

BRIGHT

Erasmus+ strategic partnership for Higher Education

**BOOSTING THE SCIENTIFIC EXCELLENCE AND INNOVATION
CAPACITY OF 3D PRINTING METHODS IN PANDEMIC PERIOD**

O3 - BRIGHT e-learning virtual laboratory platform REPORT

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	O3 - BRIGHT e-learning virtual laboratory platform for boosting the scientific capacity and innovation in teaching processes related to medical parts made by 3D printing methods in pandemic period
Date of Delivery	July 2022
Authors	Răzvan Păcurar, Filip Gorski, Miloš Simonović, Remigiusz Łabudzki, Sven Maričić, Mate Babic, Branislav Rabara, Peter Košťál
Version	FINAL VERSION

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of content

1	Introduction.....	3
2	Requirements, according to target groups	4
3	BRIGHT e-learning platform – Virtual Laboratory	5
3.1	Main concept.....	5
3.2	Main WWW interface.....	9
3.3	Description of BRIGHT Institutional Virtual Laboratory Rooms	10
3.3.1.	VL Room 1 – Technical University of Cluj-Napoca	10
3.3.2.	VL Room 2 – Poznan University of Technology	14
3.3.3.	VL Room 3 – Slovak University of Technology.....	18
3.3.4.	VL Room 4 – University of Nis.....	21
3.3.5.	VL Room 5 – Juraj Dobrila University of Pula.....	24
3.3.6.	VL Room 6 – BIZZCOM s.r.o.	26
3.3.7.	VL Room 7 – BM Plast d.o.o.....	29
3.4	Medical 3D models library.....	31
3.5	VR/AR applications	33
3.5.1.	Virtual Reality orthosis design and printing.....	33
3.5.2.	Virtual Reality product testing tutorial.....	42
3.5.3.	Augmented Reality 3D models	43
4	Conclusions.....	46

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

1 Introduction

In the context of the pandemic, when physical access to laboratories is restricted, new teaching methods are foreseen to be implemented. One modern method of teaching in this context is the realization of a Virtual laboratory platform, that can be accessed by professors and students, in which they can be engaged in the teaching process on the digital level. Therefore, such a platform has been realized in the BRIGHT project.

The intellectual output 3 is BRIGHT e-learning virtual laboratory platform for boosting the scientific capacity and innovation in teaching processes related to medical parts made by 3D printing methods in pandemic period. The virtual laboratory platform integrates several rooms (disciplines / equipment items / applications) together to create the interconnectivity between several disciplines that are engaged in developing, producing and testing of one product that is coming from medical sector, as well as experiencing and use of the virtual laboratory in developing, producing and testing of real parts that are required to be made for the medical sector by 3D printing in the context of the pandemic.

The main vision of the platform, as the BRIGHT project was realized, is that it contains a number of virtual rooms, which are representation of real laboratories of partners involved in the consortium. The rooms allow virtual tour and getting familiarized with use of the specialized equipment. They also contain all the educational materials and tools developed in the scope of the whole project. Finally, they contain a number of interactive, e-learning applications, based on Virtual Reality and Augmented Reality Technology.

The platform is a very important tool – it has been used extensively during the later phase of the BRIGHT project, is a basis for activities planned in subsequent projects and is also used in regular teaching programmes by consortium member. This report presents ideas, structure, tasks and responsibilities of partners and final results – description of the platform itself. It is a freely available tool that can be accessed directly from the project website (link: https://bright-project.eu/?page_id=320).

2 Requirements, according to target groups

The Virtual Laboratory platform is a solution containing high amount of interactive educational content, addressed to everyone who is involved in teaching process of 3D printing of medical parts, taking into account the whole process (starting from design, through various simulations, manufacturing, post processing, testing and actual use). The platform is thought to be a knowledge hub, containing most of educational results created over the scope of BRIGHT project, in an interesting, involving, interactive manner.

The main beneficiaries of this platform should be students, as they can gain lots of basic and intermediate level knowledge from the platform, allowing them to undertake more advanced topics related to 3D printing of medical parts. The platform is also addressed for professors who perform the didactic process – as the platform is free to use, all professors (not limited to the BRIGHT consortium) can use its contents to support their teaching methods, in any manner they see suitable. The third beneficiary of the platform should be the medical environment – doctors, medical professionals and specialists, who could also use its contents for education, but also increase of awareness of technical possibilities of using 3D printing and other advanced, digital technologies in medicine.

