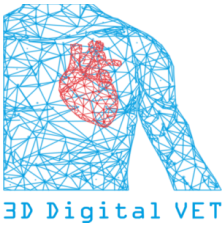

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METHODOLOGICAL GUIDELINES

3D MEDICAL DIGITAL MODELS IN HEALTH PROFESSIONALS TEACHING

Contents

Introduction

The Methodological guidelines for face to face „3D medical digital models in health professionals teaching "training course is created as part of "3D Digital VET" project, in order to support and educate teachers to make the subject of technology adopted in the medical field more familiar to the students.

"3D medical digital models in health professionals teaching" training course consists of online materials, that can be found on the project's platform https://e-3ddigitalvet.inerciadigital.com/ in English, German, Romanian, Italian, Estonian, and Spanish languages and it is designed for 20 hours of training. For face-to-face training, the course is intended for 2 days of intensive activity but can also be spread over a wider interval of time.

The course is mainly addressed to VET students/ learners - medicine students (doctors and nurses), professional doctors and nurses working in hospitals, clinics, primary medicine, nurse educators and other health professionals, VET teachers, trainers and mentors.

Materials are organized into six modules, made by each partner ant it is resumed in a table presenting the main information needed to conduct the course and to use the teaching materials. Before starting the course, trainers must be aware of the devised duration and have availability of rooms and materials for the teaching program (2 hours per module).

1. How to access Ale3andria 3D medical library and download 3D models

GENERAL GOAL:	The main goal of this training module is to train teachers on the use of the 3D medical library "Ale3xandria", thus assisting them to make efficient use of its resources in the field of health teaching.
LEARNING OUTCOMES:	The learning outcomes of this training module are: • Participants will know the Al3xandria library and how to make use of it and its resources. • Participants will be able to identify the Digital Learning Objects (DLOs) and the different elements that they are composed of. • Participants will become familiar with the three-dimensional reconstruction of human anatomy in the health sector. • Participants will gain new perspectives in the study and diagnosis of multiple pathologies. • Participants will increase their critical thinking and analysis.
METHODS	The methods to be implemented for the training module are: • Presentations (PPTs). • Self-study and self-assessment. • Online course and face-to-face training. • Polls and questionnaires (Kahoot, Quizizz and Mentimeter).
DURATION:	2 hours
RESOURCES NEEDED	The resources needed to provide this training module are: • Internet (Wi-Fi network) and computers. • Access to the online platform "Ale3xandria library" and supporting materials. • Digital projector and digital whiteboard. • Speakers, headphones, papers and pens.
SCENARIO FOR FACE TO FACE TRAINING	**SECTION 1: HOW TO ACCESS TO THE LIBRARY (1 hour)** **Activity 1:** Presentation of the training module. Main goal, objectives, target groups and learning outcomes It will consist of a presentation of the training module explaining what it will be about, the main objectives, its target audience and the learning outcomes expected at the end of the module. It will provide learners

	with a higher understanding of what they will learn and do during the module. **Activity 2:** Introduction to the Al3xandria library: Context and main objectives Learners will be introduced to the Al3xandria library which is the main element of our training module. Before accessing and making use of it, they will better know about the background of the online library, thus explaining its origin, as well as the main objectives of it. In addition, the trainer will talk about the relevance and need to implement the Al3xandria library in the health sector and how professionals can benefit from it by using it for medical purposes. This way, learners will closely understand the purpose of this library in order to later use it in a more appropriate way. **Activity 3:** Accessing the online library This activity will be carried out in a practical and interactive way by making learners the main actors in exploring the platform by themselves. To do so, the trainers will provide them with step by step guidelines to follow so that learners can register on the platform and access it successfully. They will be completing each step at the same time as the trainer will be showing and doing it on a projector so that all the instructions become clear in a more visual way.
	SECTION 2: WHAT CAN WE FIND INSIDE THE LIBRARY **Activity 1:** Introduction to the library's structure and functions. In order to familiarize students with the structure and functions of the online library, a virtual tour of the library will be made, explaining step by step the different sections of which it is composed as well as the available options for interaction. From the main menu, through the submenu and its categories to the 3D digital medical models. **Activity 2:** Using interactive 3D options The 3D model has three tools for interaction which will allow us to obtain more significant learning, as it helps us to observe and better understand the model we are working with. During this activity, participants will become familiar with the available tools.

	Activity 3: Exploring 3D medical models (3DMM) in health professionals teaching Particular emphasis will be placed on the 3D digital medical models, explaining what they consist of, how they are applied to teaching in the healthcare field and the benefits they bring to this sector. In this activity the use of the Al3xandria catalog will be the opposite of its usual use, this means that students will have to find out which model it is without knowing its information. This means that during the activity the teacher will select one of the 3D models from the Al3xandria catalog and will expose it through the projector or a digital whiteboard, however the only thing that will be exposed will be the 3D model chosen. Students will be able to visualize the automatic rotation, move, enlarge the model, etc. And in a collaborative and brainstorming way they will have to: Identify the organ, Identify the possible pathology, Identify the department or specialty that should take care of it, Identify the possible symptoms that the patient would experience, Identify the possible gender and age range (if applicable) Identify possible procedures that should be performed or have been performed The students should work in teams to choose among all the answers arguing why they have chosen them and the teacher once they have selected all the answers will be responsible for indicating their successes and errors and the relevant explanations to resolve all the doubts that may arise. The teacher will be able to choose as many models as he/she wishes from the catalog depending on the knowledge he/she wants to transmit to the students. This activity can last as long as the teacher considers necessary.
	SECTION 3 - HOW WE CAN FIND CONTENT, PATHOLOGIES AND CHARACTERISTICS OF THE PARTS **Activity 1:** Introduction to main concepts Talk on main concepts such as organs, pathologies related to them and characteristics of their parts. This way, learners will start familiarizing with key terms that will be put in practice in following activities. **Activity 2:** Interactive raffle Through the online platform “Comment Picker”, an interactive raffle will be held among the learners so that each of them is assigned to one organ. This will consist of a warming up activity for the next activity

	"Medical presentations". This way, learners will be assigned to a specific organ randomly and it is ensured that the selection process is completely transparent. **Activity 3:** Practical task "Medical Presentations" Thanks to the previous activity, each student will be assigned an organ and 3D model for which they will have to prepare their presentation. Once each student has been assigned his or her model, he or she should proceed to prepare his or her presentation. The objective is for them to study the model they have chosen, its pathologies, tests, symptomatology and any relevant information so that they can present it as if they were the doctor in charge of the case. They will also have to research and complement the information offered in Al3xandria to propose their possible solutions or procedures, what they believe is most appropriate in each case, as well as the possible risks of the procedure they choose. At the end of their presentation they will have a time for questions and doubts where their peers will be able to ask them questions about their presentation and possible doubts or concerns that may have arisen during the presentation. Users should identify the additional elements that they got from the 3D file and/or from the information available in Al3xandria, compared with the information they should have gotten without it.
	SECTION 4: REVIEWING AL3XANDRIA'S CONTENT **Activity 1:** Interactive Poll Once the medical presentations have been finalized, the learners will be provided with access to the online platform Mentimeter where they will have to select the medical presentation they consider the best one through an online poll. **Activity 2:** Kahoot collective questionnaire This activity will consist of a collective questionnaire among all the participants in Kahoot which will be moderated by the trainer of the activity. This questionnaire will be useful to reinforce the contents that they have been learning thanks to the previous activities and will also

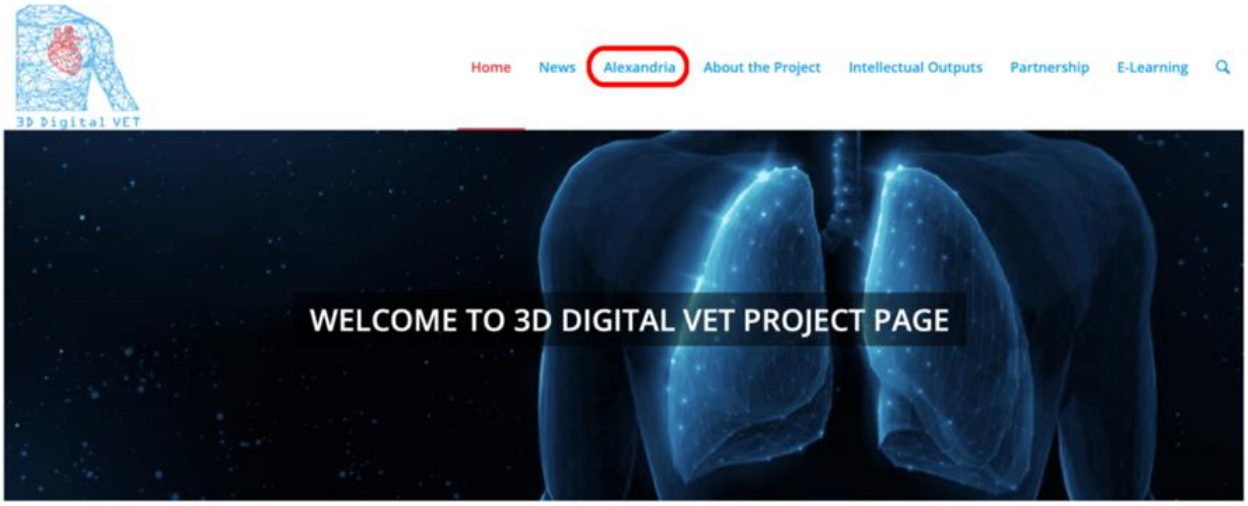
	serve as a warm-up for the final individual evaluation questionnaire that they will do in Quizizz. **Activity 3:** Practical task "Medical questionnaire" Quizizz This questionnaire, which will be carried out individually, will be used to evaluate the contents acquired by the participants in the training. There will be between 10 and 15 questions that will be asked through the Quizizz platform and will focus on the general contents of the module.
EVALUATION OF THE MODULE:	The activities carried out in section 4 will serve as evaluation tasks that will assist the trainers to check what the learners have learnt during the all training module.
KEEPING LEARNERS SAFE	• Ensure that access to the activity is available for all. • Ensure a room large enough to allow mobility for all learners. • Ensure Internet connection and accessibility to all the resources needed for the training. • Ensure a respectful educational environment in which no participant can be discriminated against or excluded.
BACKGROUND CONTENTS AND HANDOUTS	• PPt presentations • Online library (https://3ddigitalvet.inerciadigital.com/3dlibrary/) • Kahoot (https://kahoot.it/) • Quizizz (https://quizizz.com/) • Mentimeter (https://www.mentimeter.com/) • Comment Picker (https://commentpicker.com/random-name-picker.php)
REFERENCES and useful links:	Al3xandria Image Search Guide: https://docs.google.com/document/d/1WhfUnP4Pu_4cncJXHfJhXnmGP-JABo0M/edit 3D Medical Library AL3xandria: https://3ddigitalvet.inerciadigital.com/3dlibrary/

The 3D Digital VET project aims to promote the use of 3D technology in the medical sector through the creation of an online library (Al3xandria), which will have different images produced by European hospitals, and will also promote the professional development of teachers through a specific training course focused on the use of Ale3xandria and 3D in the health sector.

In order to start searching for images in Al3xandria we need to know how to access it and for this it is necessary to visit our project's web page. Once we are on the homepage of our website, we can see a top menu in which we find all the different sections of the website. We are going to

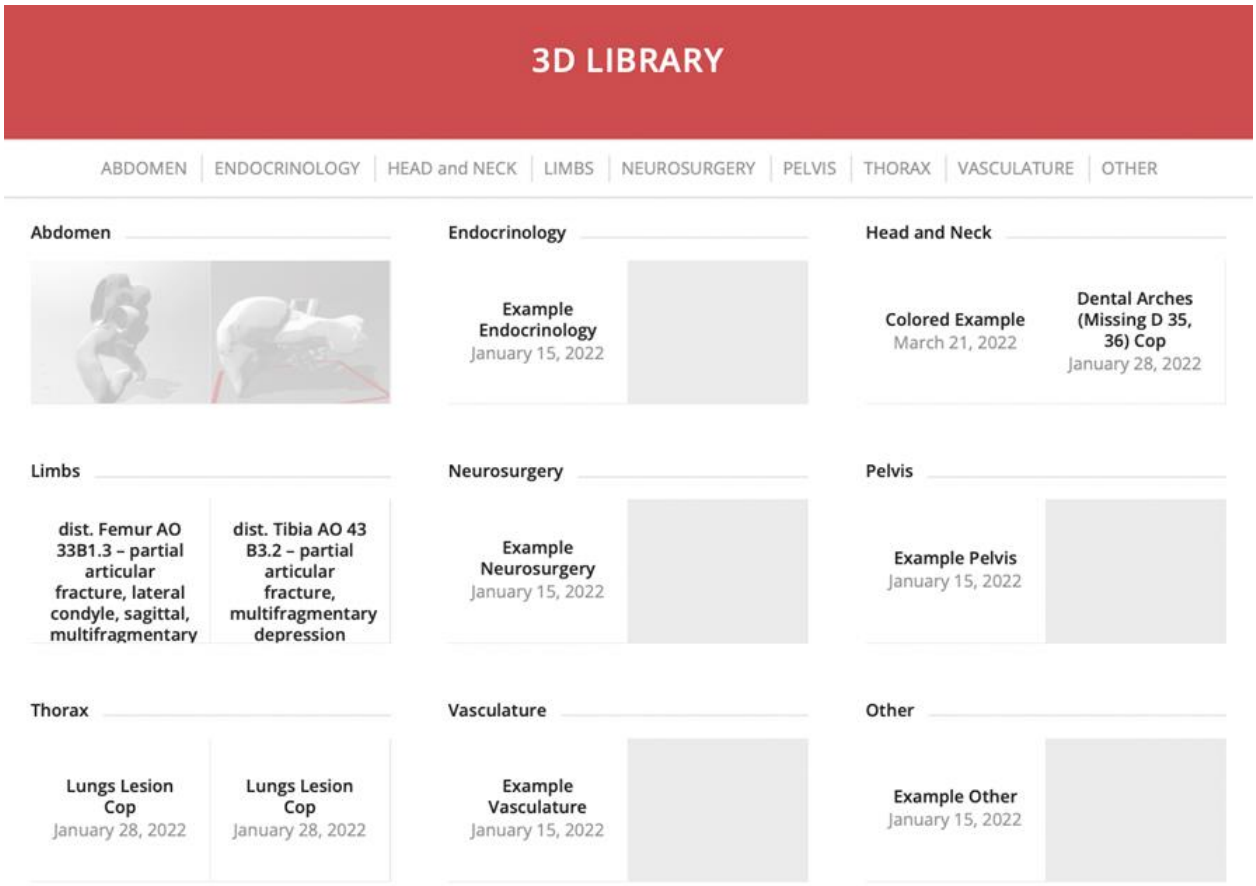
choose the "Al3xandria '' section, which will lead us to the 3D gallery (to select the section just drag the cursor to the section and click on it).

