2021).

Most of the modern virtual learning environments allow the simulation of different events and real processes, giving more realistic and coherent learning experience (ESPITIA *et al*., 2019; EVANS *et al*., 2019). Although DE methods cannot completely replace the classes and practical training in VM, it offers several advantages. One advantage is animal welfare care because of the reduction on animal use. Also, students' preparation before practical learning sessions is improved, allowing a more advanced clinical experience and preparation for future situations in their professional lives (DE BIE; LIPMAN, 2012; STRUBE; RAUE; JANECEK, 2018; MÜLLER *et al*., 2019; CALSAMIGLIA *et al*., 2020; SAWRAS *et al*., 2020; FOSS *et al*., 2021).

In the simulation field, some options have been developed in VM like the VIN virtual clinic (NOLAN; BALOGH; WALTMAN, 2019), the emergency case simulator, and others as shown in the Appendix A. There are several on-line education platforms in VM among all veterinary specialties, some of them free, some paid and other open with registration only for veterinarians and VM students (Appendix B). A mind map summarizing distance education tools in VM is presented on Figure 1.

3.3 Difficulties and challenges of DE

As new technologies and on-line learning advance, DE has shown to have the same quality and, in some cases, being better than traditional learning (DUIJVESTIJN *et al*., 2021; FOSS *et al*., 2021; MCCAW *et al*., 2021; NAVAS DE SOLIS *et al*., 2021; ROSS-ESTRADA; SNYDER, 2021). The use of DL in higher education is growing and practically every university program needs some kind of on-line resource to complement their courses (STRUBE; RAUE; JANECEK, 2018; MAHDY, 2020; PUTRA *et al*., 2021). this became much more real due to the COVID-19 pandemic.

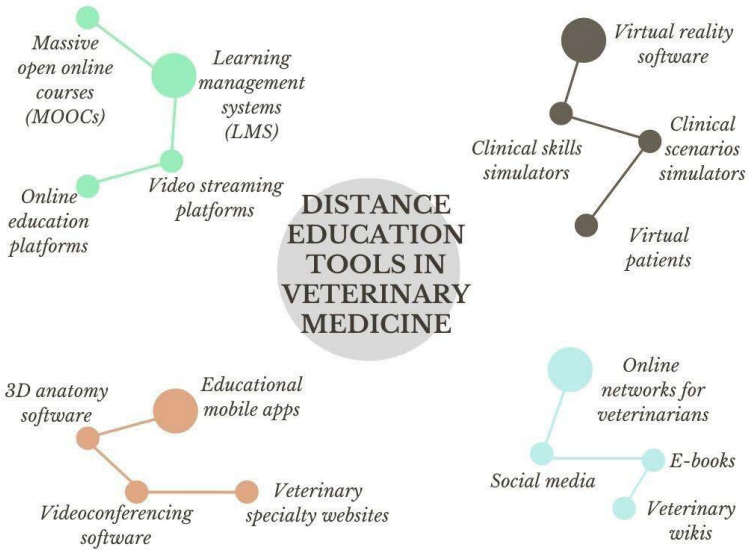

Figure 1: Summary of distance education tools in veterinary medicine
Source: authors

VM is a program with an important content of practical skills to be learned and students usually report that it could be hard to link the theoretical knowledge with the practical hands-on skills and the real clinical cases (SAWRAS *et al*., 2020). However, although today's students belong to a full information and media generation through internet, not all the procedures and skills can be learned and trained on-line such as dissections, surgery, and clinical skills (ELSAID; EMAM; ABUZEID, 2020; MOHAMED, 2020; MCCAW *et al*., 2021). It has been seen that lack of hands-on training could decrease the technical skills performance and confidence (WINDER *et al*., 2017; WARD; MULHERIN; VENGRIN, 2021). On the other hand, although some on-line materials have shown improved outcomes, not all the on-line resources have shown positive results comparing with traditional methodologies (ARAUZ *et al*., 2021; THIEMAN MANKIN *et al*., 2021).

Among the major limitations for the institutions to start using DE is the time necessary for preparing DE classes and the needed didactic resources, because good quality video production is expensive, educational content development commonly needs programming and design professionals, and creating good quality resources takes many hours (ALLENSPACH; BELL; WHITTLESTONE, 2008; ROSHIER; FOSTER; JONES, 2011; MÜLLER *et al*., 2019; ZHITNITSKIY, 2020; WARD; MULHERIN; VENGRIN, 2021).