The platform was also thought as a useful tool during the COVID-19 pandemics, as it allowed students to visit the specialized laboratories virtually, without physically getting into the universities in the period when they were closed. This greatly helped realization of remote learning and continues to be used even after pandemics, allowing students to take a peek into laboratories anytime, before or after actual classes.

The Virtual Laboratories were also used during the BRIGHT project events, such as second summer school realized in Juraj Dobrila University of Pula, as well as during the Multiplier Event, held in the same location.

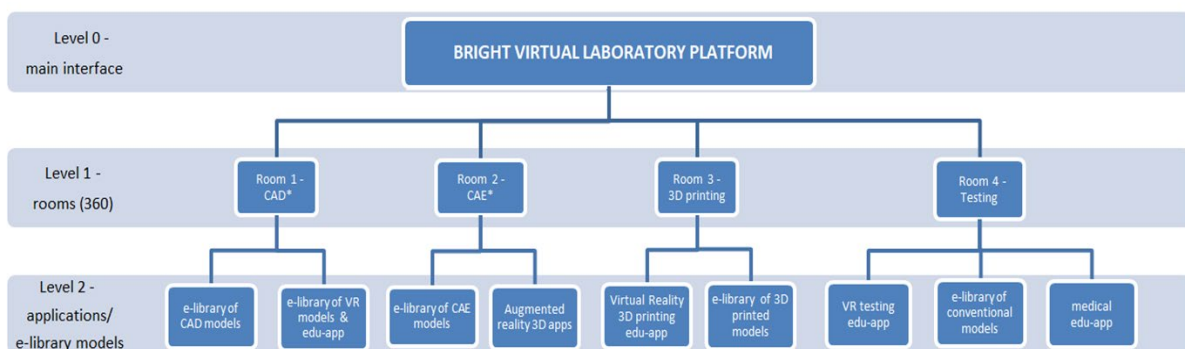
After ending of the BRIGHT project, the VL continues to be used during 3D printing and other classes, at partners of the consortium. The VL will be further developed and expanded, being a very practical educational tool.

3 BRIGHT e-learning platform – Virtual Laboratory

3.1 Main concept

The BRIGHT Virtual Laboratory is conceived as a web-based platform, accessible by WWW browser. It contains a number of basic modules – virtual rooms, accessible from a main, web-based interface. Each room is a virtual, digital image of a real laboratory of one of partners, captured by a 360 degree camera, containing e-learning information about the equipment contained in a given room and procedures possible to realize in it – in form of documents, instructions or videos, aimed mostly for teaching or self-learning by the students. In selected rooms, it is possible to download or launch dedicated external applications, with use of Virtual Reality or Augmented Reality technology. Virtual laboratory is a central interactive hub of knowledge, containing the results of the main effects of Intellectual Outputs of the project (toolkits, modules, instructions, webinars).

The scheme in Figure 1 presents the initial idea of the BRIGHT VL. In the first concept, it was assumed that there will be 4 rooms, each with a specific purpose – CAD, CAE, 3D Printing and testing. In each room, it was proposed that – apart from standard educational content – there will be more sophisticated, interactive solutions, such as VR and AR applications, along with e-library of models and presentations / teaching resources integrated into the rooms.



*CAD/CAE shared rooms

Figure 1. Initial concept of the Virtual Laboratory platform in the BRIGHT project

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The concept was expanded and changed as the task progressed – it was decided, in view of overlapping capacities of laboratories of different partners – that there will be as many Virtual Laboratories as partners in the project (5 HEIs and 2 companies – total of 7), since it has been considered added value for the users to have the chance to go through the rooms and see all the facilities of institutions, that are complementary in most of the cases. Each Virtual Laboratory at the level of institution therefore contains at least one room (sometimes more than one), with usually more than one “function”. The rough mapping between initial room concepts and contents of the VL e-learning platform at the level of each institution in its final form are presented in Table 1. The e-library of models has been constituted in the way to be able to be accessed also as a separate link and accessed from the BRIGHT website of the project (not just through Virtual Laboratories as in the initial concept).

