The Second Life metaverse and its usefulness in medical education after a quarter of a century

Francisco Sendra-Portero, Rocío Lorenzo-Álvarez, Teodoro Rudolphi-Solero, Miguel José Ruiz-Gómez

Submitted to: Journal of Medical Internet Research
on: March 30, 2024

Table of Contents

The Second Life metaverse and its usefulness in medical education after a quarter of a century

Francisco Sendra-Portero[1] MD, PhD; Rocío Lorenzo-Álvarez[2] MD, PhD; Teodoro Rudolphi-Solero[1] MD, PhD; Miguel José Ruiz-Gómez[1] PhD

[1]Department of Radiology and Physical Medicine. Facultad de Medicina Universidad de Málaga Málaga ES
[2]Department of Emergency and Intensive Care. Hospital de la Axarquía. Avenida del Sol, 43. 29740 Vélez-Málaga, Spain. Vélez-Málaga ES

Corresponding Author:
Francisco Sendra-Portero MD, PhD
Department of Radiology and Physical Medicine. Facultad de Medicina
Universidad de Málaga
Bvd. Luis Pasteur, 32. 20071 Málaga, Spain
Málaga
ES

Abstract

Background: The immersive virtual world platform Second Life (SL) was conceived 25 years ago, when Philip Rosedale founded Linden Lab in 1999 with the intention of developing computing hardware that would allow people to immerse themselves in a virtual world. This initial effort was transformed four years later into Second Life, a universally accessible virtual world, centered on the user, with commercial transactions and even its own virtual currency, which fully connects with the concept of Metaverse, recently repopularized after the statements of the CEO of Meta (formerly Facebook) in October 2021.

Objective: Second Life is considered the best-known virtual environment among higher education professionals. This article aims to review medical education in the Second Life metaverse, its evolution, its possibilities and limitations and future perspectives, focusing especially on medical education experiences, during undergraduate, residency, and Continuing Medical Education (CME).

Methods: The concept of metaverse and virtual worlds is described, making special reference to SL, its conceptual philosophy, historical evolution, technical aspects and capabilities for higher education. A narrative review of the existing literature has been performed, including at the same time a point of view from our teaching team, after an uninterrupted practical experience of undergraduate and postgraduate medical education in the last 13 years, with more than 3,700 users and 10 publications on the subject.

Results: From an educational point of view, SL has the advantages of being persistent 24/7, and creating in the student the important feeling of "being there" and co-presence. This, together with the reproduction of the 3D world, real-time interaction and the quality of voice communication, make the immersive experiences unique, generating engagement and a fluid interrelation of students with each other and with their teachers. Various groups of researchers in medical education have developed experiences during these years, which have shown that courses, seminars, workshops and conferences, PBL experiences, evaluations, teamwork, gamification, medical simulation and virtual OSCEs can be successfully carried out. Acceptance from students and faculty is generally positive, recognizing its usefulness for undergraduate medical education and CME.

Conclusions: After 25 years of its conception, SL has proven to be a virtual platform that connects with the concept of metaverse, an open system, with global access, interconnected where all humans can access to socialize or share products, for free or using a virtual currency. Second Life remains active and technologically improved since its creation. It is necessary to continue carrying out educational experiences, outlining the organization, objectives and content, measuring the real educational impact, in order to make SL a tool of more universal use. Clinical Trial: N/A

(JMIR Preprints 30/03/2024:59005)
DOI: https://doi.org/10.2196/preprints.59005

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

The Second Life metaverse and its usefulness in medical education after a quarter of a century

Abstract

Background: The immersive virtual world platform Second Life (SL) was conceived 25 years ago, when Philip Rosedale founded Linden Lab in 1999 with the intention of developing computing hardware that would allow people to immerse themselves in a virtual world. This initial effort was transformed four years later into Second Life, a universally accessible virtual world, centered on the user, with commercial transactions and even its own virtual currency, which fully connects with the concept of Metaverse, recently repopularized after the statements of the CEO of Meta (formerly Facebook) in October 2021.
Objective: Second Life is considered the best-known virtual environment among higher education professionals. This article aims to review medical education in the Second Life metaverse, its evolution, its possibilities and limitations and future perspectives, focusing especially on medical education experiences, during undergraduate, residency, and Continuing Medical Education (CME).
Methods: The concept of metaverse and virtual worlds is described, making special reference to SL, its conceptual philosophy, historical evolution, technical aspects and capabilities for higher education. A narrative review of the existing literature has been performed, including at the same time a point of view from our teaching team, after an uninterrupted practical experience of undergraduate and postgraduate medical education in the last 13 years, with more than 3,700 users and 10 publications on the subject.
Results: From an educational point of view, SL has the advantages of being persistent 24/7, and creating in the student the important feeling of "being there" and co-presence. This, together with the reproduction of the 3D world, real-time interaction and the quality of voice communication, make the immersive experiences unique, generating engagement and a fluid interrelation of students with each other and with their teachers. Various groups of researchers in medical education have developed experiences during these years, which have shown that courses, seminars, workshops and conferences, PBL experiences, evaluations, teamwork, gamification, medical simulation and virtual OSCEs can be successfully carried out. Acceptance from students and faculty is generally positive, recognizing its usefulness for undergraduate medical education and CME.
Conclusions: After 25 years of its conception, SL has proven to be a virtual platform that connects with the concept of metaverse, an open system, with global access, interconnected where all humans can access to socialize or share products, for free or using a virtual currency. Second Life remains active and technologically improved since its creation. It is necessary to continue carrying out educational experiences, outlining the organization, objectives and content, measuring the real educational impact, in order to make SL a tool of more universal use.

Keywords: Medical Education; Medical Students; Postgraduate; Computer Simulation; Virtual Worlds; Metaverse.

The metaverse, virtual worlds and Second Life

The metaverse, concept and evolution.

The term metaverse appears for the first time in Neal Stephenson's novel Snow Crash, published in 1992 [1], which recreates a fictional virtual world, reproduced by a computer in which users interacted with each other and with the elements of the world through a representation of themselves

called avatar. Cinema has popularized other examples of virtual worlds, parallel to the real one, in the Matrix tetralogy (1999-2021), written and directed by Lana and Lilly Wachowski, or the film Ready Player One (2018), directed by Steven Spielberg. The truth is that the possibility of reproducing three-dimensional (3D) virtual environments where the user can enter and interact with everything that exists in them is technologically feasible today, largely thanks to the developments of video games for consoles and computers and more recently by the dissemination of massively multiplayer online games (MMORGP, Massively Multiplayer Online Role-playing Games), with thousands of young, and not so young, users around the world. These environments allow the player to enter the world and carry out a series of activities related to the rules of the game.

Conceptually, the Metaverse is an open system, a vast virtual world that can be accessed simultaneously by millions of people through highly customizable avatars and powerful experience creation tools integrated with the offline world through its virtual economy and external technology [2]. The metaverse has been defined as an interconnected 3D virtual environment where people from all over the world can come together to share social experiences [3], “a computer-generated universe” in which people immerse themselves in experiences rather than simply observing them [4].

The term metaverse has gained great popularity recently, after Mark Zuckerberg, owner of the social network Facebook, announced in October 2021 his company's interest in developing the metaverse as a social environment, apparently as an area of interaction and commercial transactions (Figure 1). The result is that there is currently a growing interest in all matters related to the metaverse, virtual worlds and their applicability to today's society, including education.

Publications about the Metaverse include various technological approaches that can lead to some confusion, such as augmented reality, virtual reality, extended reality or virtual worlds [5]. Augmented reality (AR) is a technology that increases our perception of reality by adding digital information to the real world; virtual reality (VR) allows users to experience a completely simulated environment as if it were real; Mixed reality (MR) is a hybrid of the physical and virtual worlds in which digital objects interact with the physical environment to create an even more immersive experience; and Extended reality (XR) is a general term to refer to AR, VR and MR. A virtual world is a three-dimensional space where users interact without a specific script, they even have the freedom to develop the contents of the world and the objectives to which they want to dedicate themselves.

Some differences have been pointed out between the metaverse and XR technologies [6]. The concept of metaverse emphasizes sharing the experience, interacting with other avatar-mediated humans, thus, a student learning by means of XR cannot be considered an example of a metaverse per se [7]. The metaverse is a new method of social connection; a virtual world in which people can autonomously participate in social activities, such as meetings, discussions, collaborations, and games [8], and provides people with unique learning opportunities [9,10]. In a similar way, virtual worlds and virtual reality, while emerging from similar roots, are not interchangeable terms. Virtual reality requires a special interface with the electronic space, head devices with glasses and headphones, as well as hand controllers to interact within a virtual space. Virtual reality pays little attention to what is happening within the virtual world by other people or the community [11]. A virtual reality platform can even be designed to present the context in a more visually attractive and “realistic” way to a single user, which completely distances it from the concept of a metaverse.

Virtual worlds

Virtual communication has become an integral part of the 21st century culture [12]. The application of communication technologies has contributed to the development of digital virtual spaces that

allow participants to live in a digital environment that may resemble reality, interact with contents and visitors as much as they do in real life but without having physically to move to a common place in which to stablish such interaction. The range of activities that can be developed in these environments are practically unlimited and depends fundamentally on the ability of the developers of these malleable spaces, to transform them into a particular environment [13].

A virtual world is a synchronous and persistent network of people, represented by avatars, facilitated by networked computers [14], a computer-based simulated environment, as well as shared space that hosts an online community [15,16]. The main characteristics of virtual worlds have been described [17]: (1) shared space in which multiple users can participate at the same time; (2) graphical user interface, which visually represents the virtual space; (3) immediacy, or real-time interaction; (4) interactivity, since users have a certain degree of control over the content; (5) persistence, it is an always “active” platform; and (6) socialization/community, as in-world social groups, gatherings, and neighborhoods are encouraged. The term virtual world is synonymous with immersive environment, a 3D virtual place where users take the form of avatars visible to others, a space that simulate reality created by the site manager for a specific purpose (i.e. a collaborative workspace, a classroom, a virtual laboratory, a playground, a discussion forum, a meeting place with friends, etc.). Therefore, virtual worlds can become virtual academic places where users, students, and teachers, introduce and interact by means of an avatar, being able to speak, chat and visualize various educational contents.

The roots of virtual worlds can be found in video games and social networks [18]. Although the development of virtual worlds has reached a high level of use through simulation games, they should not be assimilated to them. A virtual world is not a MMORPG, that is, a “game”; a MMORPG, however, can exist within a virtual world [19]. Even though much of successful multiplayer games are carried out in virtual worlds, their possibilities are unlimited and not restricted to the world of gaming. In this sense, one of the activities that has been successfully tested in virtual worlds is basic education in the fields of science and arts [20,21,22]. Some examples of virtual worlds are Active Worlds, Sinespace, IMVU, Open Simulator, Sansar or Second Life [17]. The latter has been described as the most popular virtual world among higher education teachers with great educational possibilities in humanities, technology, sciences and health-related professions and is the subject of this study.

Second Life

A story of a quarter of a century

The immersive virtual world platform, Second Life (SL), was conceived 25 years ago, when Philip Rosedale founded Linden Lab in 1999 with the intention of developing computing hardware that would allow people to immerse themselves in a virtual world. This initial effort was transformed four years later into SL, a universally accessible virtual world, centered on the user, with commercial transactions and even its own virtual currency. Second Life is one of the most known and used virtual worlds, a virtual community created and/or developed by the own users. Second Life is not a game, but a multi-user virtual environment, it had always tried to distance itself from the video game universe [2]. From its beginning it was presented as an Open world with no explicit objectives, quests, or missions, explicitly and flatly stating “If you can imagine it, you can do it here” or “You choose your own goals” [2].