DE may have higher dropout rates than traditional education, commonly related with low quality resources, lack of technology knowledge or poor student support among other factors that may affect students' motivation and learning (VARNHAGEN; WRIGHT, 2008). Additionally, another possible student's demotivation fact associated with asynchronous learning is the lack of face-to-face interaction with colleagues and teachers, the feeling of loneliness and lack of practical application in the clinical setting in the case of VM (PARKES; BARRS, 2021).

In the survey led by Gledhill *et al*. (2017) with veterinary students around the world, they found that 84% of the students use search tools like Google followed by Wikipedia when looking for information to study, and most were unfamiliar with the MOOCs and OERs. This finding could suggest that most of the students lack the knowledge and skills necessary to properly find accurate and reliable information resources to complement their studies. This is consistent with the research made by Saadeh *et al*. (2021b) where they found veterinary students prefer use search tools than asking their instructors.

3.4 Current situation and future perspectives

In education (on-line e-learning) has undoubtedly caused the rapid development of distance learning courses and tools by educational institutions. Tools such as MOOCs and OERs are increasingly being developed and used in veterinary education (KUMAR, 2019).

New pedagogical methodologies are increasingly common in higher education. The use of active and student-centered methodologies, such as blended learning (BL), the flipped classroom learning and case-based e-learning are trending and very necessary in VM programs (DOOLEY *et al*., 2018; KELLY; MIHM-CARMICHAEL; HAMMOND, 2019; DOOLEY, 2020; LONDGREN *et al*., 2020; SAWRAS *et al*., 2020; URIBE; JIMENEZ; TRONCOSO, 2020; DUCKWITZ *et al*., 2021a; PIENAAR; MOSTERT, 2021). Some other methodologies and options newly explored and reported in VM include the Gamification (game-based learning) and Mobile Learning (DE BIE; LIPMAN, 2012; HANNON, 2017; OBER, 2018; FERREIRA *et al*., 2020; MOLLER KLIT; KIRKETERP NIELSEN; STEGE, 2020; ARAUZ *et al*., 2021). BL involves face-to-face classroom training mixed with distance learning mainly based on the web. More and more VM programs use this type of methodology in the world, as it combines the advantages of classroom teaching and modern technologies, and in some cases has had more acceptance than traditional classes (EDITH *et al*., 2017; VOGT *et al*., 2019; DUCKWITZ *et al*., 2021b; DUIJVESTIJN *et al*., 2021; PILLAI, 2021; WASHBURN; COOK; TAYCE, 2021).

On the other hand, Flipped Learning is a form of learning which proposes the inversion of the traditional form of classes based on passive learning. Students must study and familiarize with the content before they arrive in class and previously know the key points of the topic. Content can be made available via the internet, and class time is dedicated for the teacher to guide and monitor the learning process. This methodology has been proved as effective in VM, increasing the student's engagement, autonomy and practical kills development (DOOLEY *et al*., 2018; DECLOEDT *et al*., 2020; DOOLEY, 2020; JIMÉNEZ; PEÑA MERINO; CURAY, 2020; LONDGREN *et al*., 2020; ZHITNITSKIY, 2020; SUKUT *et al*., 2021).

Case-based learning (CBL) is also a valuable active methodology in VM that permits to familiarize the student with the real-world situations and linking to the learned in class (DUCKWITZ *et al*., 2021a; MCMICHAEL *et al*., 2021; NAVAS DE SOLIS *et al*., 2021). Nowadays exists the possibility to use CBL on DE (Case-based e-learning) and BL, as the theoretical content can be delivered on-line and practical teaching through face-to-face classes (CREEVY *et al*., 2018; ALVAREZ; REINHART, 2020; SAWRAS *et al*., 2020). CBL has also been used in VM through failure cases to enhance the students problem-solving abilities (RONG *et al*., 2020).

During the current COVID-19 pandemic situation, an international survey with VM students and researchers showed that participants used many electronic devices to keep their studies at distance, been the smartphone the most used, followed by laptop and tablet. While the educational content "were available mostly through on-line classes and pdf lectures followed by e-books, YouTube videos, university platforms, educational websites, and educational applications". Also, different on-line tools i.e. WhatsApp, Google Classroom, Google Meets, and Skype, among others, have been commonly used to access on-line classes (MAHDY, 2020).