We'll find a top menu which will redirect us to the different sections of our website. In this case we'll explain how to use the 3D gallery. To do this we'll place and click on the menu option with the same name.



As a curiosity before starting with the detailed analysis of the different sections of our Al3xandria 3D library, let's explain where the name of the library comes from because it is related to the theme of the project and the functionality of the tool itself within the project. The name of the 3D library is inspired by the Ancient Library of Alexandria, which was created a few years after the foundation of the city by Alexander the Great in 331 BC and whose purpose was to compile all the works of human ingenuity, of all times and all countries, in a collection for posterity. The importance of the Library lies not only in the volume of books it housed, but also in the fact that it was the world's first university, a center of research and dialogue, whose scholars included the mathematician Archimedes and the poet Apollonius. It was there that medical and scientific principles were discussed, as well as questions of philosophy, literature and political administration, thus making it one of the greatest centers for the dissemination of knowledge in antiquity. Thus, we hope that with our library we can create a significant creation in the field of medicine and 3D reality inspired by this ancient wonder.

Starting with the sections and options that we have within our library "Al3xandria" to interact, the first thing we'll observe is this main menu, in it we have the different sections that correspond to different parts of the body or medical disciplines. The content of the central space is a preview of the parts that we find in the submenu (the bar below the red 3D Library area).



Within each of the categories that make up the submenu we'll find the 3D digital medical models, also called Digital Learning Objects (DLOs), which guarantee free, easy and open access.

The different DLOs will contain:

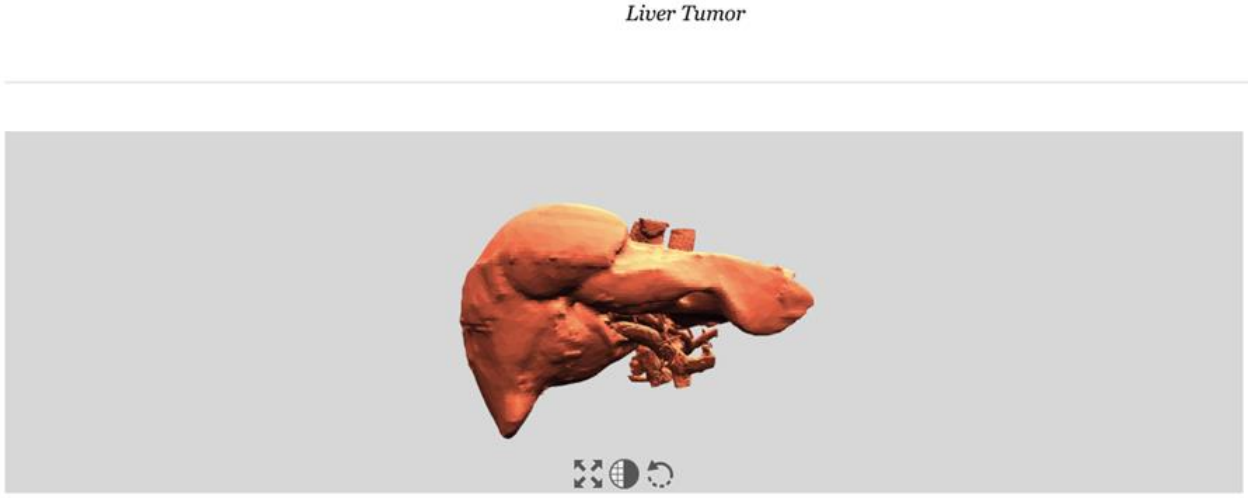
- The original medical images of the specific case (computed tomography -CT- scans, magnetic resonance imaging -MRI-, ultrasound scans, X-rays).

- A document containing the description of the patient's medical conditions (age, sex, disease, relevant previous events, treatments, etc.), where available.

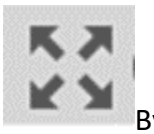
- 3D models, i.e. the three-dimensional reconstructions deriving form the available medical image, when possible.

As an example, to see what we find within each of the categories let's select the "Abdomen" category from the submenu. Once selected the first thing we'll find a list (image below) with all the DLOs that compose this category. In the list, each resource will have its date, title and a thumbnail of the 3D visualization.

Next, we'll select one of the resources, the one that catches our attention or about which we need to know the information. In our case, as an example, we'll select "Liver Tumor Cop". The first thing we'll see when we select one of the resources from the list will be the 3D digital model.



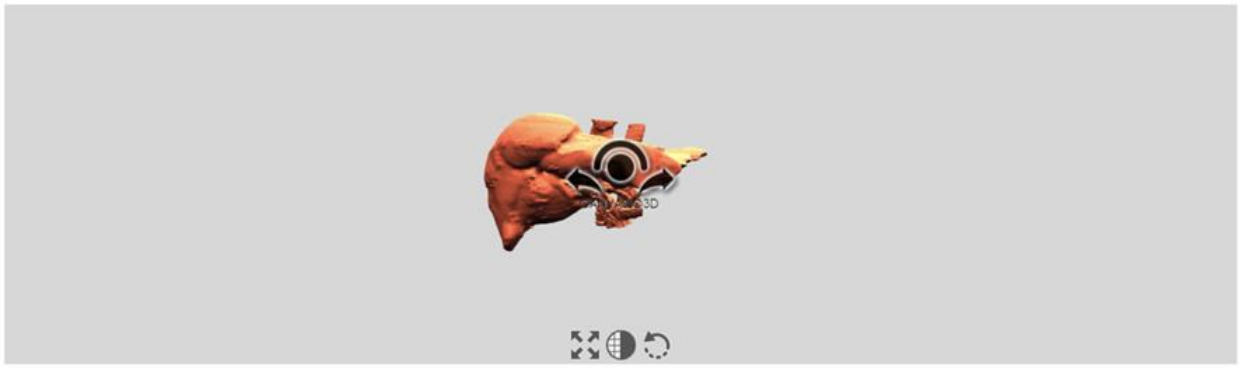
The 3D model has three tools to interact which will allow us to obtain a more significant learning, since it helps us to observe and better understand the model with which we are working.



By clicking on this option, we can access the 3D model in full screen, this is really useful as it allows us to observe the model more easily and in more detail.

By clicking on this option, the 3D modeling will be transformed into its "wireframe" option, i.e. we'll be able to observe the edges of the mesh that constitute the modeled object, since the "wireframe" is a rendering algorithm that results in a semi-transparent image. This will allow us to see internal structures in the parenchima.

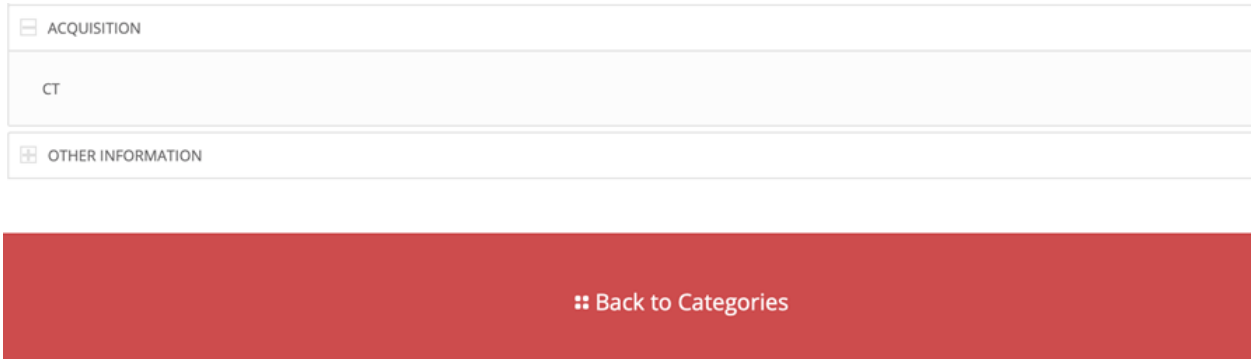
Clicking on this option will start the automatic rotation of the 3D model, turning the model completely around, we can stop this automatic rotation by clicking again on the button. To this we must add that with our mouse we can rotate and move the model as we wish only by sliding our cursor. This function is convenient if you need to make a presentation having something appealing for the audience to watch while you're discussing the case



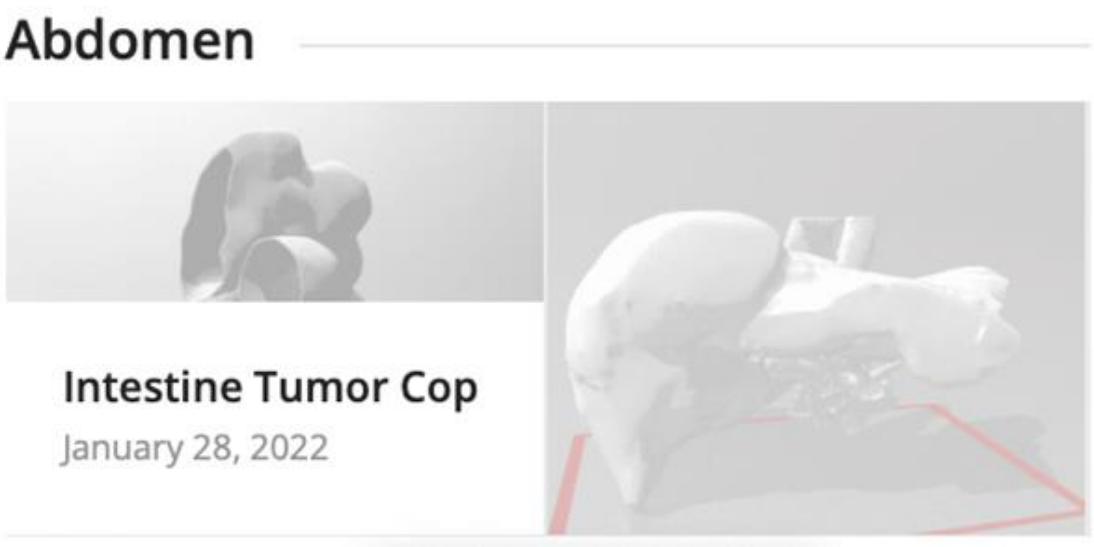
Under each of the 3D models we'll have a detailed description, divided into interactive drop-downs that we can select depending on the information we need to know about the model we are consulting. We'll visualize the content of each section if we click on it.

For example, in the model we have selected "Liver Tumor Cop" we have the following information:

- Organ: liver
- Pathologies: liver tumor
- Department of management/Specialty: general surgery
- Symptoms: N/A
- Pediatrics: No
- Gender: Male
- Age Range: 63
- Acquisition: Computed Tomography (CT) Scan
- Other Information: N/A



Once we have consulted all the information we needed or we have finished observing the 3D model, we can return to the main menu within the "Al3xandria" library by clicking on the option we see in the image above. Also in the main screen of the library we'll have the latest updates of images and models uploaded, showing the last two images uploaded in each of the categories, each one will have its related thumbnail, name and date of upload (this information will appear when sliding the cursor over the images).



It is important to mention that, if requested, users can obtain STL files of the segmentation. This will require extra work, with associated costs. However, in this way the user will be able to 3D print the models autonomously. For a surgeon, having an exact reproduction of the district to be treated is a substantial help in his work: it is now evident thanks to the large number of academic

studies published and reviewed, that there's a reduction in time and risks in medical procedures when using a physical replica of the anatomy to study and perhaps practice the procedure.

In short, for health professionals, such as doctors, nurses, physiotherapists, bioengineers, scholars and students, the difference between a set of flat images or a two-dimensional image, and a real copy of the organ or at least a three-dimensional image of the district, will be a substantial support.

Possible activities to do with students and Al3xandria

ACTIVITY 1 "MEDICAL PRESENTATIONS

In this activity, after accessing the Al3xandria catalog, each student will have to choose one of the 3D models and prepare a presentation about it in front of their classmates. To do this, a card will be created with the different models and students so that each one can write down which model has been selected and avoid repeating them on the day of the presentation.

Once each student has selected his or her model, he or she should proceed to prepare his or her presentation. The objective is for them to study the model they have chosen, its pathologies, tests, symptomatology and any relevant information so that they can present it as if they were the doctor in charge of the case.

They will also have to research and complement the information offered in Al3xandria to propose their possible solutions or procedures, what they believe is most appropriate in each case, as well as the possible risks of the procedure they choose.

At the end of their presentation they will have a time for questions and doubts where their peers will be able to ask them questions about their presentation and possible doubts or concerns that may have arisen during the presentation.

Users should identify the additional elements that they got from the 3D file and/or from the information available in Al3xandria, compared with the information they should have gotten without it.