Second Life experienced a huge rise in popularity. Until approximately 2008, virtual worlds like SL were all the rage, with headlines trumpeting the life-altering potential of these avatar-occupied worlds. Philip Rosedale considered “alternative universes” like SL a new medium of human

expression that could be the “next big thing for the Internet” [17]. But by around 2010, SL and other virtual worlds lost their former appeal, replicating Gartner's Hype Cycle, a graphical representation of a common pattern that emerges with each new technology or other innovation. The cycle begins with over-enthusiasm followed by a period of disappointment, reaching a plateau of slow growth when the relevance and role of innovation is finally understood. The lack of attraction among Internet users could be due to several factors: (1) the learning curve necessary to acquire even a modest level of competence in the virtual world; (2) time is a limiting factor, so the hours invested in “living a second life” reduce the 24 hours available for real-life activities; and (3) the technical sophistication of the platform in relation to other social interaction offerings that appeared disruptively in those years, such as Facebook, Instagram, Twitter, Snapchat and others. In short, too many easier-to-use alternatives appeared on the scene 15 years ago. The current position of SL (and other virtual worlds) in the Hype Cycle is an open question. Several studies suggest that it is on a “productivity plateau,” which implies stable but unspectacular growth over time [17]. A Search in Internet may give an idea of this (Figure 1).

In 2020, Linden Lab was purchased by Waterfield Group, an investment firm that buys companies that earn decent earnings and helps them remain profitable in perpetuity [2]. That same year, the COVID-19 pandemic put the world under quarantine and many people spent their quarantine in virtual worlds, eager to connect with others. Second Life saw a surge in old and inactive users as growing awareness of virtual worlds fueled renewed and growing interest in the Metaverse.

Now, 25 years after the founding of Linden Lab, this virtual world seems to still have some weight, especially in the world of creation and graphic design [23]. In 2021, it was reported that there were still about 64.7 million active users on SL, and Web Tribunal stated that by 2023 this had risen to 70 million accounts, with a daily average of 200,000 users in 200 countries [24]. Second Life continues to be successful as a virtual world model that connects with the concept of an equitable, diverse and creative Metaverse. Its creativity tools are open and powerful, its user community is diverse, and is made up of members free to create endless values and possibilities [2].

What is Second Life?

From a technical point of view, the SL architecture is based on a client-server model. The graphical user interface runs locally, while the 3D virtualization runs on servers owned by Linden Lab. The visual experience is presented in real time, but the objects are stored remotely, making it easy to create content for the user. But on the other hand, it puts a lot of pressure on the user's graphical capabilities and bandwidth [25].

From the user's experiential perspective, the visual and physical realism of the virtual space, interaction, and communication with others, combine to produce a deeply immersive experience. Immersion is the sensation of feeling so situated within the 3D virtual world that awareness of the environment beyond the digital screen virtually disappears [2]. It contributes to creating a feeling of "being there" and a strong sense of co-presence when other avatars are present.

From a social point of view, SL is a virtual community created and/or developed by its own users, whose sociality is visible in the links that are formed between the various virtual communities and subcultures existing within the virtual world. Through the avatars one has the feeling of being part of that world and that others can perceive it at the same time, the feeling of social presence on a virtual global platform, currently shared by diverse generations, including baby boomers, millennials, and generation X [2,17]. Within SL there are multiple communities with their own spaces that recreate scenarios designed by the users themselves. Among these communities there is their own economy, based on a virtual currency, the Linden Dollar (LD), with which users can buy and sell virtual

material, make transactions, pay for services and exchange other currencies [26] (1 LD is equivalent to 0.0029 EUR or 0.0031 USD, as of March 27, 2024). The importance of this economic system is such that it has required the development of a virtual monetary policy that manages resources and how to carry out transactions, which can be carried out in a common market ("Marketplace") or directly between users [27]. Within the communities there are also a series of rules, which in case of non-compliance can lead to the blocking or deletion of the user account. These rules prohibit intolerance, harassment, aggression (even virtual), slander, indecency and disturbance of the peace [28].

How it works?

Information related to SL can be found in its Webpage [29]. To accede to SL the user must create an account, choose an avatar and download the SL viewer [30] or any other SL compatible viewer [31] to display the virtual world on his/her computer screen. The use of SL is free for users (although a premium account can be purchased by 9 USD per month), but not for landowners/administrators, who have to pay different rates according to the size of the land.

The SL virtual world imitates the real world that we know. It consists of interlinked regions that contain land, water, and sky. A region is an entire island that is 256 m × 256 m, or 65,536 square meters. Almost all the objects that are visible in SL are built from 3D geometric primitive shapes called prims. Each region has an allotment of 15,000 prims. Prims can assume any desirable shape, and one can make prims look any way wanted by applying selected textures to their surfaces. They can be given certain qualities and features (such as transparency or the ability to flex/bend with the wind), they can be linked together, and they can be made to do things by a script written in Linden Scripting Language (LSL) [32]. Prims also allows sharing media, i.e. displaying a web page or a linked video on a face.

The avatar is the representation of the user inside SL, and by mean of it, he or she can interact with the virtual world. Interactions include viewing the world with different perspective and focus, touching objects, answering to displayed menus originated from LSL scripts, moving or adopting gestures (walk, run, fly, teleport, sit or lie down), and communicating with others (receiving and sending audio, chat, instant messages and notecards). At launch, SL avatars were human by default but not ultra-realistic. The internal prim creation tools encouraged the construction of avatar attachments, which led to a wide variety of avatar types and creative environments to explore. The arrival of mesh in SL, in 2010 —high-resolution 3D files created in offline software and then uploaded into the virtual world— greatly changed this dynamic. Thanks to mesh and other graphics enhancements, SL avatars and environments now look as detailed and as vivid as those from top video games [2].

Communication between avatars can be done through voice chat, written chat, and notecards. Voice chat gives a very important sense of presence, it gives the user the perception that they are in front of other human beings and allows them to perceive the nuances of verbal communication. Its use can be public (everyone within a predetermined distance can hear it) or private (the conversation is exclusive to an avatar or group of avatars), but only alternatively.

Written chat can also be public (local chat) or private (instant message). Local chat can be read by everyone nearby, is great for asking short answer questions to the audience (yes/no, true/false, etc.) and allows attendees to ask questions to the presenter, without interrupting the presentation. Instant messages are sent from one avatar to another who receives it immediately, if he/she is online, or as soon as he/she is online. Notecards are messages that are sent in SL and are stored in the inventory of the avatar that receives it, recording the date, time of sending and avatar of origin. In educational

activities they are very useful to collect information from students, as proof of their attendance or to complete a task or an exam (open-answer or multiple choice), requesting that they send a notecard to the teacher's avatar [33].

In essence, through SL environment we can provide specific contents to users' avatars (students, teachers or public in general), such as text, slide presentations or other multimedia content. Moreover, we can also communicate verbally, in a synchronous way (at real time), with other avatars creating a meeting or classroom-like environment where we can give (or attend to) a talk or organize a discussion group on a specific topic.

Second Life as an educational tool

Learning theories and virtual worlds

Learning theories are constructs that explain how human beings acquire knowledge, values, skills, behaviors, attitudes, and aptitudes, in a systematic, dynamic and progressive way through different training techniques, such as study, reflection, experimentation or teaching [34]. The most important theories currently considered are behaviorist theory, cognitivist theory and constructivist theory and all three are integrated into the use of virtual worlds such as SL [35,36]. The *behaviorist theory* focuses on the establishment of observable responses by the student's behavior based on a series of stimuli received during learning, which makes it necessary to establish small check points to achieve the behavioral objective [35]. Virtual worlds have been described as a suitable tool to effectively stimulate students to perform their tasks better. These environments, which can present a playful atmosphere, allow the establishment of a series of rewards or scoring systems, which motivate students to carry out their learning [37]. The *cognitivist theory*, developed reactively to behaviorism, describes the mental process that takes place in the student and how he/she can apply what he/she has learned in new experiences [35]. Virtual environments such as SL allow the development of experiential experiences where the student can carry out this transfer of knowledge. The *constructivist theory* makes the student responsible for their own training, giving them the tools required to create their own learning methodology, focusing on the students' relationship with each other and with educators [35]. Virtual worlds, and particularly SL, are social environments in which students can participate in activities with a constructivist approach, including learning experiences that imitate the real world, interacting live with classmates and teachers. This dynamic allows students to process the information received and construct meaning actively, instead of receiving information passively [36].

Learning is based on the passage of knowledge from working memory (short term) to long-term memory [38,39]. This process is analyzed with a factor known as cognitive load, defined as the mental effort necessary to perform a task by the cognitive system [40,41]. The complexity of the tasks, as well as their organization and presentation of information imposed on learners, can hinder the function of short-term memory in a given task. The intellectual complexity of the tasks is known as intrinsic cognitive load, while their presentation is known as extraneous cognitive load [42]. When teaching through virtual worlds, it is essential to consider the extraneous cognitive load, since, if the student does not have the ability to function easily in digital systems, their learning may be negatively affected [41].

Second Life from a higher education perspective.

Virtual worlds have a remarkable potential for effective teaching and learning [43,44]. These experiential environments bring the possibility to create immersive, realistic, and engaging online events that can provide high quality medical education to health-related users in remote locations [45,46,47].

Second Life is considered the most popular virtual world among educators and the most used in higher education [25,48,49,50,51] and particularly in the education of medical professionals [43,52]. It can be seen from the literature that most of the studies on the application of virtual world in higher education are based on SL [53]. Warburton produced an article on the use of SL in higher education [25], which evaluates the potential of SL as an educational tool and the obstacles to the application of 3D immersive virtual worlds in teaching, and It also summarizes the typology of the virtual world to help researchers understand the virtual world. It is the most influential paper in the field and deserves the attention of researchers [53].

Advantages and potential for learning

Second Life is free for use for participants (students and teachers), and it may not be complex to manage for young users, such as medical students. The components of the SL experience can facilitate educational innovations, through [25]:

- *Expanded or rich interactions:* referring to social interaction between individuals and communities, as well as between humans and virtual objects.
- *Visualization and contextualization:* the production and reproduction of content that is inaccessible, too expensive, imaginary, futuristic or impossible to see for the human eye.
- *Exposure to authentic content*, scientific, technical and cultural.
- *Identity play*, both individual and collective
- *Immersion* in a three-dimensional environment, where the sensation of presence, through virtual embodiment in the form of an avatar and extensive modes of communication, can impact the affective, empathic and motivational aspects of the experience.
- *Simulation:* reproduction of contexts that may be too expensive to reproduce in real life, with the advantage that some physical limitations can be overcome.
- *Community presence:* promote a sense of belonging and purpose that unites groups, subcultures and geography.
- *Content production:* opportunities for the creation and ownership of the learning environment and the objects within it.

Barriers and limitations

Although there is abundant evidence that educational activities can be carried out in scenarios specifically designed in SL, it must be recognized that there are certain barriers that may limit its use. One problem with using SL for education may lie in the technical capabilities of some users' computers and Internet connection, because the viewer has significant requirements to run adequately [54]. This is computer technology, which means that glitches or other technical interruptions occasionally occur. Insufficient graphics capacity or bandwidth can prevent the viewer from running, or produce a "lag" effect, where loads caused by too many objects in one place slow down the experience making it choppy, unstable, and frustrating [25]. There is a necessary learning curve for users, few people can simply "jump" into SL for the first time effortlessly [17]. This may cause rejection in some participants. In contrast, SL, is considered old technology by some young users, for example, it still does not have an official native mobile app. But there is an imminent release of an iOS/Android app for SL running on Unity, bringing the venerable virtual world "in top form" into the modern era [2].