The current trend in teaching VM is to make better use of time in face-to-face classes, reduce costs in infrastructure and materials, as well as optimize university resources. The new tools are more focused on simulation environments, virtual patients, virtual reality, case-based e-learning and on-line assessment tools, making it less necessary to have physical resources. These actions also improve the animal welfare, the student's clinical confidence and optimize the evaluation processes, especially when there are many students and subjects that have a practical and/or laboratory component. They are also seen by the students as more motivating and effective for learning when comparing with traditional lectures (PEREIRA *et al*., 2018; ESPITIA *et al*., 2019; VOGT *et al*., 2019; BAI, 2020; CALSAMIGLIA *et al*., 2020; INPANBUTR *et al*., 2020; SAWRAS *et al*., 2020).

Future perspectives for DE in VM should be focused on the on-line learning improvement, the development of new study material, interactive tools, virtual reality, and 3D animations (ESPITIA *et al*., 2019; MCCAW *et al*., 2021). E-learning use for DE in VM is expected to increase in the future, mainly among areas like virtual patients and cases that are currently very appreciated by the students (KLEINSORGEN *et al*., 2018; MCCAW *et al*., 2021). Virtual Reality is other important area already been developed and that is likely to grow and improve, allowing its usage in several areas and supplementing traditional learning-teaching methodologies. Additionally, augmented reality is increasingly used to improve and ease the learning in areas as anatomy, been this methodology preferred by veterinary students (LITTLE *et al*., 2021).

In the future, (the post-pandemic era) more than ever, the use of on-line and virtual educational resources is expected to be used as the main resources for teaching and learning veterinary medicine. As the COVID-19 educational crisis boosted the development of virtual/on-line educational tools (on-line platforms, virtual/augmented reality, 3D models, on-line case-based learning, artificial intelligence, among others); veterinary medicine education is likely to generalize the use of blended learning and in some cases to completely delivery subjects and educational content remotely or mediated by e-learning (JABBAR; GAUCI; ANSTEAD, 2021; LITTLE *et al*., 2021).

3.5 DE during the COVID-19 pandemic

In December 2019, the World Health Organization (WHO) was notified of a new virus outbreak, and on March 11, 2020, the WHO declared the new virus (Coronavirus / Covid-19) as a pandemic (WHO 2020). Faced with this global problem, social distance and isolation strategies have been developed worldwide as alternatives to reduce the risk of contagion. Strategies include the closure of educational institutions in most countries. According to the United Nations (2020) "The COVID-19 pandemic has created the largest disruption of education systems in history, affecting in 2020-2021 more than 1 billion learners in more than 190 countries and all continents".

Although, there are many on-line resources available, many universities were not prepared for a situation like this and did not have the technological capacity or organized disciplines to be offered via on-line (PIENAAR; MOSTERT, 2021). Additionally, the poorest countries and students, doesn't have good internet connections or the devices needed to study at home, been these the most affected during the school closures (UNESCO, 2020; UNITED NATIONS, 2020).

In VM the situation is the same as in other areas. Universities around the world have sent their students home and are offering distance courses via the web (JABBAR; GAUCI; ANSTEAD, 2021; PARKES; BARRS, 2021; WARD; MULHERIN; VENGRIN, 2021). Some difficulties have been reported by veterinary educators during pandemic remote teaching among practical subjects as veterinary anatomy, where hands-on skills like dissection are difficult to taught or learned through virtual scenarios as well as practical lessons and assessments (FREITAS RIBEIRO, 2021; SABER, 2021).

Recently, Hunt and Anderson (2021) reported the use of remote clinical skills courses for veterinary students due to the pandemic situation. It was found out that students successfully learned the clinical skills with no significant difference with previous years. Parkes and Barrs (2021) also reported the implementation of a learning platform for veterinary students due to the pandemic situation. They reported, the platform and methodology were positively accepted by the students and not represented more difficulties when compared with face-to-face learning.

Ward *et al*. (2021) reported the exceptional transition of the presential clinical rotations of veterinary students to the virtual format because of the COVID 19 pandemic. The authors said the virtual clinical rotations were well accepted by the students and showed equal or higher evaluation scores when comparing

to presential rotations. However, they were aware that hands-on skills were difficult to teach virtually, and there could be a lack of knowledge in certain areas.