Table 1. Final concept of Bright Virtual Laboratories

No.	VL – Institution	Functions of VL	Applications and libraries
1.	Technical University of Cluj-Napoca (TUCN)	CAD/CAE/3D Printing	e-library of CAD / CAE/ VR models
2.	Poznan University of Technology (PUT)	3D Printing / post processing / testing	Orthosis design and 3D printing in Virtual Reality
3.	Slovak University of Technology (STU)	flexible manufacturing / post processing / testing / CAD	e-library of CAD models / e-library of conventional models
4.	University of Nis (UNI)	testing / CAD	Strength testing in Virtual Reality / e-library of VR models
5.	Juraj Dobrila University of Pula (UNIPU)	medical testing	Medical educational application
6.	BIZZCOM	testing in augmented reality / CAE	Augmented Reality medical product presentations / e-library of conventional models
7.	BM Plast	Rapid Tooling / post processing / testing	e-library of conventional models

Since the BRIGHT virtual laboratory is intended to be one educational tool, through which the students could understand better the necessary steps in conceiving, developing, realizing of medical products by 3D printing and testing, the initially planned “rooms” were finally

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

mapped as following in terms of thematic rooms (according to the experience and expertise of BRIGHT consortium partners):

1. **CAD**: main room at TUCN + supporting capabilities in PUT, UNI and STU rooms
2. **CAE**: main room at TUCN + supporting capabilities in BIZZCOM
3. **3D Printing** (Rapid Manufacturing): main room at PUT + supporting capabilities in TUCN and BM Plast
4. **Testing**: main room at UNI + supporting capabilities in STU, UNIPU, BIZZCOM and BM Plast

For much better understanding of the virtual laboratory platform in terms of thematic rooms one scheme as the one presented in Figure 2 has been conceived, realized and has been posted on the BRIGHT project website from where the BRIGHT platform can be accessed before going to visit the rooms of the BRIGHT institutions (see: https://bright-project.eu/?page_id=320).

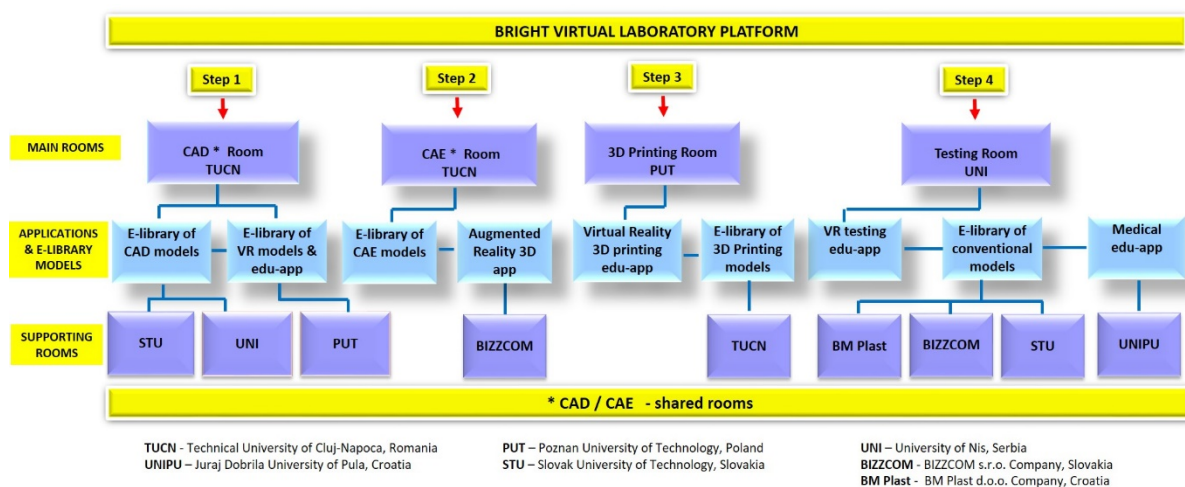


Figure 2. Main concept of BRIGHT virtual laboratory platform in terms of thematically rooms and apps