There are other cultural, social, time investment or economic barriers that must be considered. For example, as a result of the global reach of the virtual world, cultural and linguistic differences must be considered [17]. Second Life can be an isolating experience for the user, as it is not always easy to participate and integrate into new communities, in a place outside the user's "safety zone." Non-

verbal cues with avatars are almost impossible to obtain (aside from user-generated emoticons). Time can be a considerable barrier, as creating content, designing, validating, and executing educational activities requires time to address issues such as intellectual property rights, object permissions and accessibility [25]. Although SL is free for learners, with basic accounts, the overheads of designing, implementing, practicing, and maintaining virtual sites in SL often require educators to develop multiple skills to address.

Universities in Second Life

The pedagogical possibilities of virtual worlds have motivated educators, so that colleges and universities around the world have led the initiative to develop campuses in SL. The early years of SL were very active in terms of education-related activities, with enthusiastic development (partly because educational institutions could get a 50 percent reduction in the cost of virtual land). As of early 2007, 98 colleges and universities around the world had a presence in SL, a number that increased to 250 in 2009 [17]. In 2010 SL listed 78 universities as members [32], and more than 150 academic organizations were included in the SL Education Directory by 2013 [55]. At the time of writing this manuscript, a search inside SL using the term “university” returns 102, entries of places or destination guides, giving a clear idea about the increase in the use of this environment for teaching and learning projects. Among them it is worth highlighting the Rockclife University Consortium, (Figure 2) which was started in 2006 by Phelan Corrimal, with the goal of providing experiential educational opportunities in SL. In 2009, Rockclife had a virtual campus, widespread interaction with the non-profit SL community, participation from 40 to 50 real-world universities, and a peer-reviewed journal (Journal of Virtual Studies). Rockclife is the organizer of the Virtual World Best Practises in Education (VWBPE) conferences in SL (Figure 2), uninterruptedly 17 annual editions [56], having reached 4,000 attendees. Rockclife continues to actively pursue its mission of providing an environment for educational innovation, including affordability for students and teachers. Sufficient financial resources remain a problem. There are no paid staff, and the cost of books and magazines makes it difficult to run a fully configured library [17].

The Virtual Worlds Education Consortium (VWEC) launched a seven-region virtual educational campus called Eduverse in 2022 (Figure 2), comprising a group of virtual places focused on education in SL [57]. The other regions that are part of this project include include The Science Circle, Virtech, the Community Virtual Library’s Cookie region, Mayo Clinic, Whole Brain Health’s Inspiration Island region, and University of New Mexico at Rockliffe’s Rockliffe Village region. Since then, the consortium has held several weekly meetings, non-stop on the shared campus with the goal of helping groups already in SL increase collaboration and resource sharing. The VWEC’s purpose is to bring educators in virtual worlds together, both to share what has been successful and to tackle obstacles across different platforms and communities [58].

Educational possibilities

The SL platform is an online tool with advantages over other Two-dimensional (2D) tools, which allows for synchronous learning experiences, connecting teacher and student in very diverse formats with varied environments, with the only limit being the imagination.

Synchronous teaching in virtual worlds provides an alternative with respect to teaching in 2D environments, used very frequently during the covid-19 pandemic that has produced certain “fatigue” due to saturation in users [59].

Second Life allows interesting simulation and gamification experiences that are impossible (or very expensive) to do in real life, with the added value of generating more dynamic contact, even more fun for Generation Z. There are various educational formats that can be carried out in the SL

environment, adjusting to various learning areas in science, technology, and humanities. These could be summarized in the following [25]: (1) self-paced tutorials; (2) displays and exhibits; (3) immersive exhibits; (4) role plays and simulations; (5) data visualizations and simulations; (6) historical recreations and re-enactments; (7) living and immersive archaeology; (8) machinima construction; (9) treasure hunts and quests; (9) language and cultural immersion; and (10) creative writing.

Medical education within Second Life

Learning activities in medical education

There are a wide range of health-related activities on SL, and a diverse group of users, including organization groups and individuals, which have been classified in an interesting survey by Beard et al [60]. Most of them are dedicated to patient education or awareness increase about health issues. Others are dedicated to illness specific patients or peer support; marketing and promotion of health services or conducting health research in both SL and real world. There are also training sites, sometime linked to schools, offering academic training by means of classrooms, discussions, lectures, simulation and patient interaction. This review focuses especially on medical education experiences, during undergraduate, residency, and Continuing Medical Education (CME).

In fact, professional and academic education in health care contains the largest number of papers in a systematic literature review about the use of 3D virtual worlds [61]. Different learning methodologies have been adopted, dedicated to varied groups of health learners. Some of them, developing immersive and realistic virtual patients' or simulation scenarios within SL, training paramedic students in emergencies [62], the management of specific clinical situations by nurses [63], or the practice communication and assessment skills by mental health nursing students [64]. Others, holding training workshops and clinical sessions [46] or interactive seminars [45] in SL for postgraduate primary care physicians, or using SL virtual environment for mock oral examination for emergency medicine residents [65]. Academic experiences dedicated to medical students performed in SL, for example, creating a virtual laboratory for online anatomical education [66], or evaluating the use of team-based learning of anatomy [67]. Second Life also is useful for conducting online radiology training activities with remote access, in an attractive setting, especially for current generations of medical students and residents [33]. Typical classroom activities, such as courses, seminars and lectures, can be transferred to SL, taking advantage of the feeling of "being there", but active learning methods, more attractive to the student, can also be included, such as gamification, problem-based learning (PBL) or medical simulation. The development and characteristics of some of these activities in SL are developed below.

Courses, seminars, and conferences.

The structure of SL allows synchronous meetings of teachers and students to carry out lectures, courses or other typical classroom work formats. These activities can be carried out in very varied scenarios, recreating a classroom, a conference room, an open stage by the sea, a floating platform in the sky, infinite possibilities and the only limit of imagination and time to recreate these scenarios (figure 3).

Second Life has remarkable potential for effective teaching and learning, offering immersive, realistic, and engaging synchronous online events. The learning results of a synchronous educational event in SL, such as an X-ray interpretation workshop, do not show differences with those obtained in the real world if the same contents and script are maintained [68].

In addition, the persistence of the system (open 24/7) allows the inclusion of asynchronous activities

to be solved during a course, at the students' own pace. This combination of synchronous sessions with asynchronous tasks is very interesting and useful to organize an online course in SL. In a pilot study with 46 medical students (20 in the first cycle and 26 in the second cycle) carried out at the University of Malaga, the students found an extracurricular 4-week course on Radiology appropriate, interesting, and attractive, stating that they were willing to participate in future experiences in SL [69]. The combination of synchronous sessions and asynchronous tasks to complete a course in SL is very well received by medical students, and also by graduated doctors, who perceive the usefulness of this platform in continuing medical education, adapting to their work schedules and minimizing travel costs [70,71].

The Teacher´s perspective

Remote access makes it possible to invite speakers or scholarship holders from different institutions, opening new interesting and enriching avenues of educational contact between students and professors from different universities, with the advantages of reducing costs and travel times. From the perspective of the guest teachers, it represents a training experience for trainers, which allows them to learn about and compare a new online infrastructure with interesting synchronous teaching capabilities (time, accessibility, ubiquity, synchrony, facilities, sound, three-dimensionality) [72]. The perceptions of 14 medical teachers, after a 3-hour workshop, taught in SL, which gave them a first contact with the platform and its educational possibilities, were very positive, they considered it interesting and useful for teaching, and 71% responded positively to the possibility of carrying out a teaching activity in SL [73]. It is important to develop future actions in SL and other virtual worlds aimed at the training of trainers, to: (1) promote collaborative work between teachers; (2) familiarize teachers with the educational possibilities of virtual worlds and the basic applicable technology; (3) share teaching experiences carried out in SL to achieve new interdisciplinary collaborative projects; (4) use SL as a means of virtual meeting, meeting and discussion; and (5) promote the development of multidisciplinary and interuniversity collaborative educational projects.

Problem-based learning.

Problem-based learning (PBL), developed by Barrows at McMaster University in the 1960s [74], is a student-centered learning methodology in which students are faced with a problem situation that they must solve themselves by applying prior knowledge and incorporating new identified knowledge [75]. The teacher stops being the center of the educational experience and becomes a guide who facilitates and directs learning. In the medical education, this methodology contributes to acquiring skills such as real-world clinical reasoning, problem solving, and critical decision making [76]. In Medicine, these “problems” are usually generated in the form of clinical cases, creating a variant of PBL known as case-based learning [77]. Problem-Based Learning experiences have been carried out in SL with medical students, on paramedic emergencies [78], psychiatry [79] or nephrology [80]. The results showed that SL can provide a rich and attractive environment based on the authenticity of the scenarios and show the way towards the development of PBL sessions in 3D virtual worlds. The persistence of SL and the virtual contents allows students to meet in-world whenever and however they want to discuss the problems raised.

Communication skills

SL's communication features simulate real-world communication. For example, voice volume is louder or weaker as the avatar moves closer or further away from the speaker and is perceived from the right or left depending on where the speaker is located [59]. This brings great realism to the immersive experience and, therefore, SL is an ideal tool for developing transversal oral communication skills. Experiences have been described that demonstrate its usefulness in improving communication skills with patients [81]. Other experiences have shown that SL is an excellent tool for training in transversal communication skills, such as public oral presentation of a topic,

interaction with other users in real time and the establishment of links and social relationships between attendees, both in undergraduate [82] and postgraduate [83].

Meetings in SL allow for feedback from the audience, which, along with expert observation, are elements that help improve public presentation and communication skills [84]. Van Ginkel et al. [85] conducted a study with 36 first-year college students who completed a required oral presentation course in a virtual environment created with Unity (Unity Technologies, San Francisco, CA, USA). We agree with these authors that this type of virtual experience imitating real life helps to further develop oral presentation skills [82,83].

The presenter's voice is literally the instrument of connection with the attendees. When he/she gives a presentation, how the audience feels about his/her voice is integral to how they perceive the presentation [84]. The quality of audio in SL allows interaction, evaluation, and improvement of oral expression. Although on the one hand there is the disadvantage of not perceiving gestural communication, on the other hand the filter provided by the interface and the avatar in SL makes beginners feel less embarrassed when speaking in public [82] and express themselves more openly and honestly [17].

Assessment

Assessment is an essential element in the teaching-learning process. SL allows teachers to carry out various exam formats in-world efficiently. Notecards are a document that records the user who created it and what time it was delivered to the teacher's avatar. Using Notecards, deferred evaluations can be carried out, so that the student can solve the assigned questions in writing in an allotted time [69,70], or multiple-choice tests in real time, in the virtual classroom, with a short time assigned to each question [68].

The oral examination is a traditional method for assessing medical knowledge, clinical reasoning and interpersonal skills. Voice communication capabilities in SL also allow for oral exams. Schwaab et al. [65] conducted an interesting study in which 27 emergency medicine residents participated in a virtual oral exam in SL. All examinees felt comfortable communicating with the examiner, most thought the SL encounter was realistic (92.6%), and all felt the virtual exam was fair, objective, and conducted efficiently. The majority (66.6%) preferred to take oral exams using the SL rather than the traditional format and expressed interest in using the SL for other educational experiences (92.6%). McGrath et al. [86] carried out a similar experience with 35 residents, also from Emergency Medicine, randomized to SL and the real world. Examinees in both groups thought their evaluation was realistic, fair, objective, and efficient. Examiners in the virtual group reported a preference for the virtual format and felt that this format was less intimidating.