With this we'll achieve that in addition to students learning and researching on their own, increasing their critical thinking and analysis, they will also be part of more dynamic and interactive classes where they are the main protagonists and actors.

Duration of the activity (estimates):

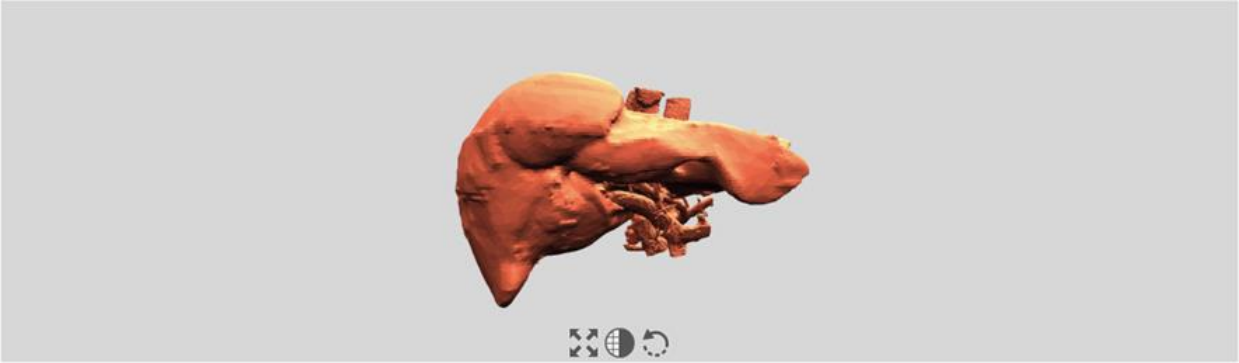
- 3 weeks for pre-research and preparation of the presentation.

- 3 sessions for the presentation of all cases (sessions may vary depending on the number of students).

ACTIVITY 2 "WHO'S WHO IN MEDICINE?"

In this activity the use of the Al3xandria catalog will be the opposite of its usual use, this means that students will have to find out which model it is without knowing its information.

In other words, during the activity the teacher will select one of the 3D models from the Al3xandria catalog and will show it in class through the projector or a digital whiteboard, but the only thing that will be shown will be the 3D model (image below).



Students will be able to visualize the automatic rotation, move, zoom the model, etc. And in a collaborative and brainstorming way they should:

- Identify the organ
- Identify the possible pathology
- Identify the department or specialty that should take care of it
- Identify the possible symptoms the patient would experience
- Identify the possible gender and age range (if applicable)
- Identify possible procedures that should be/have been performed

The students will have to work in teams to choose among all the answers arguing why they have chosen them and the teacher, once they have selected all the answers, will be in charge of indicating their successes and mistakes and the pertinent explanations to solve all the doubts that may arise.

The teacher will be able to choose as many models as he/she wishes from the catalog depending on the knowledge he/she wants to transmit to the students. This activity can last as long as the teacher considers necessary.

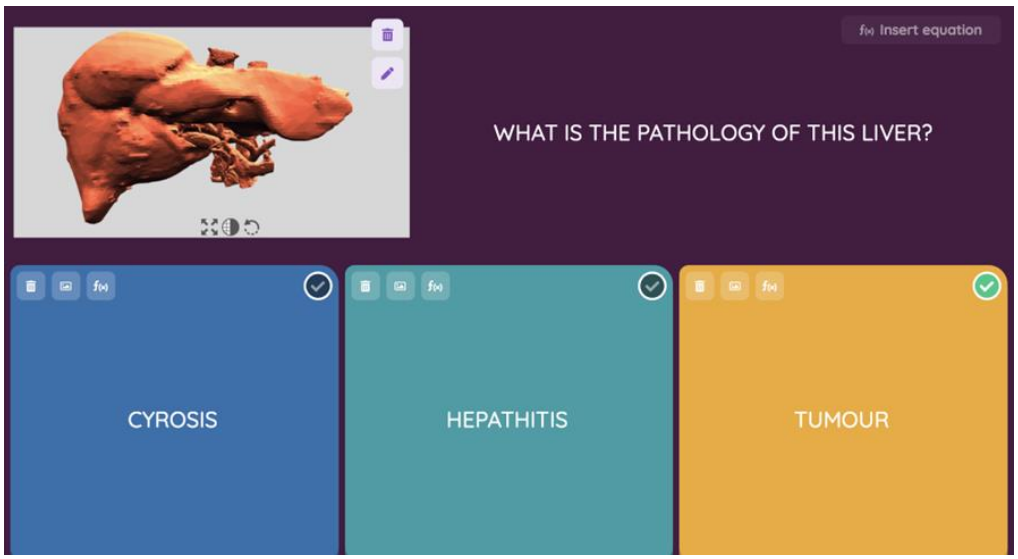
ACTIVITY 3 "MEDICAL QUESTIONNAIRE

After the use of Al3xandria in class, both by the students and the teacher, the teacher will be in charge of developing a quiz for the students to take to demonstrate the medical knowledge they have acquired.

We recommend that teachers use tools such as Kahoot or Quizizz for the quiz, as they allow the inclusion of multimedia elements, so that they can download Al3xandria content on the models and the quiz questions can be even better adapted to the Al3xandria content.

The questions to be included in the questionnaire should be adapted to the contents with which they have been working in class and which they have been consulting in Al3xandria, so that the questionnaire will act as a final evaluation for your students.

In this activity each student should complete the questionnaire individually. And the difficulty of the questions should depend on the age and group of the students.



Example of a question in a possible Quizizz quiz.

2. Using Digital Learning Objects (DLO's) for health professional

GENERAL GOAL:	The objective of this module if to offer the information needed for the undestanding and efficient use of digital learning objects in health professionals' education
LEARNING OUTCOMES:	By the end of the module, participants will be able to: Get to know the basic principles and main characteristics of Digital Learning Objects - definition, types, utilization; Understand the advantages of Web-based learning and DLO's in medical education (the past, the present and the future) Understand the impact of using DLO's in medical education- barriers and solutions; Identify different applications-exemples of using DLO's for health professionals training;
METHODS	Lectures, presentations, self-study, discussions based on case studies, group discussion, educational film, self-assessment
DURATION:	2 hours
RESOURCES NEEDED	Multimedia, paper, flipchart, markers Computer (Wi-Fi network) Access to scientific data bases (PubMed, EBSCO, etc.), online platforms/ applications
SCENARIO FOR FACE-TO-FACE TRAINING	
	Section 1-Introduction Activity 1: The trainer presents in introduction the structure of the module 5 of training, the expected results and the importance of the theme in educational context, using theoretical materials for this section. Activity 2: Participants watch a film about the future of learning in nurses education https://vimeo.com/636913564 Activity 3: Participants watch a video about Learning Objects https://www.youtube.com/watch?v=5a_VZVOEQDc&feature=emb_imp_woyt

	Activity 4: The trainer divides participants into small groups and ask them to discuss and briefly presents different aspects of e-learning in nurses education

	Section 2 - Digital learning objects - definition, types, utilization Activity 1: The trainer presents the basic informations about DLOs (definition, types, utilisation, using theoretical materials for this section. Activity 2: Participants watch a video about Digital Learning Objects in Higher Education: https://www.youtube.com/watch?v=BWqWwSs5dnU Activity 3: The trainer divides participants into small groups and ask them to discuss and briefly presents the utilization of DLO in education (nursing/ medical school or internal training on their working place)
	Section 3 - Web-based learning and DLO's in medical education - the past, the present and the future Activity 1: The trainer presents exemples of web-based learning and DLO's in medical education, using theoretical materials for this section. Activity 2: The trainer divides participants into three groups and ask them to discuss about the using of DLO in medical education. The groups have to analyze and compare the instances and highlights the benefit of using them (past-present-future), and briefly presents the conclusions to the other groups Activity 3: Participants watch Typical Learning Objects in MOOCs video: https://www.youtube.com/watch?v=5Vg-qMPSGLE.
	SECTION 4 - The impact of using dlo's in medical education-barriers and solutions Activity 1: The trainer presents the barriers and the solutions in using DLOs for medical education, using theoretical materials for this section. Activity 2: Grup discussion with trainees about the barriers and the solutions of using DLOs on their job .

	Activity 3: Participants watch Virtual and Mixed Reality for Medical Education video: https://www.youtube.com/watch?v=PzPKdlFbvYM .
	SECTION 5 - Applications- examples of using DLO's for health professionals training The trainer involve participants in 4 exercices of using DLOs for health professional training. We use cooking ingredients to explain measurement, vocabulary and cooking as a prescription refill. What else can DLO's be used for, especially in health education? Exercise 1: Create your own example like the one we gave above, but consider a medical prescription, a medicine or something similar. Use that example in a lesson you teach or to explain something. How did you use it? Exercise 2: Write a story to explain a concept. Use that story in at least two sittuations. Exercise 3: Create your own DLO starting from the folowing questions: What needs to be learned? Who needs to learn it? What do we need to prepare before we start learning? Exercise 4: Exchange the DLO you created with your colleagues. Use that DLO to explain a concept.
EVALUATION OF THE MODULE:	Teacher evaluation of student's activities and quizzes.
KEEPING LEARNERS SAFE	Ensure that access to the activity available for all Ensure room large enough to allow mobility for all learners.
BACKGROUND CONTENTS AND HANDOUTS	PPT presentation , online course, additional materials

REFERENCES and usefull links:	1. Carnwell, R. and Daly, W.M. (2003), Advanced nursing practitioners in primary care settings: an exploration of the developing roles. Journal of Clinical Nursing, 12: 630-642. 2. Fagerström L. Developing the scope of practice and education for advanced practice nurses in Finland. Int Nurs Rev. 2009 Jun;56(2):269-72. 3. Carrillo de Gea, Juan Manuel & Fernández-Alemán, José & Sánchez García, Ana. (2012). Computer-based nursing education: An integrative review of empirical studies. Journal of Nursing Education and Practice. 2. 4. Bloice MD, Simonic KM, Holzinger A. On the usage of health records for the design of Virtual Patients: a systematic review. *BMC Med Inform Decis Mak*. 2013;13:103. Published 2013 Sep 8. 5. Wiley, David A. The instructional use of learning objects. Vol. 1. Bloomington: Agency for instructional technology, 2002. 6. Verbert, Katrien & duval, erik. (2022). Towards a global component architecture for learning objects: A comparative analysis of learning object content models. Follow up of L'Allier, 1997 – Introduction into learning objects 7. Gibbons, Andrew. (2003). What and How Do Designers Design: A Theory of Design Structure. TechTrends. 47. 8. McGreal, Rory & Elliott, Michael. (2004). *Technologies of online learning (e-learning).*

2.1 Introduction

The last few years have been increasingly challenging for the medical field, and mostly today, considering the epidemic context, learning has become a difficult task. The teachers not only that need to find effective learning systems but also need to adapt to the constant change that is occurring in the world.

Digital learning objects represent the way that we change a lesson from a small, modular unit to an entire experience. Any collection of content regardless of virtual extension can be considered a digital learning object. The implementation of technology in the classroom over the years shows not only the efficiency of this resources but also demonstrates the complex multi-process that implies technology, but also the teaching component.

E-learning is characterized by the explosive growth of digital information through the latest products from the field of information and communication technology. Building an information society is a large, complex and long-lasting process, being of a technological, financial, economic, social and cultural importance. This edification does not work without

research and research projects both in the field of information technology and I&CT communications (Information and Communication Technology) as well as in education

E-learning represents an approach of teaching and learning, which is based on the use of means and electronic devices, as tools for improving access to training, communication and interaction and to facilitate the adoption of new developing methods of understanding and learning. The **term e-learning** refers to that reality through the networks and through the involvement of new digital technologies and multimedia.

At the level of the European Commission, **e-learning** is defined as the use of new multimedia technologies and the Internet to improve the quality of facilitating access to resources and services, as well as to changes and remote collaboration

Learning Objects video:
https://www.youtube.com/watch?v=5a_VZVOEQDc&feature=emb_imp_woyt

2.2 Digital Learning Objects - definition, types, utilization

A digital learning object is "any digital resource that can be reused to support learning" (Wiley,2000)

Digital Learning objects are created to assist with the development of specific knowledge and learning programs. These online libraries are widely available online to be integrated in the lessons. Computer applications that focus on a small concept that aim to facilitate the process of understanding. These represent the foundation, the building blocks of creating a more interactive experience and facilitate a more comprehensive learning experience, combined with other information to produce a more complete concept