In this way like shown in Figure 2, anyone who is accessing the virtual laboratory in order to take one visit on several BRIGHT institutions in virtual way can do it much better oriented before starting to visit the laboratories, in order to search information that is comprised in different modes in the laboratories of BRIGHT institutions. According to each step (CAD first,

followed by CAE, 3D printing and testing), step by step who is accessing the virtual laboratories can reach the main rooms of experienced institution first where most of facilities, educational tools, etc. are provided, continuing then by following the linked institutions that are providing additional support for the specific topic (CAD, CAE, 3D printing or testing) so as students will be able to comprise and have a wider picture about the steps that needed for developing medical products correlated with the complementary facilities that each institution is offering in completion. Since CAD and CAE topics are very closed linked (in both cases being used similar programs (e.g. SolidWorks for CAD, SolidWorks Simulation module for CAE analyses and since main rooms for CAD / CAE has been attributed to Technical University of Cluj-Napoca, it has been decided (even the steps needed for realizing the medical parts are different – CAD comes first, CAE following right after for validating the CAD in terms of realizing one new medical product), to keep the same room /to share rooms in this case, by sharing the information for CAD and for CAE in different corners in the same room, this aspect being mentioned to the users who are accessing the BRIGHT laboratory platform before starting to realize the visit (as shown in Figure 2 and on the BRIGHT website: (see: https://bright-project.eu/?page_id=320).

The detailed functionalities of the four main thematic rooms (CAD, CAE, 3D printing and testing) are presented in separate documents in supporting of this report, these documents being as well posted on the BRIGHT project on the above indicated link.

In terms of virtual rooms of the institutions (regardless of the thematic content / generally speaking), each Virtual Room contains the following:

- Basic Virtual Reality 360 images, with possibility of moving between different spots in a laboratory and free rotation of camera around; the 360 image can be perceived on all kinds of devices (computers, smartphones and selected VR goggles); the 360 images were registered using Insta 360 camera and processed by free Kuula software by all partners, with exception of PUT, where Matterport software and hardware was used.
- Links to external interactive applications (immersive VR & AR apps), requiring specific VR/AR hardware (e.g. SteamVR compatible goggles).

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

- Annotations at specific equipment, with possibility of clicking to obtain more information (e.g. 3D printer name, model and parameters with link to producer’s website).
- Links to educational videos of operation of specific equipment/software, connected to the above mentioned annotations (e.g. design or 3D printing of a specific medical part).
- Links to educational modules & toolkits (PDF files, results of IO1/IO2) and selected materials from the BRIGHT summer schools (tutorials).
- Links to webinars created in IO4.

The links are placed in specific locations of a 360 laboratory, so the user can gradually discover the educational content while exploring the rooms. The content is thought as an evolving space, which will be filled with more materials as the classes with the students and subsequent projects go on. The laboratories are already used by some partners in classes conducted at their universities and will continue to be used in the future.

Specific rooms and main applications that are included in the virtual laboratories of each institution are described in the following chapters.

3.2 Main WWW interface

The main interface of the Virtual Laboratory platform is available through the main website of the BRIGHT project - <https://bright-project.eu/>. After accessing the website, there is a link in the upper panel, named “Virtual Laboratories” (Figure 3).

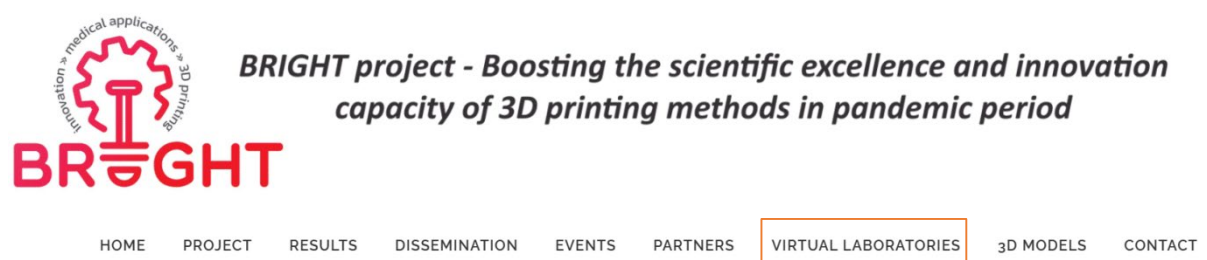


Figure 3. BRIGHT project website – access to WWW interface of Virtual Laboratory

Selecting the link opens the interface (located at https://bright-project.eu/?page_id=320). It contains map of Europe, with pins representing laboratories of

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

project consortium partners. It is divided into two sections – one for HEIs and the other for companies engaged in the project (Figure 4).



Figure 4. Access to virtual laboratories, top – HEIs, bottom – companies

Clicking on the name of each partner opens a new window, in which the selected virtual laboratory is presented and can be directly interacted with. Any extra content, such as VR applications or library models are available for download and use separately (with appropriate hardware) directly from the virtual rooms.