Some DE responses have been created during this pandemic time among fields like veterinary embryology (BATISTA DE ASSUNÇÃO; VELÁSQUEZ; MIGLINO, 2021), histology and anatomy (SABER, 2021), parasitology (JABBAR; GAUCI; ANSTEAD, 2021), clinical skills (HUNT; ANDERSON, 2021), imagenology (WILLIAMS; SAGE; VALBERG, 2021), orthopedics (MCCAW *et al*., 2021), small animal clinics (ROSS-ESTRADA; SNYDER, 2021), clinical rotations (WARD; MULHERIN; VENGRIN, 2021), surgery (THIEMAN MANKIN *et al*., 2021), among others.

The on-line survey delivered by Mahdy (2020) with over than 1,400 VM students and researchers from 92 different countries showed that most of the participants (96,7%) consider that COVID-19 pandemic affected their academic life in different degrees. Regarding on-line learning, involving problems like difficulty to teach practical lessons, sense of loneliness, lack of electronic devices and internet to access the educational content, among many others. Despite of those problems, participants also reported advantages like on-line learning is more flexible, permits self-study and more time to learn. This is consisted with reported by Freitas Ribeiro (2021) with VM students in Brazil, Parkes and Barrs (2021) in Hong Kong and Das *et al*. (2021) in India.

5. Conclusions

DE in VM has become very popular, being currently an indispensable tool to complement face-to-face courses, reduce costs and offer education to those who cannot go in person to educational institutions. This has led to the development of several platforms, applications and on-line educational resources that facilitate and enhance the teaching-learning process for educational institutions, veterinary students, and professionals. New technologies such as virtual reality and clinical simulators have helped in the process of reducing animals in classes, reducing the time for face-to-face practices, and reducing costs. In the future, more open educational resources, simulators, and virtual environments should be developed to enhance DE in VM, offer an improved learning experience to students and optimize the resources and staff for faculty.

The COVID-19 pandemic situation has forced institutions to offer their courses by distance learning, for which many were not ready. However, this may be the propitious occasion to generate partnerships between institutions and start to develop more virtual learning tools. Doing so may strengthen and make better use of distance learning, as well as help to avoid an educational crisis that interrupts the training process of VM students.

Some limitations of this systematic review include studies published in other languages than English, Spanish, and Portuguese. Besides of those articles are not indexed in the selected databases.

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APPENDIX A

Table: Simulation in Veterinary Medicine

SIMULATORS	INSTITUTION	FREE	PAID	AREA	WEB SITE
VIN Virtual Clinic	Veterinary Information Network		X*	Emergencies	https://www.vin.com/students/default.aspx?pId=680&id=8286502
Cardiac Virtual Patients	Royal Veterinary College (University of London)	X		Cardiology	https://www.rvc.ac.uk/review/cardiocases/
Virtual reality anatomical models	X Virginia Polytechnic Institute and State University	X		(Anatomy)	https://guides.lib.vt.edu/vetmed/vranatomy
Digital Slide Box	Royal Veterinary College (University of London)	X		Histology	https://www.rvc.ac.uk/review/SlideBox.cfm
Dairy Farm Simulator	Royal Veterinary College	X		Dairy Production	www.virtualdairyfarm.org

*Free for veterinary medicine students

APPENDIX B

Table: Online education platforms in Veterinary Medicine

PLATFORM	INSTITUTION	FREE	PAID	AREA	WEB SITE
Veterinary Anatomy	University of Minnesota			Anatomy	vanat.cvm.umn.edu
Virtual Veterinary Educational Tools	Colorado State University		X	Anatomy	cvmbs.colostate.edu/vetneuro
Real 3D Anatomy	University of Bristol	X		Anatomy	real3danatomy.com
Illinois Imaging Anatomy	University of Illinois	X		Anatomy Imagenology	vetmed.illinois.edu/imaging_anatomy/index.html
Online Veterinary Anatomy Museum	UK Universities Consortium	X		Anatomy	onlineveterinaryanatomy.net/
Limb Anatomy	Iowa State University	X		Anatomy	http://apps.cvm.iastate.edu/limbanatomy/
Digital Learning Showcase	Royal Veterinary College (University of London)	X		Different Vet Areas	https://www.rvc.ac.uk/about/the-rvc/our-departments/academic-support--and-development/emedia/showcase