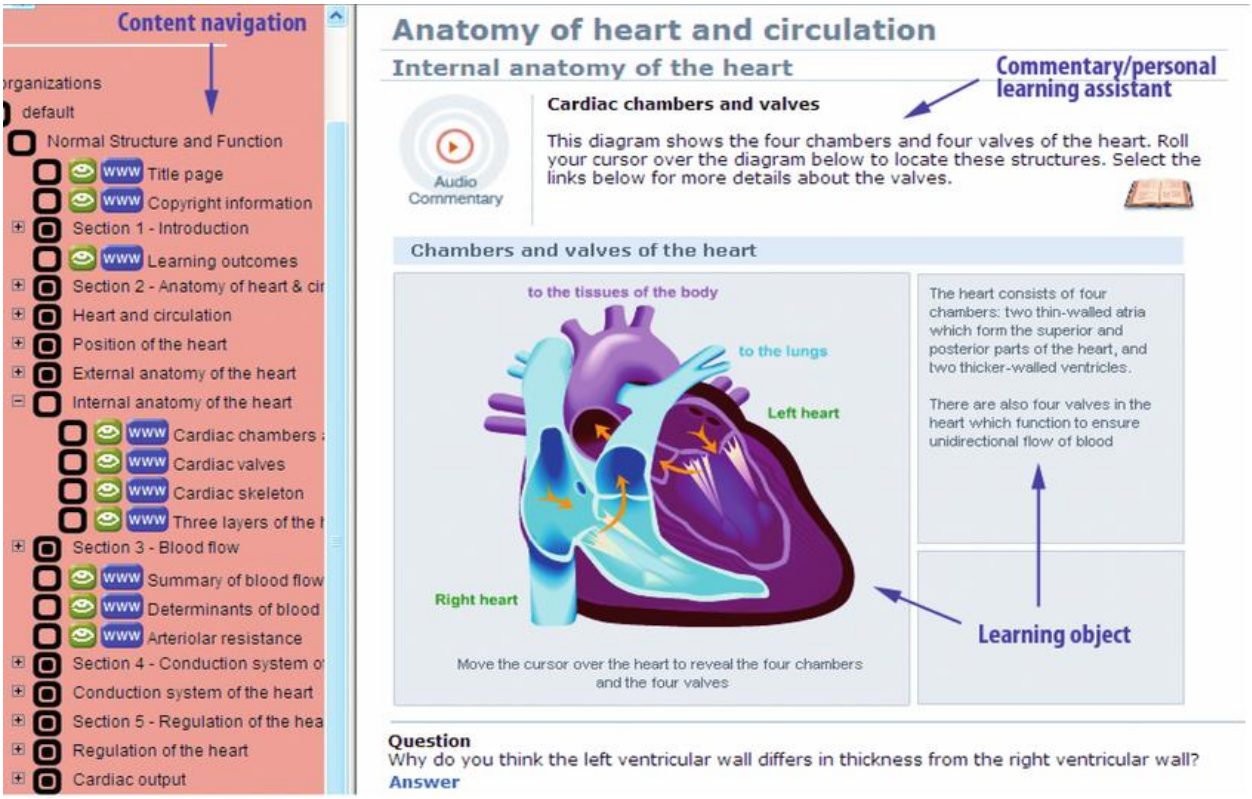
The idea of digital learning objects is to create **digital media content** that is:

- interoperable - can "plug-and-play" with any system or delivery tool
- reusable - can be used or adapted for use in multiple learning events
- accessible - can be stored a way that allows for easy search ability
- manageable - can be tracked and updated over time

Digital Learning Objects in Higher Education video:
https://www.youtube.com/watch?v=BWqWwSs5dnU
New Media Consortium (NMC) defines digital **learning objects (DLOs)** “as small reusable units that can be fitted together in any number of ways to produce customized experiences tied to an educational objective.”

Digital learning objects are also known as the following:

- Knowledge Object
- Content Object
- Information Object
- Media object
- Intelligent object
- Reusable learning object
- Unit of study
- Asset
- Educational Object
- Learning resource
- Raw media element
- Reusable information object
- Unit of learning
- Data object



Example of digital learning object (Figure 1) - Harden, Ronald & Gessner, Ira & Gunn, M & Issenberg, Barry & Pringle, S & Stewart, A. (2011). Creating an e-learning module from learning objects using a commentary or 'personal learning assistant'. Medical teacher

These objects help address better the learning objective and online libraries are widely available online. These can be focused on concepts and aim to immerse the learners and produce a more comprehensive understanding.

2.3 Web-based learning and DLO'S in medical education- the past, the present and the future.

Web-based education represents one of the core pillars in terms of strategic development in nursing, all over the globe. This pandemic unveiled the increased urgency for leaders and experts to come together and raise the level of competence and invest in the future of health.

In the context of global health challenges, quality and safety, leadership, advanced practice or innovation, nurses always need to be prepared to face any situation and adapt to changes. The last few years have been increasingly challenging for the medical field, and mostly today, considering the epidemic context that demonstrated the world, that the medical staff are indispensable leaders in the field of health.

Medical personnel needs to develop new learning methods in order to encourage discovery of unique ideas. The complexity of diseases is increasing and at the same time technology is advancing at a more rapid pace than ever. Most students are feeling unprepared for the challenges that life poses. We need them to become strong leaders and help redesign healthcare. Although future generations might feel frightened by going into real-world learning, without practical experience, educators must capitalize on technology to bridge this gap. We cannot stress enough that the medical professions must attract individuals with a vocation.

Isn't it a pity that we use cutting edge technology in areas such as social media but not in health? The goal is to immerse all professions as a field of practice, with the help of most advanced technology, such as virtual reality in order to enrich knowledge for when it comes to real-world experience. We have 3D simulations, virtual learning environments and other developments that can tremendously help, for example in multi-disciplinary teams. If not used correctly, it could also create more barriers in group activities or even technical barriers.

Medical staff already works tirelessly to care for the physical, emotional, and spiritual needs of the sick and vulnerable and often in hazardous workplaces. We need to recognize the opportunity of the digital medium and offer to mitigate some of the hurdles by doin this. DLO's in medical education can increase the quality of professional continuous education, help build more efficient learning methodologies and help professionals in health adapt faster to the educational needs of a fast-paced society.

The main values that we need to factor in when designing a learning environment are:

- to be interactive and engaging (by implementing clean UI/UX);

- accessible to people no matter the technical level;
- attention to details within end-user interaction;
- (…and most important) to be free of charge;

Typical Learning Objects in MOOCs video: https://www.youtube.com/watch?v=5Vg-qMPSGLE

The learning environment if it is built well, will help integrate new knowledge more efficient. A user-friendly interface helps users focus less on the technical part and guides them to a large range of courses subjects. Also, technical support always needs to be available through a dedicated website.

Always, medical education needs to be ready to go one step further. Building an online library of teaching resources will help experts write better courses and offer more field-based examples. Health data will be anonymized and used with the purpose of helping future professionals offer more qualitative care. We could eventually use datasets to create virtual patients using anonymized data from real cases.

In the future, we could use human-focused simulated data that will recreate the real world even in photo-realistic details. The fact that we can use these types of data to generate cases to be solved in classes is fantastic. The possibility to study becomes unlimited. This technology already exists, we just need to put it to work.

Medical staff lives a highly active lifestyle, needing to juggle between long shifts, family and personal life, so having a say in when is the best time for self-improvement and learning is crucial. Also, in the feedback surveys are needed to be able to receive real time feedback.

Of course, we need to be really careful because there are courses that cannot be taught only online. Using emerging technology and most important, integrating blended learning, we can succeed in making the most of it. With the help of experts and health specialists, we can create a better learning space, adapted to their needs, in which professionals in health, at all levels, can evolve and develop.

Medical staff is always involved in finding innovative ways to integrate technology into practice, but technology also needs to be adapted better to their needs. Manufacturers need to involve more medical professionals in (R&D) helping design their products and also consider them as a partner in the advancement of digital health systems, in order to improve patient care quality.

Furthermore, medical schools and universities are responsible for adapting the curriculum to the current needs. We need to shift our focus on balancing research skills using the

scientific method with technological competencies to cope with the fast world we live in and finally combine it with social skills, so much needed in a job that requires a high level of empathy. As advocates for well-being, they are placed across multiple types of settings and they need to adapt to each situation.

For a better future, we depend on them to build partnerships and collaborate more with officials, clinicians, companies in various industries from medical to IT and other parties to improve education and build the leadership competencies that are needed to take the next step to the future. For this, it is also needed to create space for opportunities. Leadership doesn't occur in a social or political vacuum.

2.4 The impact of using DLO's in medical education; barriers and solutions.

Digital learning objects have a profound and accelerated transformation of activities, processes, competencies and business models, according to the opportunities, digital technologies as well as their impact on cognitive-emotional activity. The behavior and actions of the individuals of the society lead to the realization of a new one economies and societies. Considering the recent changes and challenges of the medical field like personalized medicine, telehealth, blockhchain, AI&Machine learning, cancer immunotherapy, 3D printing, augumented reality & virtual reality, robotic surgery, the professionals also need to adapt.

For example, virtual reality is already transforming medical education, moving learning from the classroom, allowing students to immerse in a new world that allows them to apply their knowledge to practice and learn from mistakes without consequences. This type of technology focuses on improving competencies and helps the student learn faster and better.

Virtual and Mixed Reality for Medical Education video:
https://www.youtube.com/watch?v=PzPKdlFbvYM
This experience has the purpose of immersing ourselves in another world; it stimulates our senses and transposes us to another place, another time or another reality; we travel in time and space, in a virtual reality.

Immersive experiences are:
- live broadcasts of concerts, sports competitions, applications;
- video games, video games, confferences;
- cognitive and intuitive interfaces of software applications;
- use of reality extended or hybrid reality (XR or HR)
- augmented (AR). VR and AR are the two innovations that remove the limits and connects people, information and experiences. The degree of immersion of a experiences depends

on: visual quality (resolution, color accuracy, light, sound), sound quality (intensity, frequency, amplitude), intuitive interactions.

Using this type of technology, we can transform any space from reality into an interactive digital format or we can create a new digital space. These technologies help us, immersive, partially or totally in another world; it stimulates our senses and transposes us into one place or in another reality.

Learning from experience has three components:
- concepts, facts, information and previous experience, activities
- knowledge applied to current events, and reflection
- thinking focused on their own analysis and evaluation activity

2.5. Applications- examples of using DLO's for health professionals training

As we mentioned before, we can use cooking ingredients to explain measurement, vocabulary and cooking. We wiil try to find what else can DLO's be used for, during the exercises below.

Exercise 1: Create your own example like the one we gave above. Use that example in a lesson you teach or to explain something. How did you use it?

Exercise 2: Write a story to explain a concept. Use that story in at least two sittuations;

Exercise 3: Create your own DLO starting from the folowing questions:
a. What needs to be learned?
b. Who needs to learn it?
c. What do we need to prepare before we start learning?

3. Using DLOs for training, planning and optimization of medical procedures

GENERAL GOAL:	This module is designed to teach participants how to use 3D models for training, planning, and optimizing medical procedures using Digital Learning Objects (DLOs).
LEARNING OUTCOMES:	The participants should learn: What a DLO is and how to use it The possibilities of 2D and 3D DLOs How to apply the AO-classification How DLOs can be used for surgical training How to use DLOs for quality assurance
METHODS	Lecture, presentations, flipchart, self-study, case studies, video.
DURATION:	2 hours
RESOURCES NEEDED	Computer, Software: Powerpoint and VLC-Player Projector, Smartphone/Tablet, Internet
SCENARIO FOR FACE-TO-FACE TRAINING	
	SECTION 1 - Introduction Activity 1: Talk: Explanation of DLO's Activity 2: Talk: Explanation of the aim of the module and learning objectives
	SECTION 2 - Introduction to DLOs for medical training, planning, and optimization Activity 1: Read and discuss: Interactive 3D Digital Models for Anatomy and Medical Education Activity 2: Find and display a 3D-Model of a Tibia Plateau Fracture
	SECTION 3 – The AO classification of long bone fractures Activity 1: Talk: Introduction to the AO classification Activity 2: Independent/self-study Activity 3: Quiz
	SECTION 4 – Video: Talk by Dr. Robert Pätzold (BG Unfallklinik Murnau) Activity 1: Introduction Activity 2: Talk by Dr. Robert Pätzold (BG Unfallklinik Murnau) Activity 3: Discussion

EVALUATION OF THE MODULE:	Discussion of Quiz results
KEEPING LEARNERS SAFE	Ensure that access to the activity available for all
BACKGROUND CONTENTS AND HANDOUTS	PPT presentation, Video with Subtitles, Literature
REFERENCES and useful links:	[1] Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma. 2018 Jan;32 Suppl 1:S1-S170. doi: 10.1097/BOT.0000000000001063. PMID: 29256945. (download here: https://aotrauma.aofoundation.org/about/news/news-2018/news_classification_compendium_12072018) [2] Prat-Fabregat S, Camacho-Carrasco P. Treatment strategy for tibial plateau fractures: an update. EFORT Open Rev. 2017 Mar 13;1(5):225-232. doi: 10.1302/2058-5241.1.000031. PMID: 28461952; PMCID: PMC5367528. [3] Mair O, Pflüger P, Hoffeld K, Braun KF, Kirchhoff C, Biberthaler P, Crönlein M. Management of Pilon Fractures-Current Concepts. Front Surg. 2021 Dec 23;8:764232. doi: 10.3389/fsurg.2021.764232. PMID: 35004835; PMCID: PMC8732374. [4] Kerschbaum M, Tyczka M, Klute L, Heller MT, Koch M, Popp D, Lang S, Alt V, Worlicek M. The Tibial Plateau Map: Fracture Line Morphology of Intra-Articular Proximal Tibial Fractures. Biomed Res Int. 2021 Aug 24;2021:9920189. doi: 10.1155/2021/9920189. PMID: 34476260; PMCID: PMC8408007. [5] Gülabi D, Bekler Hİ, Sağlam F, Taşdemir Z, Çeçen GS, Elmalı N. Surgical treatment of distal tibia fractures: open versus MIPO. Ulus Travma Acil Cerrahi Derg. 2016 Jan;22(1):52-7. doi: 10.5505/tjtes.2015.82026. PMID: 27135079. 3D-Model platforms Medical platforms: embodi3d.com, 3dprint.nih.gov General platforms: thingiverse.com, grabcad.com/library, sketchfab.com Meta-search engines: thangs.com, yeggi.com

3.1 Introduction

In general, a digital learning object, or DLO for short, is understood to be so-called digital units, such as images, videos, audios or texts, which are made available via the internet. Thus, any number of people can access and use these objects simultaneously.