Simulation

Simulation is increasingly used in healthcare areas, especially in undergraduate education as a starting point for training medical professionals. Simulation-based learning experiences are useful for integrating theoretical knowledge with practice and the necessary practical skills [87,88,89]. Virtual simulation as an emerging interactive pedagogical strategy has been paid more and more attention in the undergraduate medical education. Clinical simulation environments have been developed in SL and other virtual worlds to train various skills, such as taking anamnesis to virtual patients [90], solving clinical situations in a pulmonology ward [91], training cardiopulmonary resuscitation [92] or communication skills with patients [93]. Danforth et al. [90] used SL as an immersive environment to develop a standardized virtual patient system and an Artificial Intelligence Markup Language as a dialogue engine. This first system was useful to demonstrate the viability of the approach, but the virtual environment and dialogue management at the time, 2009, were not ideal. To

manage conversations, they used more than 200,000 rules due to inefficiencies in markup language and AI syntax. For this reason, they redesigned the application using Unity 3D to create the virtual environments and implemented ChatScript to manage the dialogue [94]. Toro-Troconis-2011 et al. [91] at London Imperial College created a game-based SL simulation for medical students where they could interact with virtual pulmonology patients to develop their skills and confidence. The proposed architecture includes an availability model for patients' personal and clinical data, and an activity model to encode the available activities and student interaction with virtual patients.

Objective Clinical Structured Examination (OSCE)

The Objective Structured Clinical Examination (OSCE) is an examination format developed in different physical spaces (called clinical stations) where clinical scenarios and situations are reproduced, to evaluate the student's clinical skills in a standardized, reliable, and objective manner [95]. In recent decades, OSCE has seen marked growth in its use worldwide, at undergraduate and graduate levels [96].
The restrictions on contact and physical presence during the COVID-19 pandemic favored 2D virtual OSCEs with online access as a solution to these restrictions [97,98,99]. Virtual OSCEs have proven to be enjoyable, interactive and easy for students, as well as cost-effective [100]. Virtual world technologies such as SL make avatar-mediated 3D OSCE technically feasible to configure and execute. This has been verified in domestic accident scenarios in geriatric medicine [101], or in office or hospital settings [102], for example.

Second Life is a useful digital platform for carrying out OSCE tests, both summative and formative, as it makes it possible to design and recreate various scenarios to train decision-making in clinical cases [80]. Recently, a virtual teaching experience on emergency radiology was carried out, in which sixth-year medical students had to solve emergency radiology cases in groups of 3-4 students in 7 virtual OSCE stations. The students showed great acceptance and interest in this system, valuing very positively the environment, the OSCE cases and the training usefulness of the experience [103]. The authors are currently working on the development of virtual radiology OSCES, in which students must complete 6 radiology stations, with several questions on radiological interpretation, clinical judgment and patient management, that students must respond synchronously, in writing, having 9 minutes per station, imitating the organization of the in-person OSCE at the end of the degree (Figure 4). More than 500 students from various centers are expected to have taken this virtual radiology OSCE by May 2024 (Perez-Baena et al., unpublished data). It would be interesting to develop and implement radiological OSCEs in virtual environments such as SL, at the undergraduate, residency, and CME levels, as it would allow the optimization of resources and the performance of multicenter studies [104].

Gamification

Gamification applies elements of playful design to non-playful contexts, such as learning, for example [105,106]. Gamification can be carried out in the classroom and other real-life environments, but also through online formats that facilitate remote access and user management, including the metaverse [107]. SL is a platform that provides experiences that are a game in themselves. The users enter an imaginary world, more or less fantastic, in which they move and interact represented by avatars whose appearance they can modify to their liking. Gamification in SL has interesting applications in medical education. Toro-Troconis developed in her doctoral thesis an interesting study on gamification with virtual patients in SL [100]. The results of this thesis showed that the repetitive linear narrative of the cases did not motivate students enough, so more complex branching narratives should be implemented; that medical students are receptive to the use of virtual patients as long as it does not reduce the number of real patients in their clinical training; and that men and women show similar attitudes towards using gamification with virtual patients.

In 2015, a competitive online game in SL, called League of Rays (LOR) [108], was designed for medical students from a single university to learn radiology. Its educational objective is to provide a gamified complement to the formal teaching of radiological anatomy and radiological semiology. It is a game that lasts 6 weeks, developed on an island where 5-meters panels with educational content appear each week, and are replaced by multi-choice tests and other tasks, to earn points. The first three editions were individual competitions between third-year medical students. The first year was carried out voluntarily [108] and the participants obtained better academic results than non-participants. The following two years, participation was mandatory [109], demonstrating slightly lower perception and adherence to the game than when participation was voluntary. Subsequently, the rules were modified to participate in teams of four students, encouraging teamwork and collaboration [110], and finally, two editions of interuniversity competition were held [111] in which the reproducibility of the experience was demonstrated, ruling out proximity biases, promoting personal stimulation of students and collaborative action between teachers. Participants found team gaming useful for maintaining virtual relationships and identified this activity as a playful learning and social interaction experience during the COVID-19 pandemic [112]. This experience, maintained for eight consecutive years, with more than one thousand three hundred students having completed the game, demonstrates the usability of SL for learning games, and the possibilities of collaborative work between students while carrying out this activity. A game similar to LOR designed for Radiology residents, called "Resident Debil", is currently being started in SL.

Health related locations in Second Life

Realizing the potential of SL to connect with different generations and promote public health initiatives, several relevant institutions have explored how to leverage this 3D environment to improve healthcare. Some of the locations of these institutions are not currently active. For example, the "Isla de la Salud" hosted interesting educational experiences with family doctors [46], it even hosted, in parallel to real life, national congresses of the Spanish Society of Family and Community Medicine between 2008 and 2010, but unfortunately, it no longer exists today. Professors at Ohio University developed a nutrition game where people could learn about the impact fast food has on health [43]. Second Life offers virtual clinics to help students practice different types of skills, as well as study Spaces for those interested in genetics, where students can learn about things like DNA [43]. The University of London created a virtual hospital in SL where students can see real patients, order x-rays, record diagnoses and consult with colleagues and other students. The hospital included operating rooms where, for example, some posters show the student the steps to prepare for surgery (such as dressing, wearing a mask, and disinfecting the student after the virtual procedure). So, the student can enter the operating room, see all the equipment there is and read the explanations about it. Other parts of the hospital have also been built in practically the same way [90,112].

There are other health related virtual places that are currently active (Figure 5). The Mayo Clinic island in SL [113] includes conference facilities and a bookstore. The nonprofit medical practice regularly hosts talks and events on illnesses and diseases for interested residents. The University of South Florida [114] College of Medicine headquarters includes information about the various schools and departments, including nursing, public health, continuing education, and the Shimberg Library. Brodmann's Brain at Inspiration Bay [115] allows the visitor to walk through a giant interactive construction that displays functional areas of the human brain. Brain regions activate (brighten) based on functions, such as dancing and love. Developed by a team of virtual creators and neuroscientists. The Malaga Medical School island [116] was created in 2021 to host permanent medical education content. Around its central plaza there are a virtual hospital, a library and an auditorium. The island is also designed to host multidisciplinary OSCEs for undergraduate and graduate students.

Educational experiences in different medical disciplines

Anatomy

Interesting experiences have been carried out for teaching anatomy in SL. Morales Vadillo et al [117] use SL vs a control group to learn oral anatomy, to compare the effectiveness of using SL to the traditional teaching methods. Students who used SL scored significantly higher in questions designed to test the spatial interpretation of the anatomical structure. Gazave and Hatcher [67] implemented Virtual Team-Based Learning (TBL) in an online anatomy course held in SL with 39 medical students. They demonstrated that virtual TBL was engaging for the majority of students, who exhibited high levels of cognitive engagement. This evidence made it clear that this virtual teamwork strategy could be implemented in other courses on other subjects.

Other authors have created anatomical models so that students could evaluate them from the view of their avatar. Danforth [118] made a virtual testis model not only to explore the anatomy, but also to examine the relationships between anatomy and physiology to describe sperm production function. Richardson-Hatcher et al [119] built a 3D replica of the Pterygopalatine Fossa in SL, including the relevant divisions of the trigeminal nerve that pass through it. The SL virtual tour was used so that students could virtually experience the organization of the Pterygopalatine Fossa, maneuvering in and out of its boundaries, and following the course of the nerves through the fossa. The study data suggests that students view this new technology as a valid method for studying anatomical arrangements by improving their understanding. The same group of authors, from the University of Kentucky College of Medicine, built a multipurpose virtual anatomy laboratory in SL [66] with a series of stations with: (1) atlas/cadaver images, (2) a tour of cross-sectional anatomy, (3) cadaveric anatomy video tutorials, and (4) group quizzes. The information and questions for each station were sent via notecard to the student's inventory by clicking on the station header. To simulate a professional environment, participating students were informed about the rules of the anatomy laboratory, including the use of a lab coat and the respect due to cadavers.

Family Medicine

Perhaps one of the articles with the most impact on the use of SL in medical education is that of Wiecha et al. [45]. The authors designed a pilot postgraduate medical education program in the virtual world in which 14 primary care physicians participated. It was a one-hour interactive session in SL on the topic of type 2 diabetes. All participants agreed that this experience in SL was an effective method of medical education, that the virtual world approach to CME was superior to other online CME methods and that they would register for another similar event in SL. Lorenzo-Álvarez et al. [70] conducted a radiology course for primary care physicians on interpretation of plain radiographs. Participating physicians reached similar conclusions, found SL to be an interesting and useful online tool for CME, and were willing to participate in new educational events about SL. Melús-Palazón et al. [46] carried out a series of accredited virtual clinical sessions in SL in which 76 primary care professionals from 9 health centers participated. They concluded that SL is a tool that allows the design of educational activities that involve several health centers in different geographical locations, thus eliminating the need for travel and making more effective use of educational resources.

Psychiatry

There are some interesting experiences of medical education in psychiatry held in SL. In 2006, an inpatient psychiatric unit was built in SL in an experience recreating divers hallucinations, that allowed any SL user to participate. This was finally done by 579 users who were able to virtually experience hallucinations, and resulted in most of them having a better understanding of visual and

auditory hallucinations [120]. The authors concluded that computer simulations of the perceptual phenomena of psychiatric illnesses are feasible with the personal computer technology existing at the time. Rampling et al. [79] used SL to create a simulated patient with psychosis, medical students were asked to complete a clinical training session and provide feedback. Only 24 students participated. The consensus was that the scenario was cumbersome, did not imitate real life, and had little educational value. Interactive technology has a role in psychiatric education, but the authors do not consider it advisable to use scenarios that rely predominantly on verbal communication within SL. Finally, they propose exploring other interactive teaching methods in psychiatry, such as interactive online PBL, which may be more suitable for the topic.

Radiology

The use of e-learning and online resources to deliver radiology teaching to medical students represents an exciting alternative and an effective method to improve radiological knowledge and skills [121,122]. Second Life allows radiology teachers to carry out educational activities about radiology. Medical images can be displayed in-world with sufficient quality to interpret the findings they present, providing image support for these educational events [33]. In 2011, the group from the University of Malaga created a virtual space, called “Medical Master's Island” [123] in which diverse radiology teaching activities have been carried out uninterruptedly. More than 3,700 learners, undergraduate and graduate, have participated in these activities until February 2024. The most recent experiences are still pending publication.