3.3 Description of BRIGHT Institutional Virtual Laboratory Rooms

3.3.1. VL Room 1 – Technical University of Cluj-Napoca

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The first VL Room belongs to TUCN and it presents its facilities in terms of CAD / CAE and 3D Printing capabilities (unique to this partner), as well as examples of realized medical cases with 3D printing. It is accessible directly by the following link:

<https://nessy2022.viewin360.co/share/collection/79pbg>

Starting point of this VL is in the front of the TUCN main building, allowing to select two different paths – getting to medical 3D printing laboratory (located in another building across the street) or getting inside to regular 3D printing laboratory and CAD/CAE laboratory (Figure 5).

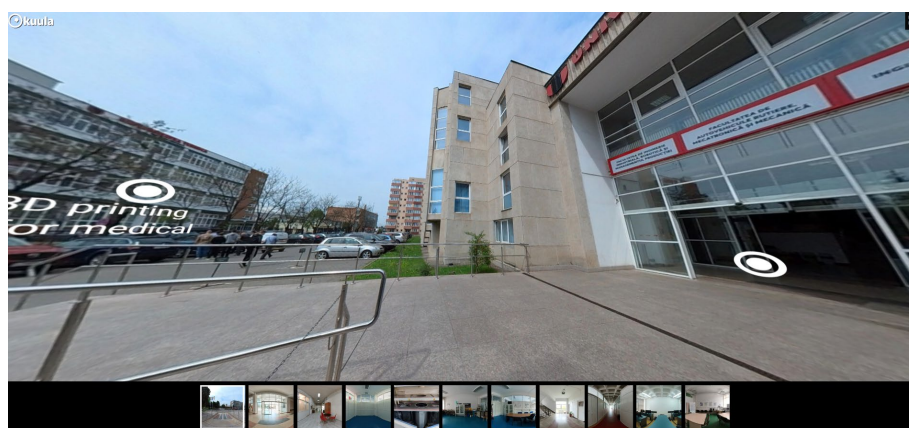


Figure 5. Virtual Laboratory of Technical University of Cluj Napoca – starting point

The whole VL of TUCN is divided into the following parts:

- 1) CAD / CAE laboratory (Figure 6), located at the upper floor of the building,
- 2) SLM 3D Printing laboratory (Figure 7), located at the lower floor of the building,
- 3) 3D printing laboratory (FDM / SLA), located in other room at the lower floor of the building (Figure 8)
- 4) Medical 3D printing laboratory (Figure 9), located in a separate building.

The 3D printing laboratory is additionally spread throughout a couple of separate rooms, containing machines working in FDM technology, as in Fig. 6, but also CAE and SLM technology (exclusive to Cluj-Napoca among the project partners) as shown in Figure 7.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 6. The CAD / CAE virtual laboratory at TUCN