3D technology and digital learning objects (DLOs) provide powerful tools with valuable applications in healthcare, especially in the planning and optimisation of medical procedures as well as in medical education and training

The learning objectives for this module are as follows:

KEY TECHNICAL OUTCOME	KNOWLEDGE	SKILLS	COMPETENCE
Retrieve information and data regarding the use of DLO´s in medicine	The Learner knows and understands: Types of DLO`s in medicine Principles of DLO use The role of DLO in training, planning and optimization of medical procedures	The Learner is able to: Gather information on DLO´s in medicine	The Learner: Is aware of the power of DLO`s in medicine When needed, is able to find and visualize information on DLO Uses this learning for more informed reading of articles regarding DLO`s in medicine
Understanding the AO classification of fractures of tubular/long bones	The Learner knows and understands: The AO Localize bones and segments Elements of fracture morphology (types, groups, qualifications)	The Learner is able to: Identify fractures in x-ray images Perform fracture classifications	The Learner: Pays attention to AO fracture classification in reports
Detecting peculiarities in 2D and 3D (AO) classification of fractures of long tubular bones.	The Learner knows and understands: Advantages and disadvantages of fracture evaluation in 2D and 3D images	The Learner is able to: Match 3D fractures with 2D image fracture classifications	The Learner: Considers carefully that pecularities of fractures may be missed in 2D images
Using 3D models (printed) from CT data in surgery planning and training	The Learner knows and understands: OR planning its benefits How to print a 3D model from medical image data The use of 3D models in surgery training	The Learner is able to: Realize the pros and cons of an OR planning To create a 3D model from medical image data Visualize fracture and fragments Assign fragments of a 3D model to a 2D image (xray)	The Learner: Uses 3D models for teaching and planning Benefits from visualization

	The easier imagination and planning power of 3D models The use of 3D models for medical education, esp. in application of osteosynthese		
Intraoperative imaging as a tool for optimisation and quality assurance	The Learner knows and understands: The use of (3D) images for quality assurance The step-by-step approach to the management of proximal tibia fractures that 3D images are not necessary for the diagnosis of all fracture types. methods for intraoperative quality assurance in orthopaedics	The Learner is able to: improve quality in healthcare avoid unneccessary postoperative checks carry out intraoperative checks	The Learner: Identifies and adresses the differences in imaging modalities and use of DLO`s Considers carefully the DLO and imaging related options for OR quality assurance

3.2 Introduction to DLOs for medical training, planning, and optimization

Activity 1: Read and discuss: Interactive 3D Digital Models for Anatomy and Medical Education
Activity 2: Find and display a 3D-Model of a Tibia Plateau Fracture

3.3 AO Classification of long bone- fractues

In the course of this module, we will discuss training, planning of care and optimisation of medical procedures using examples from orthopaedics and trauma surgery, especially the care of fractures.

For this purpose it is necessary to give you an introduction to the so-called AO classification of long bone fractures, also called Müller classification. DLOs of fractures of the extremities are also named with this classification in the Ale3andria Library.

AO stands for "Arbeitsgemeinschaft für Osteosynthesefragen" (Working Group for Osteosynthesis Issues). The AO Foundation is a medical foundation based in Chur, Switzerland.

The AO classification is a (numerical) system for describing the localisation and characteristics of bone fractures, with the aim of creating a (worldwide) unambiguous classification of fractures in order to subsequently enable standardised treatment.

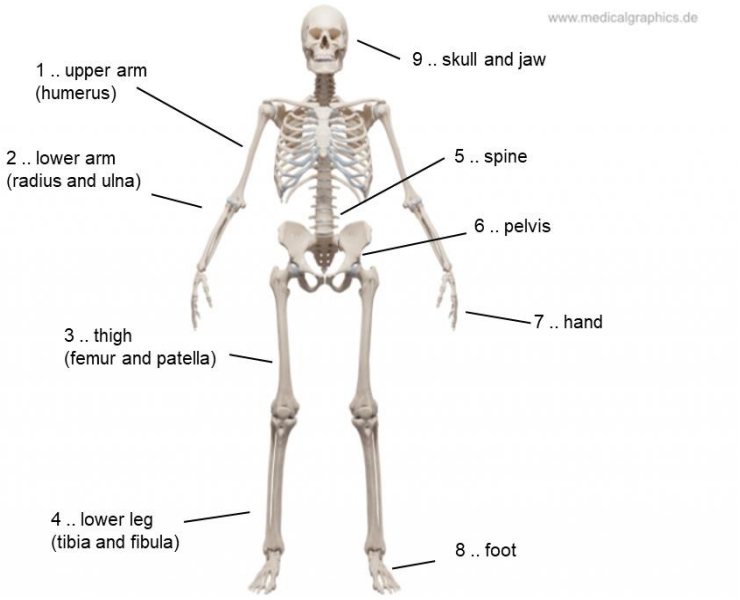
Fractures are described in the AO classification using a 5-digit code. The first number describes the region of the body where the fracture is located. The second number describes the more specific fracture location within this body region and the third number evaluates this fracture. Two further numbers can be used to describe the severity of the injury more precisely. (However, these will not be considered in detail in this course).

So the first two numbers describe the localisation of the fracture and the other three numbers describe the mophology of the fracture.

- **First position of the AO classification code: Description of the body region where the fracture is located.**

The first number of the AO code describes the region in which the fracture is located. Number 1 describes the upper arm (humerus) and number 2 both bones of the forearm, ulna and radius. The thigh (femur) is designated by number 3, while number 4 names both bones of the lower leg, tibia and fibula. The fractures of these 4 regions, the so-called long bones, will be the main focus of this module.

The other numbers are 5- the spine; number 6 describes the pelvis. The hand is number 7 and the foot number 8. As the last single digit, number 9 is attributed to the area of the head and the lower jaw.



Free illustration of a human skeleton from front (Creative commons - Attribution-NoDerivatives 4.0 International (CC BY-ND 4.0), http://www.medicalgraphics.de/en/free-pictures/skeleton/skeleton-front.html)

- **Second position of the AO classification code: Specific fracture location within the body region**

The next digit in the numerical code describes the specific region within the body region- the segment. There are only 4 different possibilities here.

1 describes that the fracture is proximal, i.e. "towards the trunk", "towards the centre of the body" or "closer".

Number 2 describes that the fracture is diaphyseal. This means that the diaphysis of the bone is affected. The diaphysis describes the shaft of a bone.

A code with number 3 in the second place, that the fracture is distal. The anatomical term distal means "further from the trunk" or also "away from the centre of the body".

In some bones there is also a fourth region, which describes that the fracture is only localised in region 3 or 4.

- **Third position of the AO classification code: Evaluation of the fracture**

The third position of the code describing types of fractures in long bones is no longer designated with numbers but with capital letters A, B and C instead.

The letter A is used to designate simple or extra-articular fractures, i.e. fractures that do not involve the joint. „B“ describes wedge fractures or fractures with partial involvement of the joint. And finally, the letter C describes severe, complex fractures or fractures with complete involvement of the joint.

- **Fourth and fifth position of the AO classification code**

For the sake of completeness: The fourth and fifth positions of the AO classification code describe the morphology of the fracture type in more detail and are divided into groups (1 to 3) and subgroups (.1 to .3). [1]

Co-funded by the Erasmus+ Programme of the European Union

AO classification

Example

(Long) Bones

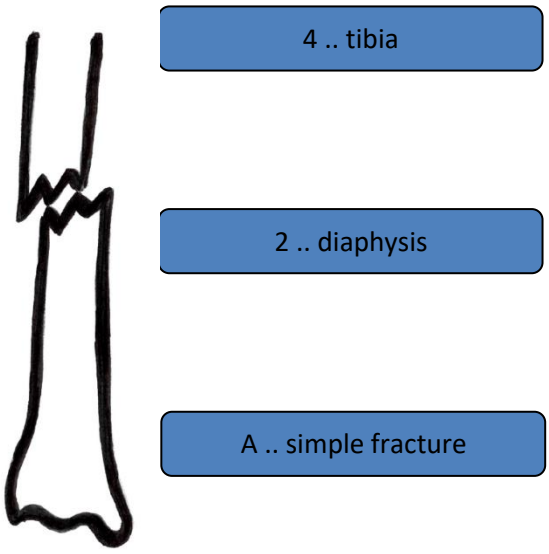
1 .. Humerus
2 .. Radius and ulna
3 .. Femur and patella
4 .. Tibia and fibula

Segment

1 .. Proximal
2 .. Diaphyseal
3 .. Distal
4 .. Exceptions (e.g. malleolar fractures)

Fracture Type

A .. simple or extra-articular
B .. wedge fractures or fractures with partial involvement of the joint
C .. complex fractures or fractures with complete involvement of the joint



Independent/self study

Navigate to https://aotrauma.aofoundation.org/about/news/news-2018/news_classification_compendium_12072018 and download the AO Classification 2018. It is downloadable there for free.

Take some time to go through this comprehensive booklet. In this self-study, look especially at the chapters "Fundamentals of fracture classification" (S4-S8), "Alphanumeric structure of the AO/OTA classification" (S9) and the fracture types of the long bones (S11-S70). Pay particular attention to the fracture types of the tibia (S49-S59), because will focus on fractures of the tibia during the course.

3.4 Video: Talk by Dr. Robert Pätzold (BG Unfallklinik Murnau)

4. Using DLO's for training in the diagnostic process

GENERAL GOAL:	The general goal of the module is to provide basic material for understanding of digital learning objects and how it can be used in medical diagnostic process, especially to study and visualize Digital Learning Objects (DLOs) from Ale3xandria online library.
LEARNING OUTCOMES:	By the end of the module, participants will be able to: ● Get to know the basics of DLOs and its applications in the diagnostic process ● Gain knowledge on diagnostic process and decision making ● Discover the field of simulation-based training and learning ● Understand the challenges connected with use DLO-s in diagnostic process ● Appraise how deep learning models coupled with image processing ● Understand how DLO-s can help diagnosing and decision-making process using Ale3xandria library.
METHODS	Self-reading, self-study, idea presentations, educational film, videos, self-assessment,discussion and group discussion can be added.
DURATION:	2 hours
RESOURCES NEEDED	Computer or laptop, Internet connection (LAN or Wi-Fi network) Monitor, video-projector, Multimedia, paper, flipchart, markers Access to scientific data bases (PubMed, EBSCO, etc.), online platforms / applications necessary links Access to 3DdigitalVet e-Learning Platform Access to Ale3xandria library
SCENARIO FOR FACE TO FACE TRAINING	

	SECTION 1 - Introduction Activity 1: Short introduction to the course, a discussion The aim of the module is: ● Introduction of the module content, learning outcomes and structure ● To give an overview about activities and materials available ● To explain the independent course-work tasks and evaluation criteria. Activity 2: Independent reading (material provided in Moodl**e).** The aim of the module is: ● To describe the situation in the field of DLO-s in the field of digital health services ● To give an overview of global initiatives and directions
	SECTION 2 - Diagnostic process, decision making Activity 1: Independently reading "Diagnostic process and decision making" (material provided in moodle) Students analyze the diagnostic processes and decision-making challenges in the era of digital medicine when higher education system need to be prepared to give a new complex skills and competences to the students. Activity 2: Independent work "My personal experience gaining digital skills for diagnosing and decision making during my studies. Experience of using DLO-s during the studies". "Think and write down your positive and negative experiences. Bring up some ideas and solutions how to increase digital skills and competences in medical decision making in university curriculums." Activity 3: Present your ideas. Each learner is presenting their ideas and solutions how to increase digital skills and competences in medical decision making in high-school curriculums.
	SECTION 3 - Classification Activity 1: watching a video-lecture "(AI Applications in Medical Imaging) Classification"

	SECTION 4 - Simulation-based training Activity 1: Independent reading "Simulation-based training/learning" (material provided in Moodle) Given material introduces the simulation as a learning tool. It also gives definitions and examples, how simulation-based training and learning is used in medicine. Activity 2: Watching a video "Using 3D models in virtual surgical planning in dentistry" Student must watch the video and then answer questions in Activity 4.
	SECTION 5 - Future: deep learning models coupled with image processing Activity 1: Independent reading (Material provided in Moodle). How technology changes and advancements have always directly influenced the radiography profession with radiographic practice evolving and adapting in response to the operation of new technologies and the advanced imaging opportunities offered by their adoption. Lecture introduces new perspectives. Activity 2: watching video "How AI is making it easier to diagnose disease"
	SECTION 6 - Challenges **Activity 1: Independent learning** Students must list all the challenges, based on all materials they have got during the module.
	SECTION 7 - Comparison exercises 2D (x-ray) and 3D using Al3xandria 3D medical library Activity 1 – Exercise 1: Comparison exercises 2D (x-ray) and 3D using Al3xandria 3D medical library**.** Three x-ray images attached (CEPH1.tif, OPTG1.tif, OPTG2.tif) Students compare the 2D and 3D images (attached) and then submit their answers using Moodle "online text" assignment and Al3xandria medical library. Please take a look into the 3D medical library and find a case diagnosed as cleidocranial dysplasia. Please take a look at all added x-rays separately as well as a digital model and think what you can see and

	maybe cannot see on those separate diagnostic materials. What can you see more, if you have all 3 images available during the diagnosing process? Activity 2 – Exercise 2: Comparison exercises 2D (x-ray) and 3D using Al3xandria 3D medical library**.** Three X-ray images attached (CEPH1.tif, OPTG1.tif, OPTG2.tif). Students compare the 2D and 3D images (attached) and then submit their answers using Moodle "online text" assignment and Al3xandria medical library. Please take a look into the 3D medical library and find a case diagnosed as cleft lip and palate. Please look at all added x-rays separately as well as a digital model and think what you can see and maybe cannot see on those separate diagnostic materials. What can you see more, if you have all 3 images available during the diagnosing process?
EVALUATION OF THE MODULE:	Eg: Teacher evaluation of student's activities and quizzes.
KEEPING LEARNERS SAFE	Whole module is free of charge for everybody, but needs online registering to ensure logging in several times COVID-19 prevention – in case of another COVID-19 outbreak, the course is available totally online via Moodle environment, to keep learners safe, but in other time FACE-TO-FACE training can also be conducted with minor adaptations
BACKGROUND CONTENTS AND HANDOUTS	Video "Using 3D models in virtual surgical planning in dentistry": https://youtu.be/KgUfUkDIQoE Video by Pratik Shah https://youtu.be/mhEYvrFOP88 Video lecture 1 https://youtu.be/xSyot-U0hrM Video lecture 2: https://youtu.be/6O71XBqZ-wc Video lecture 3: https://youtu.be/ryUCJHk2ckU Video lecture 4: https://youtu.be/6pQbJKo1WsY
REFERENCES and useful links:	**List of references:** Ahlberg, G., Enochsson, L., Gallagher, A. G., Hedman, L., Hogman, C., McClusky, D. A., Ramel, S., Smith, D., Arvidsson, D. (2007). Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies.