After a first pilot study carried out in 2011, with 46 medical students [69], radiological interpretation courses were held in 2012 and 2013 in which 48 third-year students participated [70]. Both experiences made it possible to specify the feasibility of teaching radiology in SL and demonstrated that the students had a great value of SL as an educational platform, recognizing the effort made by the teachers to provide them with this opportunity. In 2014, a randomized study was carried out with 156 third-year students [68]. An abdominal radiology seminar was taught in SL and a control group received the same seminar in the classroom in-person. No significant differences were found between both groups in the pre- and post-exposure tests, concluding that radiology education in SL fosters participatory learning and results in similar acquisition of interpretive skills as a traditional face-to-face classroom. Between 2019 and 2022, X-ray interpretation courses were held for 96 Family Medicine residents and 67 Radiology residents from all over Spain [71].

Between 2015 and 2022, the multi-user game LOR was carried out in consecutive annual editions, designed to learn anatomy and radiological semiology, previously described in the gamification subchapter. It started as an experience at a single university [108,109,110], continuing as an interuniversity competition [111] in which, for three years, 129 teams of four students from 20 different universities participated. These experiences show the applicability of remote access to asynchronous gamification, thanks to the persistence of the platform. Additionally, universities and medical schools can provide a sense of belonging to team members, an important factor in creating work dynamics, and a motivating element in the learning competition. Recently, in 2021 and 2023, synchronous gamification experiences have been carried out in SL, playing games such as Trivial and The Alphabetic to learn radiology [124].

During these thirteen years, PBL experiences in radiology have also been carried out with medical students, and other activities based on the training of communication and public speaking skills on radiology topics with undergraduate and graduate students. Currently, the activity of this group from the University of Malaga is focused on medical simulation and carrying out virtual OSCEs in SL. Additionally, the aim is to establish institutional alliances to promote the culture of virtual worlds between teachers and students.

Impact of the Covid-19 pandemic on medical education in Second Life

The COVID-19 pandemic accelerated the application of new technologies in learning [125], caused stress in medical students [126], and reduced doctor-student contact [127]. Two-dimensional platforms such as Zoom (Zoom Video Communications, San Jose, CA, USA), Google Meet (Google, Mountain View, CA, USA), Facebook Live (Meta for Media, Menlo Park, CA, USA). USA). USA), Skype (Skype; Microsoft, Redmond, WA, USA), or Microsoft Teams (Microsoft Corporation, Redmond, WA, USA), which allow educational experiences with synchronous communication between the teacher and the public in a two-dimensional environment [128,129,130], have had great technological development since the COVID-19 pandemic [128,131,132]. One might ask, if these 2D remote connection methods already exist, why are 3D environments needed? On the one hand, 3D environments like SL have some advantages over synchronous 2D communication platforms [25,133], since: (1) they are a 24/7 persistent environment; (2) they allow immediate, real-time interactions between users and objects in the 3D environment; (3) they induce a strong feeling of presence (sense of “being there”) in users; (4) they promote social awareness or the ability to sense the presence and location of participants in a learning environment, reinforcing the perception of “who is there” and “what is happening”; and (5) they generate a greater sense of belonging to a community. On the other hand, there is a phenomenon of fatigue from 2D videoconferencing, which has been called "Zoom fatigue", triggered by the intensive use of videoconferencing since the COVID-19 pandemic, for which 3D environments appear as an alternative of change of scenery [59].

The need to continue the teaching-learning process in the pandemic scenario, and the limitations of 2D virtual modalities, in which it is difficult to carry out experiential learning, led to the development of learning scenarios through the metaverse and the virtual worlds [134]. Thanks to having resources in SL such as classrooms, teaching buildings, etc., previously organized, when confinement was declared, the scheduled Radiology teaching of 220 real-life medical students could be quickly transferred to SL [135]. More than 90% felt more committed to teaching thanks to the seminars in SL, they stated that they found the virtual platform to be an attractive and fun environment, and that if they returned to a situation of confinement, they would like to carry out similar learning activities [135]. Furthermore, participants in an inter-university competition to learn radiology held in SL during confinement found the team game useful to maintain virtual relationships and identified this activity as a playful experience of learning and social interaction during the COVID-19 pandemic [111].

The future

The Metaverse is alive and so is SL. Constant technical improvements are sought. Virtual world data is no longer housed in large server rooms but is hosted in the Amazon cloud. Linden Lab is a more decentralized company, based on the remote work of its employees. The company is slowly rolling out its "Puppetry Project," a new feature that allows the user to capture their real movements and facial expressions via a webcam and other motion capture devices, and then display them on their avatar in real time [2].

The contributions of the community of creators also offer technological changes for the immediate future. For example, viewers with more capabilities continue to be developed. The SL viewer and the third-party Firestorm viewer are usually updated to a new version several times a year. Crystal Frost, a new external SL viewer running on Unity, is in development. Designed by Berry Bunny, a SL community creator, it is in its beta phase, currently a downloadable virtual world viewer for Windows like Firestorm, but will also be available on Linux and Mac and on mobile devices [136].

Generative AI can bring exciting possibilities to medical education in SL, for example AI-powered

chatbots. This would allow for more immersive human/computer interface loops, from conversations with patients or virtual therapists to interactions of very diverse types. Since there is user input, AI could be used to train highly customizable responses or generate unique stories per use [2].

In conclusion

After 25 years of its conception, SL has proven to be a virtual platform that connects with the concept of metaverse, an open system, with global access, interconnected where all humans can access to socialize or share products, for free or using a virtual currency. Second Life continues to be successful as a virtual world model that connects with the concept of an equitable, diverse and creative Metaverse. Its creativity tools are open and powerful, its user community is diverse, and is made up of members free to create endless values and possibilities.

Second Life remains active and technologically improved since its creation. Future improvements are also expected, such as the creation of viewers for IOs and Android that will allow it to be used on mobile devices, or the incorporation of generative AI, which will provide more enriching and non-repetitive experiences.

From an educational point of view, SL has the advantages of being persistent 24/7, and creating in the student the important feeling of "being there" and co-presence. This, together with the reproduction of the 3D world, real-time interaction and the quality of voice communication, make the immersive experiences unique, generating engagement and a fluid interrelation of students with each other and with their teachers. Various groups of researchers in medical education have developed experiences during these years, which have shown that courses, seminars, workshops and conferences, PBL experiences, evaluations, teamwork, gamification, medical simulation and virtual OSCEs can be successfully carried out. Acceptance from students and faculty is generally positive, recognizing its usefulness for undergraduate medical education and CME.

These 25 years have made SL a platform where different generations coexist. The past COVID-19 pandemic gave it unique value in education, demonstrating its usefulness as a remote access educational tool. It is necessary to continue carrying out educational experiences, outlining the organization, objectives and content, measuring the real educational impact, in order to make SL a tool of more universal use.

Acknowledgements

This work was partially supported by the educational innovation project of the University of Malaga PIE22-045. Funding for open access charge: Universidad de Málaga / CBUA.

Conflicts of Interest

None declared.

Abbreviations

2D: Two-dimensional
3D: Three-dimensional
AR: Augmented Reality
CME: Continuing Medical Education
COVID-19: Coronavirus Disease-19
LD: Linden Dollar
LOR: League of Rays
MMORPG: Massively Multiplayer Online Role Playing Games

MR: Mixed Reality
OSCE: Objective Structured Clinical Examination
PBL: Problem-Based Learning
SL: Second Life
VR: Virtual Reality
VWBP: Virtual World Best Practices
VWEC: Virtual World Education Consortium
XR: Extended Reality

References

1. Stephenson N. Snow crash. Bantam Book. New York, USA: Bantam Book, 1992. ISBN:9780553088533
2. Au JW. Making a Metaverse that matters from Snow Crash & Second Life to a virtual world worth fighting for. Hoboken, NJ: Willey & son Inc.; 2023. ISBN: 9781394155811
3. Mystakidis S. Metaverse. Encyclopedia. 2022;2(1):486–497. doi:10.3390/encyclopedia2010031
4. Rospigliosi P. Adopting the metaverse for learning environments means more use of deep learning artificial intelligence: this presents challenges and problems. Interact Learn Environ. 2022;30(9), 1573–1576. doi:10.1080/10494820.2022.2132034
5. Wider W, Jiang L, Lin J, Fauzi MA, Li J, Chan CK. Metaverse Chronicles: A bibliometric analysis of its evolving landscape. Int J Hum-Comput Interact. 2023 Jun 27. Forthcoming. doi:10.1080/10447318.2023 . 2227825
6. Park SM, KimYG. A Metaverse: Taxonomy, components, applications, and open challenges. IEEE Access. 2022;10, 4209–4251. doi:10.1109/ACCESS.2021.3140175
7. Jovanovi´c A, Milosavljevi´c A. VoRtex metaverse platform for gamified collaborative learning. Electronics. 2022;11(3):317. doi:10.3390/electronics11030317
8. Chen Z. Exploring the application scenarios and issues facing Metaverse technology in education. Interactive Learn Environ. 2022 16 Oct. doi:10.1080/10494820.2022.2133148
9. Collins C. Looking to the future: Higher education in the metaverse. EDUCAUSE Rev. 2008; 43(5):51–63.
10. Hwang GJ, Chien SY. Definition, roles, and potential research issues of the Metaverse in education: An artificial intelligence perspective. Comput Educ Artif Intell. 2022;3:100082. doi:10.1016/j.caeai.2022.100082
11. Schroeder R. Defining virtual worlds and virtual environments. J Virtual World Res. 2008;1(1), 1–3. doi:10.4101/jvwr.v1i1.294
12. Czepielewski S, Christodoulopoulou C, Kleiner J, Mirinaviciute W, Valencia E. Virtual 3D Tools in Online Language Learning. In Czepielewski S, editor. Learning a Language in Virtual Worlds: A Review of Innovation and ICT in Language Teaching Methodology. V-lang international conference, Warsaw: Warsaw Academy of Computer Science, Management and Administration; 2011. p. 7-14. ISBN:9788388910364.
13. Hassouneh D, Brengman M. A motivation-based typology of social virtual world users. Comput Human Behav 2014 Apr;33: 330-338. doi:10.1016/j.chb.2013.08.012
14. Bell MW. Toward a definition of “virtual worlds”. J Virtual Worlds Res. 2008;1(1);1–5. doi:10.4101/jvwr.v1i1.283
15. Mahaley S, Teigland R. Advancing learning through virtual worlds. In Murugesan S, editor. Handbook of research on Web 2.0, 3.0, and x.0: technologies, business, and social applications. Information Science Reference, Hershey; 2010. p. 556-572. ISBN:9781605663852.
16. Zhang P, Ma X, Pan Z, Li X Xie K. Multi-agent cooperative reinforcement learningin 3D