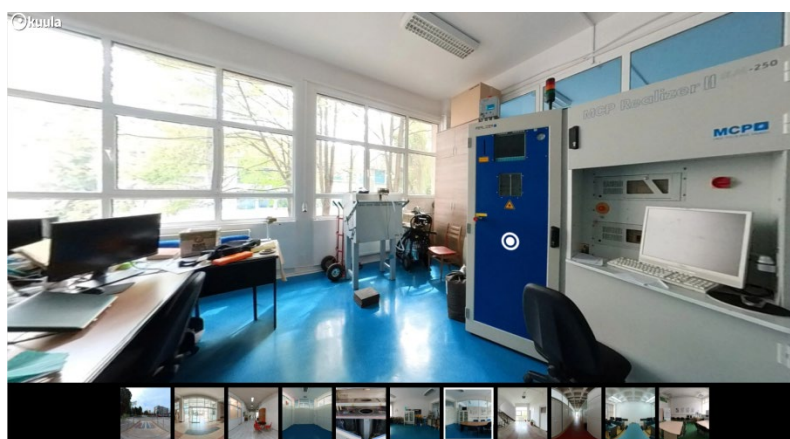


Figure 7. SLM 3D printing room at TUCN

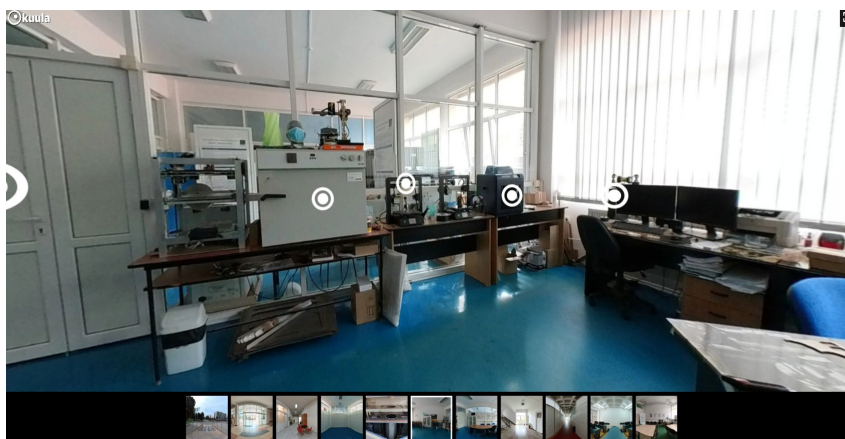


Figure 8. 3D Printing laboratory (FDM / SLA room) at TUCN

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

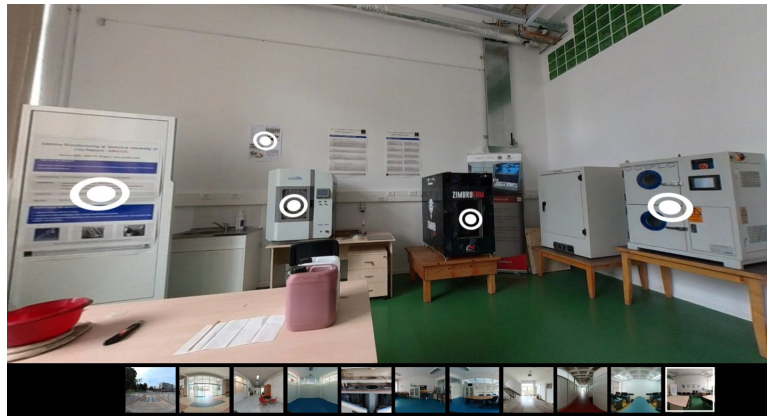


Figure 9. 3D Printing for medicine laboratory at TUCN

The CAD room at TUCN contains all the knowledge necessary in these two topics. Technically, both CAD and CAE are located within the same space (CAD / CAE rooms are shared) and the laboratory is just a regular computer teaching laboratory. The educational contents of this part of the VL is as following:

- links to modules developed in O1 of the project,
- links to toolkits developed in O2 of the project,
- manuals, instructions presented to the students at the BRIGHT summer schools – regarding CAD design, along with downloadable models,
- manuals for the CAE part,
- lecture materials for CAD,
- links to webinars on CAD
- CAD e-library models
- CAE e-library models
- VR library models.

The content is linked to various places (computers) in the virtual lab (Figure 10).

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 10. Example of contents in CAD room

The 3D printing part of the virtual laboratory of TUCN, contains descriptions, videos, photographs, tutorials and scientific papers related to 3D printing, mostly of various medical parts. The part of 3D printing laboratory rooms of TUCN were used to support thematic room of 3D printing (main room of 3D printing that has been assigned to Poznan University of Technology in the Virtual platform according to Figure 2) since in the Technical University of Cluj-Napoca, there are 3D printing equipment items that are not available at Poznan University of Technology and vice-versa.

As it was mentioned before, the TUCN laboratory (CAD / CAE room) also contains VR application presenting selected 3D models of medical parts, corresponding to the 3D models library of CAD / CAE and VR models, accessible from the Virtual Laboratory in this room.

3.3.2. VL Room 2 – Poznan University of Technology

The second VL Room is faithful representation of PUT's laboratory of Rapid Manufacturing. Unlike all the other laboratories, this has been captured using Matterport software and camera, meaning slightly different (more advanced) capabilities. The laboratory is available from the main interface, but also through a short link – <http://3dspot.pl/120BM>.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The initial view is of a simplified 3D model (resulting of 3D scan performed by the camera) of the whole laboratory (Figure 11). Then, the view starts outside, on a corridor of building of Faculty of Mechanical Engineering. The whole VL Room is, contrary to other laboratories, a single, yet advanced and packed laboratory of Rapid Manufacturing (3D Printing).