American Journal of Surgery, 193(6), 797–804. https://doi.org/10.1016/j.amjsurg.2006.06.050

AHSN Network AI Report (2018): https://wessexahsn.org.uk/img/news/AHSN%20Network%20AI%20Report-1536078823.pdf

Biese, K., Moro-Sutherland, D., Furberg, R., Downing, B., Glickman, L., Murphy, A., Jackson, C., Snyder, G., Hobgood, C. (2009). Using screen-based simulation to improve performance during pediatric resuscitation. Academic Emergency Medicine, 16(2), 71–75. https://doi.org/10.1111/j.1553-2712.2009.00590.x

Cook, D. A. (2014). How much evidence does it take? A cumulative meta-analysis of outcomes of simulation-based education. Medical Education, 48(8), 750–760. https://doi.org/10.1111/medu.12473

Cook, D. A., Brydges, R., Zendejas, B., Hamstra, S. J., Hatala, R. (2013). Technology-enhanced simulation to assess health professionals: A systematic review of validity evidence, research methods, and reporting quality. Academic Medicine, 88(6), 872–883. https://doi.org/10.1097/ACM.0b013e31828ffdcf

Council of European Union. Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0745

Cruz, I. Moodle and nursing teaching: a brief experience report. Online Braz J Nurs. 2009;8(1) Davidsson, P., Verhagen, H. (2017). Types of simulation. In Edmonds, B., Meyer, R. (Eds.), Simulating social complexity. Understanding complex systems (pp. 23–37). Springer. https://doi.org/10.1007/978-3-319-66948-9_3

Dinggang, S., Guorong, W., Heung-Il S. (2017) Learning in Medical Image Analysis (free article for home-reading). Annu Rev Biomed Eng 19:221-248. doi: 10.1146/annurev-bioeng-071516-044442
https://pubmed.ncbi.nlm.nih.gov/28301734/
Google Scholar: link

Graber ML, Franklin N, Gordon R. Diagnostic error in internal medicine. Arch Intern Med. 2005;165(13):1493-9

Hegland, P. A., Aarlie, H., Strømme, H., Jamtvedt, G. (2017). Simulation-based training for nurses: Systematic review and meta-analysis. Nurse Education Today, 54(1), 6–20. **(Suggested reading about curriculum development)**https://doi.org/10.1016/j.nedt.2017.04.004

Kuhn, T., P. Basch, M. Barr, and T. Yackel. 2015. Clinical documentation in the 21st century: Executive summary of a policy position paper from the American College of Physicians. Annals of Internal Medicine 162(4):301–303
Ober, K. P. 2015. The electronic health record: Are we the tools of our tools? The Pharos 78(1):8–14

Springer „3D Virtual Treatment Planning of Orthognathic Surgery“ , 2017 https://link.springer.com/book/10.1007/978-3-662-47389-4

Tamashiro LMC, Peres HHC. Desenvolvimento e avaliação de objetos de aprendizagem sobre administração de medicamentos por via intramuscular. Rev Latino-Am Enfermagem. 2014; 22(5):716-23.

Thomas S. Kuhn: The Structure of Scientific Revolutions. The University of Chicago press. 1996

Liaw, S., Chan, S., Chen, F. G., Hooi, S., Siau, C. (2014). Comparison of virtual patient simulation with mannequin-based simulation for improving clinical performances in assessing and managing clinical deterioration: Randomized controlled trial. Journal of Medical Internet Research, 16(9), Article e214. https://doi.org/10.2196/jmir.3322
Oxford Reference: link
Sawaya, R.D., Mrad, S., Rajha, E. et al. Simulation-based curriculum development: lessons learnt in Global Health education. BMC Med Educ 21, 33 (2021). https://doi.org/10.1186/s12909-020-02430-9
(Suggested reading about curriculum development)
WHO Focus Group on Artificial Intelligence for Health: https://www.itu.int/en/ITU-T/focusgroups/ai4h/Pages/default.aspx

5. 3D printing of DLO's

GENERAL GOAL:	The general goal of this module is to provide basic understanding of the principles underlying the 3D printing processes with the aim of choosing the most appropriate combination of production material(s) and kind of 3D printer.
LEARNING OUTCOMES:	Knowledge about 3D printing Ability to choose the right design software Ability to choose the right production machine Acquire basic principles of 3D productions Acquire basic understanding of 3D printing materials
METHODS	Reading documents Watching videos and tutorial Practice with own 3D printers (if available) Practice with own software (if available) In case of face-to-face teaching, discussions with teacher(s) and other colleagues
DURATION	2 hours
RESOURCES NEEDED	Computer, Internet access, Free reading software (Adobe Acrobat Reader) Free design software (es.g. 3D Slicer). A basic knowledge should be acquired before the course in order to explain to students the concepts. Free slicing software (depending on 3D printer; we'll explore PreForm). A basic knowledge should be acquired before the course in order to explain to students the concepts. Understanding of standard DICOM fomat Understanding the concept of set of planar imaging (CTs, MRIs, ECO3D)
SCENARIO FOR FACE-TO-FACE TRAINING	
	SECTION 1-Introduction: what is a 3D printed DLO Activity 1: Introduction to 3D printing Activity 2: Introduction to models of anatomic replicas Activity 3: Introduction to medical design for 3D printing
	Use documents and videos to show the use of anatomic replicas for learning purposes. Go to Al3xandria platform and show 3D models

	Show 3D slicer to demonstrate how the process to get a 3D file starting with a DICOM file works
	SECTION 2 – CAD Principles Activity 1: What a CAD is and why we need it Activity 2: INPUT data: TC, MRIs, ECO3D, 3D Scan Activity 3: Segmentation
	SECTION 3 -3D printing in the Biomedical field Activity 1: From DICOM to STL and vice versa Activity 2: Use case of anatomic replicas Activity 3:
	SECTION 4 -3D Printing Technologies Activity 1: 3D printing technologies Activity 2: Focus: FDM Activity 3: Focus: SLA
	Section 5: 3D printing materials Activity 1: Available materials for DLOs Activity 2: Choosing the right material(s)
	Section 6: 3D Design Activity 1: Available materials for DLOs Activity 2: Choosing the right material(s)
EVALUATION OF THE MODULE:	Students will be evaluated using quizzes In person and with the availability of proper software and 3D printers, practical tests can be performed.
KEEPING LEARNERS SAFE	· Ensure that access to the activity available for all · Ensure room large enough to allow mobility for all learners. • 3D printers can incorporate hot ends and other elements potentially dangerous for users. Be aware to keep all the safe requirements described by the producer of the machine
BACKGROUND CONTENTS AND HANDOUTS	The use of anatomic replicas in dental surgery : https://youtu.be/MJQgtuGoYpg The use of soft tissues anatomic models https://youtu.be/NDDRxivHoYw Anatomic models for surgical planning: https://youtu.be/-ZmbBYR-3e4

REFERENCES and usefull links:	PUBMED articles on simulation: https://pubmed.ncbi.nlm.nih.gov/24958045/ https://pubmed.ncbi.nlm.nih.gov/24776857/ https://pubmed.ncbi.nlm.nih.gov/26438547/ https://pubmed.ncbi.nlm.nih.gov/27366318/

6. Using DLO's in conjunction with Virtual Reality

GENERAL GOAL:	The general goal of the module is to equip learners with basic understanding of Virtual Reality (VR) technology and how it can be used in medical training, especially to study and visualize Digital Learning Objects (DLOs) from Ale3andria online library.
LEARNING OUTCOMES:	By the end of the module, participants will be able to: • Get to know the basics of VR technology and its applications in the medical field • Gain knowledge on the uses of VR in medical training • Demonstrate the understanding of VR applications for visualization and analysis of DLOs • Understand how VR can be used to study and visualize DLOs from Ale3andria
METHODS	Lectures, presentations, self-study, discussions based on case studies, group discussions, self-assessment, videos.
DURATION:	**2 hours**
RESOURCES NEEDED	For face-to-face training: • Access to 3DdigitalVet e-Learning Platform, Access to Ale3andria library • Paper, flipchart, markers • Laptop (for presentation), Monitor/projector,Internet connection • Personal computers with the *3D Slicer* application installed • Useful links

SCENARIO FOR FACE-TO-FACE TRAINING	
	SECTION 1 - Introduction Activity 1: Short introduction to the course. The aim of the module is being explained in the most detailed manner. The module is aiming to increase

	the awareness of learners in the field of Virtual Reality (VR) technology for medical training. Learning outcomes of the module are being presented and explained. • The first learning outcome is the ability to describe the basic features of VR technology and its applications in the medical field. Learners are introduced to the definition, types and principle of VR, interactive devices, VR advantages and limitations, and VR applications in the medical field. • The second learning outcome is the ability to provide examples of VR applications in medical training. Learners are introduced to the benefits and challenges related to the use of VR for medical training, and VR applications in Medical Training. • The third learning outcome is the ability to describe how VR can be used for Digital Learning Objects (DLOs) visualization. Learners are introduced to the visualization of unsegmented image data (DICOM files) and of segmented images (3D models) using VR and VR combined with 3D-printed models. In addition, the students learn about the unique value propositions from both VR and 3D printing technologies in the field of medical images visualization. • The fourth learning outcome is the ability to use VR in order to study and visualize DLOs from the Ale3andria library. Learners are introduced to the free and open-source *3D Slicer* application and learn how to use it for Ale3andria 3D models visualization. Activity 2: Group discussion "My personal experience in DLOs visualization" The learners are divided in two groups, which discuss the benefits and challenges of various techniques for 3D digital medical models' visualization. The discussion is moderated by the trainer. The resolution is being created in the end of discussion.
	SECTION 2 - Introduction to Virtual Reality Activity 1: Lecture „ What is Virtual Reality? " The trainer lectures on VR with the help of the section „ What is Virtual Reality?" of the "Using DLOs in conjunction with Virtual Reality" module from 3DdigitalVet e-Learning Platform. Theoretical interactive lecture is covering general aspects related to VR technology: definition, principle, types of VR and equipment. Activity 2: Group discussion "My personal experience with VR" The learners are divided in small groups, which discuss the main features of VR, the differences between the 3 types of VR and the characteristics of the most common devices used in VR applications.

	SECTION 3 – Virtual Reality in the medical field Activity 1: Lecture „Virtual Reality in the medical field" .The trainer lectures on VR with the help of the section „ Virtual Reality in the medical field" of the "Using DLOs in conjunction with Virtual Reality" module from 3DdigitalVet e-Learning Platform. Theoretical interactive lecture is covering the main aspects related to VR applications in the medical field: key medical areas where VR is used, specific applications, advantages, limitations. In addition, the future of VR applications in the medical field is discussed. Activity 2: Case Study Seminar. Learners are working in small groups. They are analyzing the cases based on their own personal experience related with VR applications. In the first 10 minutes, they conduct a brainstorming activity, share ideas in the group and select a possible medical application of VR to be further analyzed. The main questions for case analysis are: how VR could transform the selected application and how this application can be improved in the future thanks to the expected technological advances.
	SECTION 4 – **Medical training using Virtual Reality** Activity 1: Lecture „Virtual Reality in Medical Training" .The trainer lectures on VR with the help of the section „ Virtual Reality in Medical Training" of the "Using DLOs in conjunction with Virtual Reality" module from 3DdigitalVet e-Learning Platform. Theoretical interactive lecture is covering the main aspects related to VR applications for medical training: benefits, challenges, specific applications. Activity 2: Watching a video on VR medical emergency training Participants watch a video about the use of VR to train physicians for pediatric emergencies (video 1) Activity 3: Video discussion. The trainer divides participants into small groups and ask them to discuss the following: • What are the benefits of using VR for medical emergency training? • Why is important for a doctor to be trained for emergency situation? • What other medical training types could benefit from VR technology? Activity 4: Watching a video on VR surgery training. Participants watch a video about the use of VR to train surgeons (video 2) Activity 5: Video discussion the trainer divides participants into small groups and ask them to discuss the following: • What are the benefits of using VR for surgery training?