virtual world. In Tan Y, Shi Y, Tan KC, editors. Advances in swarm intelligence. First international conference, ICSI 2010, Part I, LNCS 6145. Springer-Verlag, Berlin; 2010. p. 731-739. ISBN:9783642134944.
17. Johnson ML. Social Virtual Worlds and Their Places. Singapore: Palgrave Macmillan; 2022. ISBN:9789811686269
18. Messinger PR, Stroulia E, Lyons K. A typology of virtual worlds: Historical overview and future directions. J Virtual World Res. 2008;1(1):1–18. doi:10.4101/jvwr.v1i1.291
19. Girvan C. What is a virtual world? Definition and classification. Educ Technol Res Develop. 2018.66(5):1087–1100. doi:10.1007/s11423-018-9577-y
20. Good J, Howland K, Thackray L. Problem-based learning spanning real and virtual words: a case study in Second Life. ALT-J: Res Learn Techol. 2008 Sep;16(3): 163–172. doi:10.1080/09687760802526681
21. Jamaludin A, Chee YS, Ho CML. Fostering argumentative knowledge construction through enactive role play in Second Life. Comput Educ. 2009;53(2):317-329. doi:10.1016/j.compedu.2009.02.009
22. Girvan C, Savage T. Identifying an appropriate pedagogy for virtual worlds: A Communal Constructivism case study. Comput Educ 2010, 55(1):342-349. doi:10.1016/j.compedu.2010.01.020
23. Douglas R. 20 years on: Second Life, the fashion-forward metaverse that keeps on giving. Fashionunited.uk. July 28, 2023. https://fashionunited.uk/news/business/20-years-on-second-life-the-fashion-forward-metaverse-that-keeps-on-giving/2023072870819 [accessed Mar 24, 2024]
24. Galov N. 18 Second Life Facts in 2023: What It Means to Live in a Virtual World. Webtribunal.net. Mar 6, 2023. https://webtribunal.net/blog/second-life-facts#gref [accessed Mar 24, 2024]
25. Warburton S. Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. Br J Educ Techol. 2009;40(3), 414-426. doi:10.1111/j.1467-8535.2009.00952.x
26. Savin-Baden M. A Practical Guide to using Second Life in Higher Education. Maidenhead, Berkshire, UK: McGraw-Hill Open University Press. 2010. ISBN: 9780335242146
27. Ernstberger P. Linden Dollar and Virtual Monetary Policy. SSRN. 2009 Jan 23. doi:10.2139/ssrn.1339895
28. Rymaszewski M, Au WJ, Wallace M, Winters C, Ondrejka C, Batstone Cunningham B. Second Life®: the official guide. Indianapolis, Wiley Publishing Inc; 2007. ISBN:9780470096086
29. Linden Lab Inc. Second Life main Webpage (URL). http://www.secondlife.com [accessed Mar 24, 2024]
30. Linden Lab Inc. Second life viewer download. 2024. http://secondlife.com/support/downloads/ [accessed Mar 24, 2024]
31. Linden Research Inc. Second Life third party viewer directory. 4 January 2024. http://wiki.secondlife.com/wiki/Third_Party_Viewer_Directory [accessed Mar 24, 2024]
32. Ahem N, Wink DM. Virtual learning environments: second life. Nurse Educ. 2010 Nov-Dec;35(6):225-227. doi:10.1097/NNE.0b013e3181f7e943
33. Lorenzo Álvarez R, Pavía Molina J, Sendra Portero F. Possibilities of the three-dimensional virtual environment tridimensional Second Life® for training in radiology. Radiologia. 2018 Jul-Aug;60(4):273-279. doi:10.1016/j.rx.2018.02.006
34. Matienzo R. Evolución de la teoría del aprendizaje significativo y su aplicación en la educación superior. Dialektika: Revista De Investigación Filosófica Y Teoría Social 2020 2(3), 17-26. https://journal.dialektika.org/ojs/index.php/logos/article/view/15 [Accessed Mar 27, 2024]

35. Williamson KB, Gunderman RB, Cohen MD, Frank, MS. Learning theory in radiology education. Radiology. 2004;233(1):15-18. doi:10.1148/radiol.2331040198.
36. Minocha S, Hardy C. Navigation and wayfinding in learning spaces in 3D virtual worlds. In Sue G, Lee MJW, Dalgarno B, Tynan B editors. Learning in virtual worlds: research and applications. Edmonton, AB: AU Press, Athabasca University. 2016 pp:3-41. ISBN: 9781771991339 doi:10.15215/aupress/9781771991339.01
37. Charles D, Charles T, McNeill M, Bustard D, Black M. Game-based feedback for educational multi-user virtual environments. Br J Educ Technol. 2011;42(4):638-654. doi: 10.1111/j.1467-8535.2010.01068.x.
38. Paas F, Tuovinen J, Tabbers H, van Gerven PW. Cognitive load measurement as a means to advance cognitive load theory. Educ Psychol. 2003;38(1):63-71. doi:10.1207/S15326985EP3801_8.
39. Hessler KL, Henderson AM. Interactive learning research: Application of cognitive load theory to nursing education. Int J Nurs Educ Scholar. 2013;10(1):133-141. doi:10.1515/ijnes-2012-0029.
40. Sweller J. Cognitive load theory, learning difficulty, and instructional design. Learn Instruct. 1994;4(4), 295-312. doi:10.1016/0959-4752(94)90003-5.
41. Van Nuland SE, Rogers KA. E-learning, dual-task, and cognitive load: The anatomy of a failed experiment. Anat Sci Educ. 2016;9(2):186-196. doi:10.1002/ase.1576.
42. Sweller J. Element interactivity and intrinsic, extraneous, and germane cognitive load. Educ Psychol Rev. 2010;22:123-138. doi:10.1007/s10648-010-9128-5.
43. Boulos MN, Hetherington L, Wheeler S: Second life: an overview of the potential of 3-D virtual worlds in medical and health education. Health Info Libr J 2007 Dec;24(4):233-245. PMID:18005298
44. Hansen MM, Murray PJ, Erdley WS. The potential of 3-D virtual worlds in professional nursing education. Stud Health Technol Inform 2009;146:582-586. PMID:19592909 doi:10.3233/978-1-60750-024-7-582
45. Wiecha J, Heyden R, Sternthal E, Merialdi M: Learning in a virtual world: experience with using second life for medical education. J Med Internet Res. 2010 Jan 23;12(1):e1. PMID: 20097652 doi:10.2196/jmir.1337
46. Melus-Palazon E, Bartolome-Moreno C, Palacin-Arbues JC, Lafuente-Lafuente A, Garcia IG, Guillen S, Esteban AB, Clemente S, Marco AM, Gargallo PM, Lopez C, Magallon-Botaya R. Experience with using second life for medical education in a family and community medicine education unit. BMC Med Educ 2012 May 15;12:30. PMID:22587562
47. Miller M, Jensen R: Avatars in nursing: an integrative review. Nurse Educ 2014; 39(1):38–41. PMID:24300258 doi:10.1097/01.nne.0000437367.03842.63
48. Baker SC, Wentz R K, Woods MM. Using virtual worlds in education: Second Life® as an educational tool. Teach Psychol. 2009;36(1):59-64. doi:10.1080/00986280802529079
49. Inman C, Wright VH, Hartman JA. Use of Second Life in K-12 and Higher Education: A Review of Research. J Interact Online Learn. 2010;9(1):44-63. https://www.ncolr.org/jiol/issues/pdf/9.1.3.pdf [accessed 27 Mar, 2024]
50. Potkonjak V, Gardner M, Callaghan V, Mattila P, Guetl C, Petrović VM, Jovanović K. Virtual laboratories for education in science, technology, and engineering: A review. Comput Educ. 2016;95:309-327. doi:10.1016/j.compedu.2016.02.002
51. Gong W. Education and three-dimensional virtual worlds: A critical review and analysis of applying second life in higher education. Master dissertation. University of British Columbia; 2018. https://open.library.ubc.ca/media/download/pdf/42591/1.0371092/4 [accessed 27 Mar, 2024]
52. Liaw SY, Carpio GA, Lau Y, Tan SC, Lim WS, Goh PS. Multiuser virtual worlds in healthcare education: A systematic review. Nurse Educ Today. 2018;65:136–149.

doi:10.1016/joined.2018.01.006.
53. Zhang F, Luo H. Visual Analysis of Virtual World Research in Education from 2013 to 2022. 2023 5th International Conference on Computer Science and Technologies in Education (CSTE), Xi'an, China, 2023, pp. 202-207. doi:10.1109/CSTE59648.2023.00042.
54. Linden Lab Inc. Second Life System requirements. 2024. https://secondlife.com/support/system-requirements [accessed Mar 24, 2024]
55. Linden Research Inc. Second Life Education Directory. Academic organizations in Second Life. 6 February 2013. https://wiki.secondlife.com/wiki/Second_Life_Education_Directory [accessed Mar 24, 2024]
56. VWBPE. Virtual World Best Practises in Education. 2024. https://www.vwbpe.org/ [Accessed Mar 28, 2024]
57. Kariuki D. Eduverse to launch in Second Life this weekend. 2022 May 20. https://www.hypergridbusiness.com/2022/05/eduverse-to-launch-in-second-life-this-weekend/ [Accessed Mar 28, 2024]
58. VWEC. Virtual World Education Consortium. 2024. https://www.vweconsortium.org/ [Accessed Mar 28, 2024]
59. Speidel R, Felder E, Schneider A, Öchsner W. Virtual reality against Zoom fatigue? A field study on the teaching and learning experience in interactive video and VR conferencing GMS J Med Educ. 2023;40(2):19. doi:10.3205%2Fzma001601
60. Beard L, Wilson K, Morra D, Keelan J. A survey of health-related activities on second life. J Med Internet Res 2009 May 22;11(2):e17. PMID:19632971 doi:10.2196/jmir.1192
61. Ghanbarzadeh R, Ghapanchi AH, Blumenstein M, Talaei-Khoei A. A decade of research on the use of three-dimensional virtual worlds in health care: a systematic literature review. J Med Internet Res 2014 Feb 18;16(2):e47. PMID:24550130 doi:10.2196%2Fjmir.3097
62. Conradi E, Kavia S, Burden D, Rice A, Woodham L, Beaumont C, Savin-Baden M, Poulton T. Virtual patients in a virtual world: Training paramedic students for practice. Med Teach 2009 Aug;31(8):713-720. PMID:19811207. doi:10.1080/01421590903134160
63. Patel V, Lee H, Taylor D, Aggarwal R, Kinross J, Darzi A. Virtual worlds are an innovative tool for medical device training in a simulated environment. Stud Health Technol Inform. 2012;173:338-343. PMID: 22357014
64. Kidd LI, Knisley SJ, Morgan KI. Effectiveness of a second life(®) simulation as a teaching strategy for undergraduate mental health nursing students. J Psychosoc Nurs Ment Health Serv. 2012 Jul;50(7):28-37. PMID:22694785 doi:10.3928/02793695-20120605-04
65. Schwaab J, Kman N, Nagel R, Bahner D, Martin DR, Khandelwal S, Vozenilek J, Danforth DR, Nelson R. Using second life virtual simulation environment for mock oral emergency medicine examination. Acad Emerg Med. 2011 May;18(5):559-562. PMID: 21521404 doi:10.1111/j.1553-2712.2011.01064.x
66. Richardson A, Hazzard M, Challman SD, Morgenstein AM, Brueckner JK. A "Second Life" for gross anatomy: applications for multiuser virtual environments in teaching the anatomical sciences. Anat Sci Educ. 2011 Jan-Feb;4(1):39-43. PMID: 21265036 doi:10.1002/ase.195
67. Gazave CM, Hatcher ER. Evaluating the Use of Second Life™ for Virtual Team-Based Learning in an Online Undergraduate Anatomy Cours. Med Sci Educ 2017;27:217–227. doi:10.1007/s40670-017-0374-8
68. Lorenzo Álvarez R, Rudolphi Solero T, Ruiz Gomez MJ, Sendra Portero F. Medical student education for abdominal radiographs in a 3 D virtual classroom versus traditional classroom: A randomized controlled trial. AJR Am J Radiol 2019 Sep;213(3):644–650. doi:10.2214/AJR.19.21131
69. Lorenzo-Álvarez R, Pavía-Molina J, Sendra-Portero F. Exploring the potential of undergraduate Radiology education in the virtual world Second Life with first-cycle and