Neuroanatomy of the Dog	Universidad Autonoma de Barcelona	X		Anatomy	https://www.neuroanatomyofthedog.com/
Equine Distal Limb - Anatomy and Imaging	Royal Veterinary College (University of London)	X		Anatomy Imageneology	https://www.rvc.ac.uk/static/review/equine-distal-limb/index.html
Ivala Learn	Ivala®		X-	Anatomy	https://www.ivalalearn.com/
Equine Hoof Explorer	Effigos®		X	Anatomy	https://hoofexplorer.com/
Tha Glass Horse / The Glass Dog	University of Georgia – Science in 3D®		X	Anatomy	http://sciencein3d.com/
Biosphera	Biosphera®		X	Anatomy	https://biosphera3d.com/
VetBact	Swedish University of Agricultural Sciences	X		Bacteriology	https://www.vetbact.org/?startpage=1
ECLINPATH	Cornell University	X		Pathology	http://eclinpath.com/
The Joint Pathology Center	National Capital Region Medical Directorate	X		Pathology Histology	http://www.askjpc.org/vspo/
Swiss Virtual Animal Pathology	University of Zurich	X		Pathology	https://www.animal-patho.org/en/
Veterinary Pathology Image Database	Universidad Autonoma de Barcelona	X		Pathology	https://veterinariavirtual.uab.cat/archivopatologia/index.php
Cardio Academy	Ceva Santé Animale	X		Cardiology	https://www.cardioacademy.cevalearn.com/
Antimicrobial Resistance Learning Site	University of Minnesota Michigan State University	X		Microbiology Pharmacology Public Health	https://amrls.umn.edu/
Veterinary Histology	The Ohio State University	X		Histology	https://ohiostate.pressbooks.pub/vethisto/
Virtual Fetal Pig Dissection	Whitman College	X		Anatomy	https://www.whitman.edu/academics/departments-and-programs/biology/virtual-pig
Rooney's Guide to the Dissection of the Horse	Cornell University	X		Anatomy	https://secure.vet.cornell.edu/oed/Horsedissection/search.asp
Anatomy Museum Collection	Royal Veterinary College (University of London)	X		Anatomy	https://www.rvc.ac.uk/review/anatomy/
KASHVET	KASHVET	X		All Vet Areas	http://www.kashvet.org/e-learning.htm

Veterinarios en Web	Universidad Católica de Salta	X	X'	All Vet Areas (Spanish)	https://www.veterinariosenweb.com/
Merk Veterinary Manual	Merck & Co	X		(Spanish)	https://www.merckvetmanual.com/
Wiki Vet	UK Universities Consortium	X'		All Vet Areas	https://en.wikivet.net/Veterinary_Education_Online
VIN	Veterinary Information Network		X*'	All Vet Areas	https://www.vin.com/vin
NOVICE	European Commission	X'		All Vet Areas	http://noviceproject.eu/
IVIS	International Veterinary Information Service	X'		All Vet Areas	https://www.ivis.org/
The Webinar Vet	The Webinar Vet®		X'	All Vet Areas Online Courses	https://www.thewebinarvet.com/
Vetstream	Vetstream Ltd		X'	All Vet Areas Online Courses	https://www.vetstream.com/home
Veterinary Partner	Veterinary Information Network	X		All Vet Areas	https://veterinarypartner.vin.com/default.aspx?pid=19239
Guide to Veterinary Diagnostic Parasitology	Royal Veterinary College - Food and Agriculture Organization	X		Parasitology	https://www.rvc.ac.uk/Review/Parasitology/Index/Index.htm
Veterinary Bacteriology and Mycology	University of Copenhagen			Microbiology	https://atlas.sund.ku.dk/microatlas/veterinary/
Cabi VetMed Resource	CAB International	X		All Vet Areas	https://www.cabi.org/vetmedresource/
Dechra Academy	Dechra Pharmaceuticals	X'		Online Courses	https://academy.dechra.com/learn
Vetgirl	Vetgirl LLC		X'	Online Courses	https://vetgirlontherun.com/
LafeberVet	Lafeber Company	X'		Exotic Animals	https://lafeber.com/vet/
Hill's Veterinary Nutritional Advocate	Hill's Pet Nutrition	X'		Nutrition	https://vna.hillsvet.com/?checked=true
Online VetMed	University of Illinois		X'	Online Courses	https://online.vetmed.illinois.edu/courses
Vet Book	University of Sidney	X		All Vet Areas (DOG)	http://www.vetbook.org/wiki/dog/index.php/Dog
The sheep brain atlas	Michigan State University	X		Anatomy Histology	https://msu.edu/~brains/brains/sheep/index.html