	• Why is important for a surgeon to be trained for a specific procedure?
	SECTION 5 – DLOs visualization with VR Activity 1: Lecture „ VR application for DLOs visualization The trainer lectures on VR with the help of the section „VR application for DLOs visualization" of the "Using DLOs in conjunction with Virtual Reality" module from 3DdigitalVet e-Learning Platform. Theoretical interactive lecture is covering the main aspects related to DLOs visualization: the visualization of unsegmented image data (DICOM files) and of segmented images (3D models), the use of VR and of VR combined with 3D-printed models. In addition, the unique value propositions from both VR and 3D printing technologies in the field of medical images visualization are presented and discussed. Activity 2: Ale3andria 3D models visualisation with 3D Slicer The learners select a 3D model from Al3xandria 3D medical library and download it on computers having the *3D Slicer* open-source application installed. Then, they open the 3D model in *3D Slicer,* using "Load Data" button, and use the existing visualisation tools to explore the model.
EVALUATION OF THE MODULE:	Quizz
KEEPING LEARNERS SAFE	Ensure that access to the activity available for all Ensure room large enough to allow mobility for all learners.
BACKGROUND CONTENTS AND HANDOUTS	• Teaching material "Using DLOs in conjunction with Virtual Reality" module • Video 1 https://youtu.be/LGzzdlAP_S0 • Video 2 https://youtu.be/S0eMvdZElgc
REFERENCES AND USEFUL LINKS:	• A list of free and open source medical imaging softwarehttps://idoimaging.com/ • A list of free DICOM viewers, www.postdicom.com/en/blog/top-25-free-dicom-viewers • A list of open-source web-based DICOM viewers https://medevel.com/14-best-browser-web-based-dicom-viewers-projects/ • Medical Software Solution https://www.materialise.com/en/medical/software • UCSF ChimeraX software, https://www.cgl.ucsf.edu/chimerax/

	• Tutorial on VR vizualisation of DICOMs https://www.rbvi.ucsf.edu/chimera/data/dicom-feb2019/images/dicomvr.mp4 • Elucis, a VR platform for creating and using 3D medical models, https://www.realizemed.com/elucis/ • The Physiology of the Eye, an interactive VR platform, https://store.steampowered.com/app/582200/The_Physiology_of_the_Eye/ • Dissection Master XR, a VR dissection and anatomy lab for anatomy teaching, https://www.medicalholodeck.com/en/human-anatomy-lab-virtual-reality/ • Medical Imaging XR, enables the processing of DICOM data in VR, https://www.medicalholodeck.com/en/dicom-viewer-medical-virtual-reality/ • Anatomy Master XR, a human anatomy lab in VR, https://www.medicalholodeck.com/en/3D-human-anatomy-by-zygote-in-virtual-reality/ • Sharecare YOU, a real-time simulation of the human body, https://www.sharecare.com/pages/vr • Immersive VR Anatomy Learning and Simulation Training, https://www.mai.ai/bodymap/ • ImmersiveView Surgical Plan, a platform that generates high-fidelity 3D VR replicas from DICOM files, https://www.immersivetouch.com/immersiveview-surgical-plan • SimLab Mobile AR/VR Viewer https://www.simlab-soft.com/technologies/simlab-mobile-viewer.aspx • 3D Slicer, a software to solve advanced image computing challenges with a focus on clinical and biomedical applications, https://www.slicer.org/ • "VIVATOP" project (Versatile Immersive Virtual and Augmented Tangible OP), http://vivatop.de/en/ • What Is Fully-Immersive VR? – Technology Explained, https://cyberpulse.info/what-is-fully-immersive-vr-technology-explained/ • 10 applications of virtual reality in medicine, https://www.outsource2india.com/Healthcare/articles/10-applications-of-virtual-reality-in-medicine.asp

	• 5 Ways Medical Virtual Reality Is Already Changing Healthcare, https://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/ • Virtual Reality in Healthcare, https://visualise.com/virtual-reality/virtual-reality-healthcare • Implementing VR & AR in Medicine and Medical Training, https://onix-systems.com/blog/implementing-virtual-reality-in-medicine-and-medical-training

6.1 Introduction

Digital Learning Objects (DLOs) of the online library (Ale3andria) are 3D digital medical models that contain the original medical imaging of a specific case (computed tomography (CT) scans, magnetic resonance imaging (MRI) scans, ultrasound, radiography), a document containing the description of the medical conditions of the patient (age, sex, illness, relevant previous facts, treatments, etc.) and 3D models (the three-dimensional reconstruction (segmentation) of a set of planar images).

Virtual Reality (VR) is a technology that creates a virtual environment which enable people to explore and interact with 3D models. It is a great option for delivering educational content and experiences and can be used to visualise the 3D models from Ale3andria, as a virtual experience or in conjunction with 3D printed objects.

The aim of this module is:

- to provide a basic understanding of VR technology
- to provide knowledge on uses of VR in medical training
- to suggest ways of using VR to study/visualize DLO's from Ale3andria

The main learning outcomes of the module are:

- The first learning outcome is the ability to describe the basic features of VR technology and its applications in the medical field. Learners are introduced to the definition, types and principle of VR, interactive devices, VR advantages and limitations, and VR applications in the medical field.
- The second learning outcome is the ability to provide examples of VR applications in medical training. Learners are introduced to the benefits and challenges related to the use of VR for medical training, and VR applications in Medical Training.

- The third learning outcome is the ability to describe how VR can be used for Digital Learning Objects (DLOs) visualization. Learners are introduced to the visualization of unsegmented image data (DICOM files) and of segmented images (3D models) using VR and VR combined with 3D-printed models. In addition, the students learn about the unique value propositions from both VR and 3D printing technologies in the field of medical images visualization.
- The fourth learning outcome is the ability to use VR in order to study and visualize DLOs from the Ale3andria library. Learners are introduced to the free and open-source *3D Slicer* application and learn how to use it for Ale3andria 3D models visualization.

6.2. Introduction to Virtual Reality

Virtual reality (VR) is a computer-generated simulation of an environment or three-dimensional image where people can explore and interact through sensory stimuli (usually sight and sound). VR applications immerse the user in this environment through the use of interactive devices, which send and receive information. The devices can be worn as goggles, headsets, gloves, etc. The stereoscopic 3D image is created by projecting a pair of two-dimensional images, one to each eye, with a slight difference in perspectives.
A person using VR equipment is able to look around the artificial world, move around in it, and interact with virtual features or items.

VR has multiple applications in various fields, from military training and sport to mental health treatment and therapy, medical training, and education. For example, thanks to its interactive nature, VR is used by surgeons and medical students in order to practice surgeries and procedures. Among the features that make VR very useful for education and training, we can mention:
- it presents environments and/or objects in 3D
- it allows for a direct interaction with the environment
- it is able to give audio, visual and even haptic feedback

VR offers a number of advantages, such as:

- enables and promotes active learning, by enabling interactivity and feedback during training
- offers a detailed and sharp view of 3D models or environments
- Provides training in a safe and affordable manner
- Enhance the effectiveness of learning materials
- Offers new and formerly “impossible” experiences

The main challenges and limitations of VR are related with the difficulty of finding or producing the content. Also, the initial cost to setup VR applications can be quite high and the high-quality VR devices can be quite expensive. In addition, VR immersion can induce mild and temporary discomforts such as nausea, dizziness or headache.

Types of VR

There are types of VR which engage users in their specific ways.

- **Non-immersive VR** - provides users with a computer-generated environment without a feeling of being immersed in the virtual world. The users can control some characters or activities within the virtual environment, but the this is not directly interacting with them. An example of non-immersive VR is a computer game where the user can control aspects of the character and they will have an effect on the virtual environment of the game. Technically the user is interacting with a virtual environment but not directly, the character in the game does that.

- **Semi-immersive VR** - allows users to experience and move around virtual 3D environments but they have only visual experience, with no physical sensations. An example of semi-immersive VR is a virtual tour.
- **Fully-immersive VR** – ensures a realistic virtual experience allowing users to perceive environments using visuals, auditory, and haptics. An example of fully-immersive VR is a Virtual Gaming Zone, where the players can interact with the virtual environment using special gear, all at the same time, and play with or against each other.

VR equipment

The most common devices used in VR applications are:

- **Head-mounted display** (HMD) are devices having a head strap mounted onto the user's head, with the display lenses and earphones attached to the strap. HMDs provide an immersive VR experience where objects are placed in front of the user. Some examples of HMDs: Oculus Quest, HTC Vive, Valve Index VR Kit, Gear VR, Google Cardboard, etc.
- **Smart glasses** are wearable computer glasses and can have different functions, including to add information in conjunction with or to what the wearer sees. Some examples of smart glasses: Vuzix Blade, Ray-Ban Stories, Amazon – Echo Frames and Microsoft – HoloLens.
- **Haptic gloves** are wearable devices allowing for realistic interactions with virtual environments through advanced tactile feedback. They recreate a realistic touch

experience for users. Thanks to their capability to reproduce surgical simulations, the haptic gloves can make the surgical training more immersive and effective. Some examples of haptic gloves: HAPTX GLOVES DK2, VR Gluv, Prime X Haptic VR gloves, SenseGlove. Depending on the type of VR, other equipment may be used.

Non-immersive VR systems rely on a computer or video game console, display, and input devices like keyboards, mice, and controllers. Gaming non-immersive VR systems can also use racing wheels, pedals, and speed shifters to provide users with an enhanced gaming experience. Using various input devices, users can interact with digital content on a display

Semi-immersive VR systems rely on high-resolution displays, powerful computers, and cockpits, hard simulators that partially replicate design and functionality of real-world machineries. For example, a flight simulation system can include a physical display (the airplane cockpit and chair), a large, concave screen, and powerful computer program that runs the simulation and transmits a digital 3D image on the screen. Another example is a car simulator based on a true size car model with a steering wheel and commands enabling users to drive it within a virtual environment.

Fully-immersive VR experiences involve at least three types of components: image, sound, and haptic feedback. The image and sound can be provided by a head-mounted display (HDM) or a VR headset. The haptic feedback can be provided as a force feedback, vibration, thermal feedback, electrostimulation, etc.

6.3 Virtual Reality in the medical field

VR is used in four key medical areas: therapy, training, surgery related applications, and medical research. The applications include healthcare training, patient treatment, and educating people about a disease or a medical process.

VR applications in the medical field

VR has a multitude of applications in the medical field, from developing new techniques to training the doctors of the future. Currently, the most common are the therapeutic applications.

Below are presented some examples of applications implemented in order to train and support healthcare professionals, to improve lives and to heal patients.

- ***Healthcare education***

The use of VR is emerging as a high-tech solution for improving healthcare education. It allows students to train and practise their skills in immersive and safe environments, thus gaining more confidence regarding the application of the acquired knowledge in real-life situations.

There are many VR systems currently used in medical training. For example, the VR training solutions developed by Health Scholars address emergency care training for adults, infants and children as well as various scenarios in diverse hospital settings.

- ***Exposure therapy***

Exposure therapy is a psychological treatment that involves gradual and repeated exposure of the patient to feared stimuli. It is a helpful treatment or treatment component for problems such as phobias ((fear of flying, fear of heights, fear of needles/injections, fear of dentists, fear of speaking in public, fear of dogs, fear of insect, claustrophobia, etc.), anxiety, post-traumatic stress disorder, panic disorder, obsessive-compulsive disorder, etc.

VR exposure therapy is a very effective tool allowing easy implementation of individualized, engaging, controllable, repeatable, and safe experience. It makes exposure therapy easier and more acceptable for therapists and patients, it allows therapist to see what the patient sees in the virtual environment and to choose and personalize the VR content for the patient.

- ***Patient education***

Treatments, rehabilitation, and other medical procedures are much more effective when the patient fully comprehends what they can expect. VR can help patients in understanding their health status, set appropriate expectations of various stages of a treatment plan and get a better understanding of what will happen to their body during and after a procedure.

For example, they can be taken through their surgical plan by virtually stepping into a patient-specific 360° VR reconstruction of their anatomy and pathology and get an improved understanding of the treatment as well as realistic expectations of the recovery process.

- ***Pain management***

For many patients, pain is a very serious issue and VR can be an effective treatment modality for pain management. The treatment usually involves the use of a VR headset that displays computer-generated and interactive audio and visual content designed to reduce pain through techniques such as distraction, relaxation, and mindfulness [1]. For example, the EaseVRx VR headset uses techniques like cognitive behavioural therapy to help with pain reduction in adults.

- ***Cognitive rehabilitation***

VR is a useful tool for cognitive research, evaluation, and rehabilitation and can be used as an assessment method of the cognitive function of patients with brain injury [2]. VR systems

enable patients to interact in various sensory environments, to participate in activities in settings and environments similar to those encountered in real life and to obtain real-time feedback on their performance. In addition, their performance, including cognitive function, can be accurately measured and recorded in order to help delivering better therapeutic stimulation.

- ***Social cognition training***

VR is a promising tool for improving social skills, cognition, and functioning in autism. It can be used by people with Autism Spectrum Disorder (ASD) as a learning tool, to teach safety skills, to hold their interest and practice social interactions. It is also a motivating platform to safely practice and rehearse social skills and offers an effective treatment option for improving social impairments commonly found in ASD.

- ***Stroke rehabilitation***

VR is currently applied in clinical trials of stroke rehabilitation and helps in developing more effective rehabilitation approaches. It allows patients to engage in intensive, repetitive and task-oriented practice thus promoting neuroplasticity and recovery. A recent study shown the benefits of using a VR-game together with a treadmill for gait rehabilitation after stroke. Both involved clinicians and patients saw a high potential of implementing VR-games in clinical practice.

Main benefits of using VR in the medical field

VR can help patients communicate and better understand their health situation, treatment plan, etc. In conjunction with medication and other kinds of therapy and treatments, VR can improve the patients' quality of life in real time or over long periods.

VR has the potential to revolutionize healthcare and medical training, to improve visualization of human anatomy, while reducing medical costs, decreasing trauma, and improving results. Some of the main benefits of using VR in the medical field are discussed below.

- ***Reduces risks for patients and healthcare professionals***

VR training can give healthcare professionals the training they need without putting anyone's life in danger. Surgeons can gain experience for how to complete a complicated surgery and emergency technicians can learn how to properly perform various critical procedures. Both patients and healthcare professionals benefit from a real-time hands-on training made possible by VR technology.

- ***Improved patient education and more effective treatments***

VR enables patients to learn about their diagnoses and medications, to understand tests and procedures, to have a better view about what is involved in the clinical trial and, ultimately, to have better understanding about their conditions. This enables more effective treatments, rehabilitation, and other medical procedures.

- **Better stress management for patients**

VR helps patients to manage stress by providing them with easy to understand information, making them to more in control and comfortable and helping them to reduce patients stress, anxiety and need for pain medication.

More detailed medical imaging for doctors

VR can improve the doctor's understanding of patient structures and diseases by providing 3D forms of CT scan and MRI images. This will result in better outcomes for patients, in a shorter time.