second-cycle medical students. Acad Radiol. 2018 Aug;25:1087–1096. doi:10.1016/j.acra.2018.02.026.
70. Lorenzo-Álvarez R, Ruiz-Gómez MJ, Sendra-Portero F. Medical students and family physician attitudes and perceptions toward radiology learning in the Second Life virtual world. AJR Am J Roentgenol 2019 Jun; 212(6):1295-1302. doi:10.2214/AJR.18.2038
71. Pino Postigo A, Domínguez Pinos D, Eduardo Ochando Pulido E, Navarro Sanchis E, Sendra Portero F. Un curso de radiografía simple para residentes de radiodiagnóstico en un entorno virtual inmersivo. 6º Congreso Nacional de la Sociedad Española de Radiología Médica SERAM. 26 de mayo de 2022. Málaga, España. https://piper.espacio-seram.com/index.php/seram/article/view/8398/6864 [Consultado el 29 de marzo de 2024]
72. Alonso-Martinez JM, Ravaei S, Rudolphi-Solero T, Sendra-Portero F. Radiology Seminars with Guest Professors in the Virtual Environment Second Life®: Perception of Learners and Teachers". Proceedings 2020; 54(1):16. doi:10.3390/proceedings2020054016
73. Rudolphi-Solero T; Jimenez-Zayas A, Sendra-Portero F. Introduction to Second Life® As a Virtual Training Environment: Perception of University Teachers. Proceedings 2020; 54(1):18. doi:10.3390/proceedings2020054018
74. Barrows H. Problem-Based learning in medicine and beyond: A brief overview. New Dir Teach Learn 1996; 1996:3–12. doi:10.1002/tl.37219966804
75. Bodagh N, Bloomfield J, Birch P, Ricketts W. Problem-based learning: a review. Br J Hosp Med (Lond) 2017; 78:C167–C170. doi:10.12968/hmed.2017.78.11.c167
76. Jones RW. Problem-based learning: description, advantages, disadvantages, scenarios and facilitation. Anaesth Intensive Care 2006; 34:485–488. doi:10.1177/0310057x0603400417
77. Carrasco GA, Behling KC, Lopez OJ. Evaluation of the role of incentive structure on student participation and performance in active learning strategies: A comparison of case-based and team-based learning. Med Teach 2018; 40:379–386. doi:10.1080/0142159x.2017.1408899
78. Beaumont C, Savin-Baden M, Conradi E, Poulton T. Evaluating a Second Life Problem-Based Learning (PBL) demonstrator project: what can we learn? Interact Learn Environ 2014; 22:125–141. doi:10.1080/10494820.2011.641681
79. Rampling J, O'Brien A, Hindhaugh K, Woodham L, Kavia S. Use of an online virtual environment in psychiatric problem-based learning. The Psychiatrist 2012; 36:391–396. doi:10.1192/pb.bp.111.037630
80. Jivram T, Kavia S, Poulton E, Hernandez AS, Woodham LA, Poulton T. The Development of a Virtual World Problem-Based Learning Tutorial and Comparison with Interactive Text-Based Tutorials. Front Digit Health 2021; 3:611813. doi:10.3389/fdgth.2021.611813
81. Mitchell S, Heyden R, Heyden N, Schroy P, Andrew S, Sadikova E, Wiecha J. A pilot Study of motivational interviewing training in a virtual world. J Med Internet Res. 2011Sep 26;13(3):e77. doi:10.2196/jmir.1825
82. Lozano-Durán A, Rudolphi-Solero T, Nava-Baro E, Ruiz-Gómez MJ, Sendra-Portero F. Training Scientific Communication Skills on Medical Imaging within the Virtual World Second Life: Perception of Biomedical Engineering Students. Int J Environ Res Public Health. 2023 Jan 17;20(3):1697. doi:10.3390/ijerph20031697
83. Pino-Postigo A, Domínguez-Pinos D, Lorenzo-Alvarez R, Pavía-Molina J, Ruiz-Gómez MJ, Sendra-Portero F. Improving Oral Presentation Skills for Radiology Residents through Clinical Session Meetings in the Virtual World Second Life. Int J Environ Res Public Health 2023;20:4738. doi:10.3390/ijerph20064738
84. Schraeder TL. Public Speaking and Presentation Skills. In Schraeder TL, editor. Physician Communication: Connecting with Patients, Peers, and the Public. Oxford, UK: Oxford University Press; 2019:113–166. ISBN:9780190882440
85. Van Ginkel S, Gulikers J, Biemans H, Noroozi O, Roozen M, Bos T, van Tilborg R, van

Halteren M, Mulder M. Fostering oral presentation competence through a virtual reality-based task for delivering feedback. Comput Educ. 2019;134, 78–97. doi:10.1016/j.compedu.2019.02.006
86. McGrath J, Kman N, Danforth D, Bahner DP, Khandelwal S, Martin DR, Nagel R, Verbeck N, Way DP, Nelson R. Virtual alternative to the oral examination for emergency medicine residents. West J Emerg Med. 2015 Mar;16(2):336-43. doi:10.5811/westjem.2015.1.24344
87. Nara N, Beppu M, Tohda S, Suzuki T. The introduction and effectiveness of simulation-based learning in medical education. Intern Med. 2009;48:1515–9. doi:10.2169/internalmedicine.48.2373
88. Koh J, Dubrowski A. Merging problem-based learning with simulation-based learning in the medical undergraduate curriculum: the PAIRED framework for enhancing lifelong learning. Cureus. 2016 8:e647. doi:10.7759/cureus.647
89. Theodoulou I, Nicolaides M, Athanasiou T, Papalois A, Sideris M. Simulation-based learning strategies to teach undergraduate students basic surgical skills: a systematic review. J Surg Educ. 2018; 75:1374–1388. doi:10.1016/j.jsurg.2018.01.013
90. Danforth DR, Procter M, Chen R, Johnson M, Heller R. Development of virtual patient simulations for medical education. J Virtual Worlds Res. 2009;2(2):1–11. doi:10.4101/jvwr.v2i2.707.
91. Toro-Troconis M. Game-Based Learning for Virtual Patients in Second Life®. Doctoral Thesis dissertation. Luleå University of Technology. 2011. https://www.diva-portal.org/smash/get/diva2:999020/FULLTEXT01.pdf [Accessed Mar 28, 2024]
92. Creutzfeldt J, Hedman L, Felländer-Tsai L. Cardiopulmonary resuscitation training by avatars: A qualitative study of medical students' experiences using a multiplayer virtual world. JMIR Serious Games. 2016;4:e22. doi:10.2196/games.6448.
93. Lee J, Kim H, Kim KH, Jung D, Jowsey T, Webster CS. Effective virtual patient simulators for medical communication training: A systematic review. Med Educ. 2020;54:786–795. doi:10.1111/medu.14152
94. Maicher K, Danforth D, Price A, Zimmerman L, Wilcox B, Liston B, Cronau H, Belknap L, Ledford C, Way D, Post D, Macerollo A, Rizer M. Developing a Conversational Virtual Standardized Patient to Enable Students to Practice History-Taking Skills. Simul Healthc. 2017 Apr;12(2):124-131. doi:10.1097/SIH.0000000000000195.
95. Staziaki PV, Sarangi R, Parikh U, Brooks JG, LeBedis CA, Shaffer K (2020) An objective structured clinical examination for medical student Radiology clerkships: Reproducibility study. JMIR Med Educ 6:6(1) DOI:10.2196/15444
96. Khan KZ, Ramachandran S, Gaunt K, Pushkar P (2013) The objective structured clinical examination (OSCE): AMEE Guide No. 81. Part I: An historical and theoretical perspective. Med Teach 35:1437–1446. DOI:10.3109/0142159X.2013.818634.
97. Blythe J, Patel NSA, Spiring W, Easton G, Evans D, Meskevicius-Sadler E, et al (2021) Undertaking a high stakes virtual OSCE ("VOSCE") during Covid-19. BMC Med Educ. 21:1–7. DOI:10.1186/s12909-021-02660-5.
98. García-Seoane JJ, Ramos-Rincón JM, Lara-Muñoz JP (2021) Changes in the Objective Structured Clinical Examination (OSCE) of University Schools of Medicine during COVID-19. Experience with a computer-based case simulation OSCE (CCS-OSCE). Rev Clin Esp. 221:456–463. DOI:10.1016/j.rce.2021.01.004.
99. Shorbagi S, Sulaiman N, Hasswan A, Kaouas M, Al-Dijani MM, El-Hussein RA, et al (2022) Assessing the utility and efficacy of e-OSCE among undergraduate medical students during the COVID-19 pandemic. BMC Med Educ 22:1–12. DOI:10.1186/s12909-022-03218-9.
100. Agarwal A, Batra B, Sood AK, Ramakantan R, Bhargava SK, Chidambaranathan N et al (2010) Objective structured clinical examination in radiology. Indian J Radiol Imaging

20:83–88. DOI:10.4103/0971-3026.63040.
101. Andrade AD, Cifuentes P, Oliveira MC, Anam R, Roos BA, Ruiz JG (2011) Avatar-mediated home safety assessments: piloting a virtual objective structured clinical examination station. J Grad Med Educ 3:541–545. DOI:10.4300/JGME-D-11-00236.1.
102. Kava BR, Andrade AD, Marcovich R, Idress T, Ruiz JG. Communication skills assessment using human avatars: Piloting a virtual world objective structured clinical examination. Urol Pract. 2017;4:76–84. doi:10.1016/j.urpr.2016.01.006
103. Pérez Baena AV, Lorenzo Álvarez R, Sendra Portero F. ECOE-RX: Gamificación y aprendizaje basado en casos para aprender radiología clínica en pregrado. 36º Congreso Nacional de la Sociedad Española de Radiología Médica SERAM. 26 de mayo de 2022 . Málaga, Spain https://piper.espacio-seram.com/index.php/seram/article/view/8394 [Accessed Mar 28, 2024]
104. Pérez Baena AV, Sendra Portero F. The objective structured clinical examination (OSCE): Main aspects and the role of imaging. Radiologia (Engl Ed). 2023 Jan-Feb;65(1):55-65. doi:10.1016/j.rxeng.2022.09.006.
105. Brigham TJ. An introduction to gamification: Adding game elements for engagement. Med. Ref. Serv. Q. 2015; 34(4):471–480. doi:10.1080/02763869.2015.1082385.
106. Seaborn K, Fels DI. Gamification in theory and action: A survey. Int J Hum-Comput Interact 2015;74:14-31. doi:10.1016/j.ijhcs.2014.09.006.
107. Aguado-Linares P, Sendra-Portero F. Gamification: Basic concepts and applications in radiology. Radiologia. 2023;65(2):122-132. doi:10.1016/j.rxeng.2022.10.014.
108. Lorenzo-Álvarez R, Rudolphi-Solero T, Ruiz-Gómez MJ, Sendra-Portero F. Game-based learning in virtual worlds: A multiuser online game for medical undergraduate radiology education within Second Life. Anat Sci Educ. 2020 Sep;13(5):602–617. doi:10.1002/ase.1927.
109. Rudolphi-Solero T, Lorenzo-Álvarez R, Ruiz-Gómez MJ, Sendra-Portero F. Impact of compulsory participation of medical students in a multiuser online game to learn radiological anatomy and radiological signs within the virtual world Second Life. Anat Sci Educ. 2022 Aug;15(5):863-876. doi:10.1002/ase.2134
110. Rudolphi-Solero T, Jiménez-Zayas A, Lorenzo-Álvarez R, Domínguez-Pinos D, Ruiz-Gómez MJ, Sendra-Portero F. A team-based competition for undergraduate medical students to learn radiology within the virtual world Second Life. Insights Imaging. 2021 Jun29;12(1):89. doi:10.1186/s13244-021-01032-3
111. Rudolphi-Solero T, Lorenzo-Álvarez R, Domínguez-Pinos D, Ruiz-Gómez MJ, Sendra-Portero F. An Interuniversity Competition for Medical Students to Learn Radiology in the Second Life Metaverse. J Am Coll Radiol. 2023 Nov 3. Forthcoming. doi: 10.1016/j.jacr.2023.09.012.
112. Lee A, Berge ZL. Second Life in healthcare education: Virtual environment's potential to improve patient safety. Knowl Manag E-Learn. 2011;3(1):17-23. doi:10.34105/j.kmel.2011.03.003
113. Linden Lab Inc. Mayo Clinic. Second Life Map Location (SLURL). http://maps.secondlife.com/secondlife/USF%20Health%20Annex/103/157/25 [accessed March 28, 2024]
114. Linden Lab Inc. USF Morsany College of Medicine. Second Life Map Location (SLURL). http://maps.secondlife.com/secondlife/USF%20Health%20Annex/103/157/25 [accessed March 28, 2024]
115. Linden Lab Inc. Brodmann brain in Inspiration Bay. Second Life Map Location (SLURL). http://maps.secondlife.com/secondlife/Inspiration%20Bay/60/60/3503 [accessed March 28, 2024]
116. Linden Lab Inc. Malaga Medical School. Second Life Map Location (SLURL). http://