Canine Radiographs	Royal Veterinary College (University of London)	X		Anatomy Imageno-logy	https://www.rvc.ac.uk/Review/canine_radiographs/index.htm
Intructional Resources	Oklahoma State University	X		Different Vet Areas	https://instruction.cvhs.okstate.edu/
Research Podcasts – Veterinary Science on the Move	Royal Veterinary College (University of London)	X		All Vet Areas	https://www.rvc.ac.uk/research/podcasts
Veterinary Dentistry	Royal Veterinary College (University of London)	X		Dentistry	https://www.rvc.ac.uk/Review/Dentistry/index.htm
Classic Cases in Veterinary Dermatology	Royal Veterinary College (University of London)	X		Dermato-logy	https://www.rvc.ac.uk/Review/Dermatology_Cases/Index.htm
Diagnosis in Dermato-logy	Royal Veterinary College (University of London)	X		Dermato-logy	https://www.rvc.ac.uk/review/dermatology/
The Canine Abdomen	Royal Veterinary College (University of London)	X		Embriology	https://www.rvc.ac.uk/Review/abdomen/HTML/index.htm
Evidence-based Veterinary Medicine (EBVM)	Royal College of Veterinary Surgeons	X		Eviden-ce-based Veterinary Medicine	https://learn.rcvsknowledge.org/course/view.php?id=2
Veterinary Radiology	Dr. Allison Zwingenberger (University of California)	X		Imageno-logy	http://www.veterinaryradiology.net/
Information on aquatic and terrestrial animal diseases	World Organisation for Animal Health (OIE)	X		Public He-alth	https://www.oie.int/animal-health-in-the-world/information-on-aquatic-and-terrestrial-animal-diseases/
WAHIS Interface	World Organisation for Animal Health (OIE)	X		Public he-alth	https://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home
Veterinary Food Safety Education Learning Object Repository	University of Wisconsin, University of Georgia and Texas A&M University	X'		Food Safety	http://webcls.utmb.edu/d2d/default.asp
Livestock Behaviour, Design of Facilities and Humane Slaughter	Dr. Temple Grandin	X		Animal Wel-fare	http://www.grandin.com/
The biology of the Goat	Karin Christensen	X		Anatomy Physiology Parasitology	http://www.goatbiology.com/index.html
Animal Ethics Dilemma	Malmö University	X'		Animal Ethics and Welfare	http://www.aedilemma.net/

Case Studies In Small Animal Cardiovascular Medicine	UC-Davis School of Veterinary Medicine	X		Cardiology	https://viper.vetmed.ucdavis.edu/public/cardio_kittleson/cases/index.htm
Plants Poisonous to Livestock	Cornell University	X		Toxicology	http://poisonous-plants.ansci.cornell.edu/index.html
Small and Large Animal Health Topics	American College Of Veterinary Surgeons	X		All Vet Areas	https://www.acvs.org/
Rumen Biochemistry	The University of Queensland	X		Biochemistry	http://www.vet.ed.ac.uk/clive/cal/RUMENCAL/vetcal.html
Advice and Welfare	Royal Society for the Prevention of Cruelty to Animals	X		Animal Welfare	https://www.rspca.org.uk/adviceandwelfare
Vetscope	Vetscope	X'		Different Vet Areas	https://vetscope.vet/
Vetmed Academy	Vetmed Academy	X'		All Vet Areas	https://vetmedacademy.org/
Vet-Revise	Jist – Royal Veterinary College	X'		All Vet Areas	https://vetrevise.com/login
The Pig Site	5m Enterprises Inc	X		All Vet Areas (Pig)	https://thepigsite.com/
The Poultry Site	5m Enterprises Inc	X		All Vet Areas (Poultry)	https://thepoultrysite.com/

Note. * Free for veterinary medicine students,' Registration needed, - Free for VIN members