- ***Faster rehabilitation***

Immersive VR therapy can help patients with stroke and brain injury to regain motor and cognitive functions faster than physical therapy. The patients are motivated to practice the activities while physiotherapists are assisted in making informed decisions related to the training programme.

Using VR, the healthcare professionals can help their patients to exercise and to move their bodies in ways that may be difficult in physical therapy. In a simulated environment, patients end up exercising faster or more easily.

- ***Savings in costs and material resources***

VR offers the opportunity to experience things without large operational costs and the need for travel. It also can save on costly and precious natural resource used in training, such as blood, cadavers etc.

- ***Improved and new services***

VR can improve the quality of healthcare services by allowing healthcare professionals to practice in a virtual clinical setting whenever it is needed.

VR also has brought a range of new services into the healthcare industry.

Main challenges for VR technology

VR, like other information technologies, has confronted general challenges, including reduced

face-to-face communications, cost limitations, educational, and users' attitude challenges.

- ***High cost of equipment and software***

Most of the VR implementations in healthcare involve complex hardware and sophisticated software in order to create an immersive experience. While there are some low-cost solutions such as using cardboard boxes and smartphones instead of VR glasses and headsets, these usually don't offer the good quality immersion and realistic atmosphere.
Regarding the software, the development costs might be reduced by using ready-made VR software development kits (SDKs) and game engines (i.e., Unity or Unreal engines and Oculus SDKs). However, it might be challenging to adapt these to healthcare purposes.

- ***Virtual Reality Sickness***

One important limitation of VR is the tendency to cause VR sickness (or cybersickness). The symptoms include but are not limited to eye fatigue, disorientation, vertigo, and nausea [3]. Given the health conditions of the patients, they may generally be more susceptible to such effects.

- ***Lack of content***

One of the main impediments to VR adoption in healthcare is the lack of adequate content and the difficulties relating to produce such content. In addition to costs, another important reason is related to the fact that designing, implementing, and approving new treatment methods require substantial time and must follow very strict procedures.

- ***Potential Addiction***

With the increasing quality of graphics and immersive and engaging content, the possibility of addiction to VR is very real. The risk is particularly high for patients with dementia who have difficulties in recognizing and interacting with the real world or for patients with severe disabilities who might prefer escaping to the virtual world.

The future of VR in the medical field

Many of the current applications of VR in the medical field are still in their infancy. In the future, VR will be used more and more to improve the accuracy and effectiveness of medical procedures, and to enhance the capabilities of both healthcare professionals and patients. The potential for VR in the medical sector is huge, the main limit being the creativity and ingenuity of those creating and applying the technology.

The VR technology is developing rapidly. Only a few years ago, it required expensive computers and peripheral equipment, compared to today where standalone VR headsets are easily available at reasonable costs. Hardware is only getting better and cheaper and, with new players coming into the market, including Apple and Facebook, it is likely that VR

solutions will quickly become even more affordable. Lower prices and more hardware options will open up more use cases for VR, including medical applications.
The technological advances will increase the viability and use of hand control (for complex procedural tasks), voice control (for communication skills) and haptics (the sense of touch). All these technological advances will be integrated within scenarios, blurring the lines between the real and the virtual.

The integration of Artificial Intelligence (AI) will make the interaction with virtual patients more realistic while enabling increasingly in-depth analysis of clinical performance. AI can be used to solve particular issues across large numbers of learners and offer dynamic, personalized scenarios to meet specific learning needs.

The spreading of 5G technology will have a significant impact on the VR applications as it enables the delivery of richer, more interactive, and more immersive experiences across all devices.

VR simulation will continue to expand, stimulated by the continuing pressure to increase delivery of simulations. Learners will be able to do various scenarios, allowing constant improvement in performance to suit their needs.
VR will become commonplace in assessment and recruitment of healthcare professionals. It will be more and more used for continuing medical education and revalidation, becoming a benchmark to ensure clinical competency and patient safety across healthcare systems.

Multiplayer VR is becoming increasingly available and allows for many disparate learners to interact with each other (and the patient) in the same virtual scenario. This allows remote, collaborative learning in a real time clinical case, something that wasn't possible before. With such systems, a doctor in Europe can be seeing a virtual patient supported by a nurse in Asia while being mentored by a professor in USA. This co-learning across cultures has the ability to revolutionise global healthcare education.

VR can offer increased virtual clinical exposure, allowing an early focus on human factors and nontechnical skills, also promoting the acceleration of learning curves, and thus contributing to a potential shortening of training duration.

6.4. Medical training using Virtual Reality

VR technologies can greatly improve the accessibility, scale, quality, and cost of medical training content. In the same time, they can make the face-to-face time more productive and

effective. High fidelity graphics and immersive content allows students to explore complex subjects in a way not possible with traditional teaching methods.

In VR medical training, a student wears a VR headset and is immersed within a 3D virtual environment simulating, for example, a hospital ward or intensive care unit. The student has freedom to walk about the virtual space and use the controllers to pick up and interact with equipment.

VR can be used to train clinicians in complex procedures, can improve communication skills, enhance critical thinking and improve clinical decision making.

Benefits of VR in Medical Training

One the most important benefits of VR for medical training is that it allows students to repeatedly practice complex and difficult tasks in a safe environment. This is extremely important for procedural tasks like surgical operations or dental procedures that cannot be carried out on patients before achieving a certain level of competency. In addition, VR allows students to gain cognitive skills through experiential learning by exposing them to environments that can be too problematic to visit in reality.

Giving medical students and doctors the opportunity to directly experience environments or situations that are difficult to replicate by using traditional teaching methods (e.g., lectures, slideshows, videos), VR makes an important contribution to education.

The use of VR for medical training has many advantages:

- reduces the risks for patients and healthcare professionals
- the tasks can be carried out without danger for trainee or for a patient
- errors are allowed, even encouraged as they are formative
- the learning can include various scenarios with realistic sensations, the learner can be put in more realistic situations and environments, and in rare conditions and/or impossible to realize in reality
- the course can be taken in any place at any desired time
- reduced cost and the occupied space
- can enrich learning by integrating important sensory aspects in many contexts

Challenges for VR in Medical Training

Despite the advantages, VR is not a solution to all medical training problems. It is not suitable for every possible educational opportunity and has limitations related to technology level, which may not be enough in order to satisfactory deal with things like complexities of language processing and facial expressions, in certain situations.

Sometimes, it can be difficult to engage some trainers as they may see VR as a game, rather than an educational tool.

Even if the illustrative aspect of VR is remarkable for educational purposes, VR use for skill training cannot compete with real-life practice. Even elaborate trainings cannot provide completely realistic feedback, especially in terms of tactile response.

Applications of VR in Medical Training

VR is used in medical and nursing schools as well as in postgraduate education all around the world.

- ***Development of medical skills***

Doctors need to know many procedures that they may rarely use, and these procedures must be performed quick and perfect when necessary. VR makes possible the practice of medical procedures, no matter how complicated, in a fully immersive situational experience. In addition, real-time evaluation of trainees' performance can be given, further supporting the medical skills development.

- ***Trauma and emergency room simulation***

VR simulations are increasingly used in emergency medicine education and training, especially for training nontechnical skills. They allow students to face the real-life situation of treating trauma victims in the emergency room. They can assess the patients, make quick decisions, and perform the required procedures to save patient lives and stabilize their condition.

- ***Surgical training***

VR training allows surgeons and medical students to practice in a controlled and safe environment, without exposing patients to any harm. Complete surgical workflow can be practiced while receiving valuable feedback and performance metrics to improve performance. The same procedure can be practiced repeatedly until the required skill level is reached. Thus, the time and risk associated with the surgery complications are reduced and the efficiency and accuracy in the operating rooms are improved.

VR headsets and haptic gloves are used to imitate real-life surgical procedures. VR platforms, such as ImmersiveSim™, provides users with a fully immersive experience of an operating room. While in the simulation, a robotic stylus replicates the sensation of using various surgical tools, and use of VR hand controllers replicate exactly the user's hand motions. Another example, the Fundamental Surgery platform uses VR and mixed reality healthcare simulation solutions to help train surgeons using real-world scenarios [4].

- ***Empathy***

In addition to skills, a good doctor also needs to have a strong empathy for the patients being treated. VR has a significant positive effect on emotional empathy [5]. It offers students the

opportunity to experience, to a degree, certain illnesses that their eventual patients may be facing thus helping them to develop strong and necessary empathy skills.

- ***Understanding of human anatomy***

VR helps medical students to explore accurate and real human anatomy, including the cardiovascular system, central nervous system, muscles, and bones, without using cadavers, in a completely immersive environment.

6.5 DLOs visualization with VR

DLOs visualisation with VR

VR can be used to visualize and analyse 3D models, including DLOs of the Ale3andria library, on different scales, from molecular to anatomical structures. The 3D visualization of the human anatomy could be an important asset for both medical students and doctors and VR can provide clear and realistic views, without the need of physical models, cadavers or surgery. Currently, VR is used for teaching biological concepts of cell structures and anatomical structure at high school and university levels [6], for preoperative liver surgery planning [7] and other.

The visualisation of medical image data in VR can take two main paths:

- visualization of unsegmented image data (DICOM files)
- visualization of segmented images (3D models)

- ***DICOMs visualisation in VR***

VR files can be generated directly from DICOM files. For example, the platform ImmersiveView Surgical Plan [8] can generate high-fidelity 3D VR replicas from DICOM files and provides a variety of tools for use directly on the model in VR. This allows for studying, assessment and planning of surgical operations, collaborations among surgical team members, and patients education about their upcoming surgery.

3D Slicer [9] is a free open-source platform for medical image visualization and analysis. It covers the generic medical image computing functions, and offers many extensions to support specialized fields. Among these extensions, Slicer Virtual Reality provides immersive virtual reality visualization, exploration and navigation during image-guided therapy training and planning, using the functionality of the 3D Slicer ecosystem [10].

- ***3D models visualisation in VR***

3D models, such as the ones available in Ale3andria library, can be visualised in various VR systems. There are many software applications that allow the VR visualisation of these 3D

models. For example, Sketchfab [11] allows for visualisation of models in virtual reality directly from the web by using HTC Vive, Oculus or Microsoft Mixed Reality headsets.
The most widely used file type for VR applications is .obj, which has the ability to include material properties such as color and shading [12].
The main advantage of VR is that allows virtual immersion which makes possible the placement of user inside of any structure of the human body and to view the 3D models from every angle, thus greatly improving the education, training and research. Also, a VR model can be edited in order to improve visibility of desired areas, to remove or replaced certain parts, to colour or set transparency, etc.
Finally, VR is an efficient way to improve the level of anatomy knowledge of the learners [13]. One reason can be that VR helps improve the mental construction of 3D internal organs, which is important for anatomy learning [14].

VR combined with 3D-printed models

3D-printed anatomical models are very useful for doctors in the planning and communication of complex cases. They can be touch, closely analysed, or used as instructional objects. On the other hand, VR glasses allow for an even more detailed display, can provide additional information about the 3D-printed models, make possible virtual meetings of the medical team or with the patient and can improve the communication. Consequently, VR can play an important complementary role as a faster, low-cost option for interactive models [15]. By combining VR and 3D-printed models it is possible to simulate patient-specific surgical procedures and doctors can plan and explain more precisely the procedure.

"VIVATOP" project (Versatile Immersive Virtual and Augmented Tangible OP) [16] is developing a system based on VR and 3D printing designed to effectively support the planning and execution of surgeries as well as training and education.

VR and 3D-printing

Both 3D printing and VR technologies are providing a better visualization experience compared to the conventional visualization techniques. In fact, both technologies are currently transforming and improving visualization techniques for medical imaging [17, 18] and are increasingly incorporated in advanced visualization workflow.

However, there are also unique value propositions from both technologies.

For VR, the construction process of a final product is often less costly, and the user can manipulate the objects in a more adaptive way (for example, the user can zoom in and out, can virtually section the model to see internal structures, etc.). The user can also superimpose other information onto the existing model.

But, registration of the virtual model to the physical world is a problem for current VR technology, as it is the representation of tissue deformation and tactile information from the real world. Moreover, significant technological issues include data transmission latency on current wireless networks, bulky and expensive headsets, additional hardware requirements including graphic cards, etc.

A unique value of a 3D-printed model is that it can directly interact with the physical world. For example, surgeons can use a mandibular bone to pre-bend a metal plate before surgery, but this is not possible with VR models. Also, once a model is printed, this can be used and shared without the need for any additional equipment or network, as it is now entirely physical.

However, printing anatomical models is best suited for personalised cases, such as patient-specific surgical planning, where only one model needs to be produced. For other applications such as education and training, multiple similar models are needed and 3D-printing is not an efficient approach for mass production. A good solution is to use VR as a supplement to 3D printing [19].

There are many studies and applications where VR and 3D Printing are used complementary to each other.

There is no doubt that 3D-printing provides immense value to the healthcare sector, as it revolutionising many aspects, from how doctors make diagnoses, plan complex surgeries, design and fabricate patient-specific implants, and educate their patients and trainees. However, 3D-printing implementation in healthcare pose two important challenges: image segmentation and printing time. VR can help in addressing these challenges.

Medical images can be segmented directly in VR, in an easy and effective way. For example, the VR platform Elucis [20] enables to quickly model the regions of interest from a patient's anatomy based on user input, image values, and a few user-defined settings. The 3D structures of the anatomy appear in real time and the user has full control over its visual characteristics, including the size, colour, and transparency. The structures created can be further post-processed for 3D printing and saved as 3D printing files.

Other applications involve the use of 3D-printed models as a tangible user interface that allows the user to interact and manipulate it in a virtual environment [21, 22] and there are results showing that the combination of VR and 3D printing can improve efficacy, accuracy, and patients' experience [23].