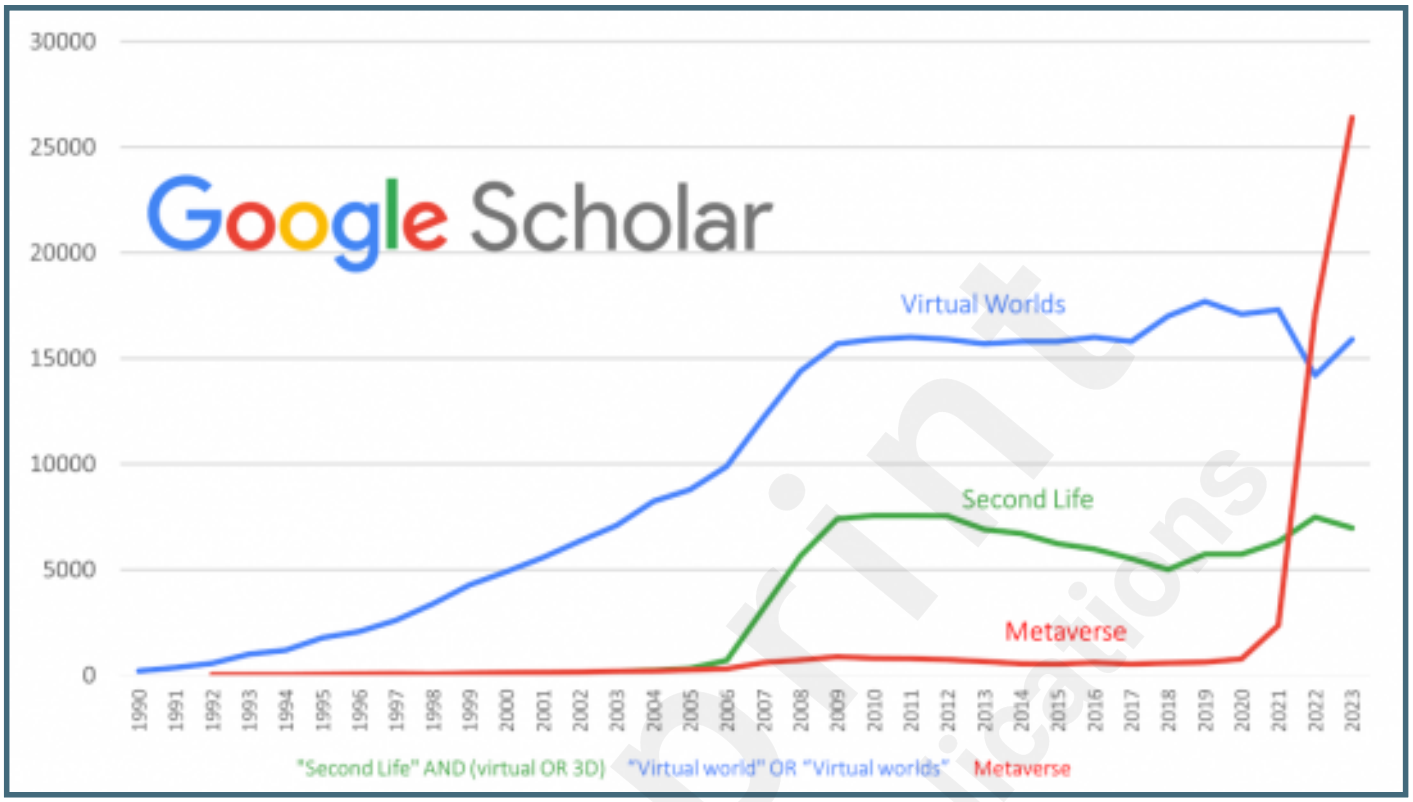
maps.secondlife.com/secondlife/Malaga%20Medical%20School/147/96/26 [accessed March 28, 2024]
117. Morales-Vadillo R, Guevara-Canales JO, Flores-Luján VC, Robello-Malatto JM, Bazán-Asencios RH, Cava-Vergiú CE. Use of virtual reality as a learning environment in dentistry. Gen Dent. 2019;67(4):21-27 PMID: 31355760
118. Danforth DR. Development of an Interactive Virtual 3-D Model of the Human Testis Using the Second Life Platform. In Thomas M, editor. Design, Implementation, and Evaluation of Virtual Learning Environments. Hershey, PA: Information Science Reference. 2012:153-167. ISBN13: 9781466617704. doi:10.4018/978-1-4666-1770-4
119. Richardson-Hatcher A, Hazzard M, Brueckner-Collins J. Using a Three-Dimensional Virtual Platform to Teach the Pterygopalatine Fossa. Med Sci Educ. 2014 Sep;23(3):308-312 doi:10.1007/BF03341639
120. Yellowlees PM, Cook JN. Education about hallucinations using an internet virtual reality system: a qualitative survey. Acad Psychiatry. 2006 Nov-Dec;30(6):534-9. doi:10.1176/appi.ap.30.6.534.
121. Salajegheh A, Jahangiri A, Dolan-Evans E, Pakneshan S. A combination of traditional learning and e-learning can be more effective on radiological interpretation skills in medical students: a pre- and post-intervention study. BMC Med Educ. 2016 Feb 3;16:46. PMID:26842495 doi:10.1186/s12909-016-0569-5
122. den Harder AM, Frijlingh M, Ravesloot CJ, Oosterbaan AE, van der Gijp A. The Importance of Human-Computer Interaction in Radiology E-learning. J Digit Imaging. 2016 Apr;29(2):195-205. PMID:26464115 doi:10.1007/s10278-015-9828-y
123. Linden Lab Inc. The Medical Master Island. Second Life maps location (SLURL). http://maps.secondlife.com/secondlife/Medical%20Master%20Island/121/87/23 [accessed Mar 24, 2024]
124. Alonso Martínez JM, Ravaei S, Lorenzo Álvarez R, Rudolphi SoleroT, Sendra Portero F. Juegos sociales para aprender radiología en pregrado dentro de un entorno virtual 3D: trivial y pasapalabra. 6º Congreso Nacional de la Sociedad Española de Radiología Médica SERAM. 26 de mayo de 2022 . Málaga, Spain. https://piper.espacio-seram.com/index.php/seram/article/view/8395/6861 [Accessed Mar 29, 2024]
125. Awan OA. Virtual radiology readouts after the coronavirus disease (COVID-19) pandemic. AJR Am J Roentgenol. 2021;217:765-766. doi:10.2214/ajr.21.25607
126. O'Byrne L, Gavin B, McNicholas F. Medical students and COVID-19: the need for pandemic preparedness. J Med Ethics. 2020;46:623-626. doi:10.1136/medethics-2020-106353
127. Byrnes YM, Civantos AM, Go BC, McWilliams TL, Rajasekaran K. Effect of the COVID-19 pandemic on medical student career perceptions: a national survey study. Med Educ Online. 2020;25:1798088. doi:10.1080/10872981.2020.1798088
128. Muñoz-Núñez CF. Online training in radiology during the COVID-19 pandemic. Radiologia 2022;64:433–444. doi:10.1016/j.rxeng.2022.09.004.
129. Lieux M, Sabottke C, Schachner ER, Pirtle C, Danrad R, Spieler B. Online conferencing software in radiology: Recent trends and utility. Clin Imaging 2021;76;116–122. doi:10.1016/j.clinimag.2021.02.008.
130. Kauffman L, Weisberg EM, Fishman EK. Using Facebook Live and Zoom as Tools for Online Radiology Education: A Practical Guide. Curr Probl Diagn Radiol. 2022;514:423–426. doi:10.1067/j.cpradiol.2022.01.003.
131. McRoy C, Patel L, Gaddam DS, Rothenberg S, Herring A, Hamm J, Chelala L, Weinstein J, Smith E, Awan O. Radiology Education in the Time of COVID-19: A Novel Distance Learning Workstation Experience for Residents. Acad Radiol. 2020;27:1467–1474.

doi:10.1016/j.acra.2020.08.001.
132. Slanetz PJ, Bedi, H, Kesler T, Chetlen A. Optimizing Journal Clubs in the Post-COVID-19 Era. J Am Coll Radiol. 2020;17:1496–1498. doi:10.1016/j.jacr.2020.07.031.
133. De Lucia A, Francese R, Passero I, Tortora G. Development and evaluation of a virtual campus on Second Life: The case of SecondDMI. Comput Educ. 2009;52(1), 220-233. doi:10.1016/j.compedu.2008.08.001
134. Chamorro-Atalaya O, Durán-Herrera V, Suarez-Balazar R, Gonzáles-Pacheco A, Quipuscoa-Silvestre M, Hernández-Hernández M, et al. The Metaverse in University Education during COVID-19: A Systematic Review of Success Factors. Int J Learn, Teach Educ ResVol. 2023; 22(5):206-226. doi:10.26803/ijlter.22.5.10
135. Ravaei S, Alonso-Martínez JM, Jiménez-Zayas A, Sendra-Portero F. Reflections about Learning Radiology inside the Multi-User Immersive Environment Second Life® during Confinement by Covid-19. Proceedings 2020, 54(1):9. doi:10.3390/proceedings2020054009
136. Kariuki D. Crystal Frost viewer development to continue despite Linden Lab announcing a mobile viewer. 2023 March 22. https://www.hypergridbusiness.com/2023/03/crystal-frost-viewer-development-to-continue-despite-linden-lab-announcing-a-mobile-viewer/ [Accessed Mar 29, 2024]

Supplementary Files

Figures

Google Scholar search graph by year for the terms Virtual Worlds, Second Life and Metaverse. Below the horizontal axis the term strings used are shown.



Screenshots of university organizations in Second Life. Above: A lecture at the 2020 Virtual World Best Practices (VWBP) meeting and the Rocklife University Consortium Library building. Below: A view of the island of the University of Aveiro and the meeting point of the Eduverse Campus of the Virtual Worlds Education Consortium (VWEC).

Screenshots of various scenes during medical education activities in Second Life. Left: Lectures with groups of about 30 avatars in a virtual classroom and an outdoor setting. Right: Scenes of student group meetings to discuss and prepare radiological cases.

Screenshots of various scenes during a virtual OSCE in Second Life. Above: distributor of an OSCE room with students in front of the door of each station, before starting and scene of a student at a radiology station. Below: scene of a student reading the clinical scenario presented on a poster on the wall and scene in which the student interacts with a simulated patient represented by another avatar.

Screenshots of several health-related virtual locations that are currently active in Second Life. Above Mayo Clinic hospital and Brodmann's Brain at Inspiration Bay, representing functional areas of the human brain. Below: Malaga Medical School island and the University of South Florida (USF) College of Medicine.