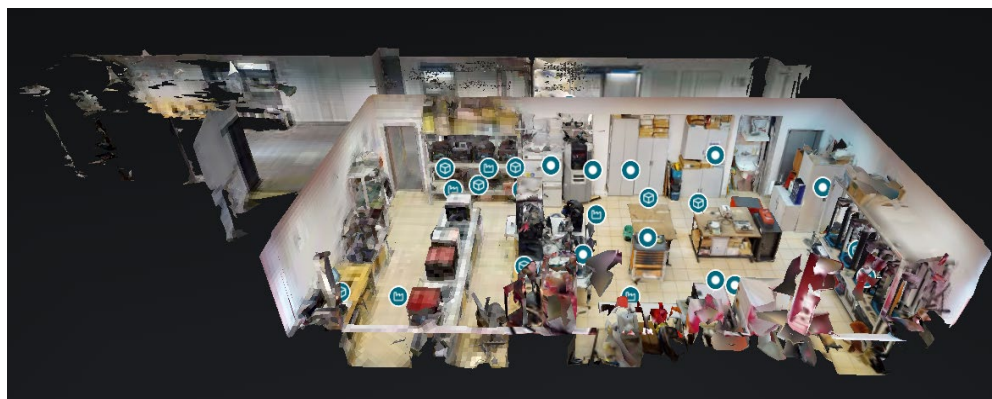


Figure 11. Virtual Laboratory of Rapid Manufacturing at Poznan University of Technology – outside view

The laboratory itself contains well over 40 3D printing machines, along with Vacuum Casting equipment, strength testing machine and many other auxiliary tools (Figure 12). Most of the pieces of equipment are tagged with annotations and they contain teaching content for student, created during the BRIGHT project.

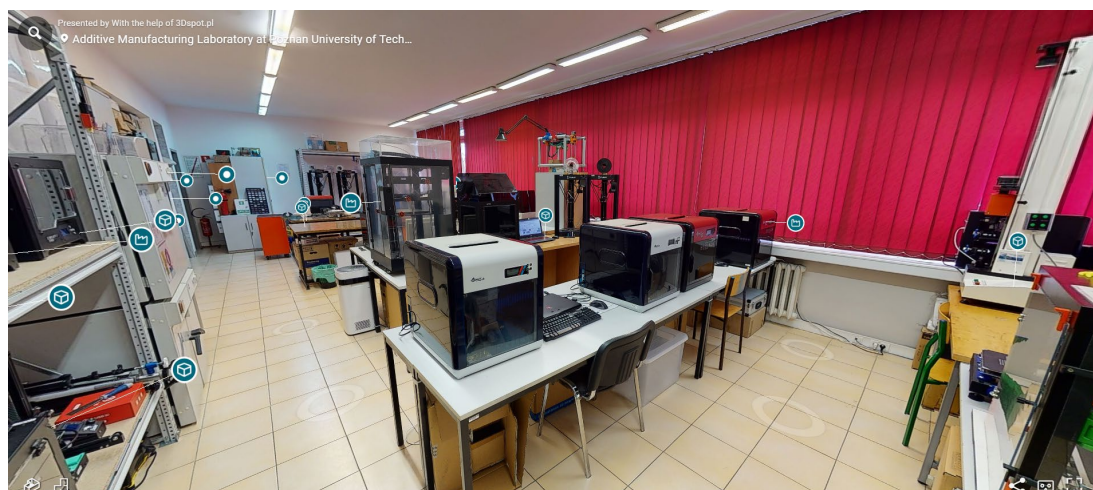


Figure 12. Virtual Laboratory of Rapid Manufacturing at Poznan University of Technology – inside view

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Examples of the teaching content in the VL include, but are not limited to:

- educational videos of 3D printing of medical parts (uploaded using laboratory's own YouTube channel) – Fig. 13,
- educational videos of post processing of 3D printed parts – Fig. 14,
- educational videos of strength testing and 3D scanning accuracy measurement – Fig. 15,
- photographs showing interior of cabinets containing tools and material (helping understand work processes in the laboratory) – Fig. 16,
- link to BRIGHT webinar #3 on 3D printing,
- a number of educational videos showing the work of the equipment, by external providers (mostly machine producers),
- link to educational interactive Virtual Reality application made for the BRIGHT project, allowing to take part in the process of 3D scanning, design, 3D printing and post processing of customized orthoses (described in another chapter)

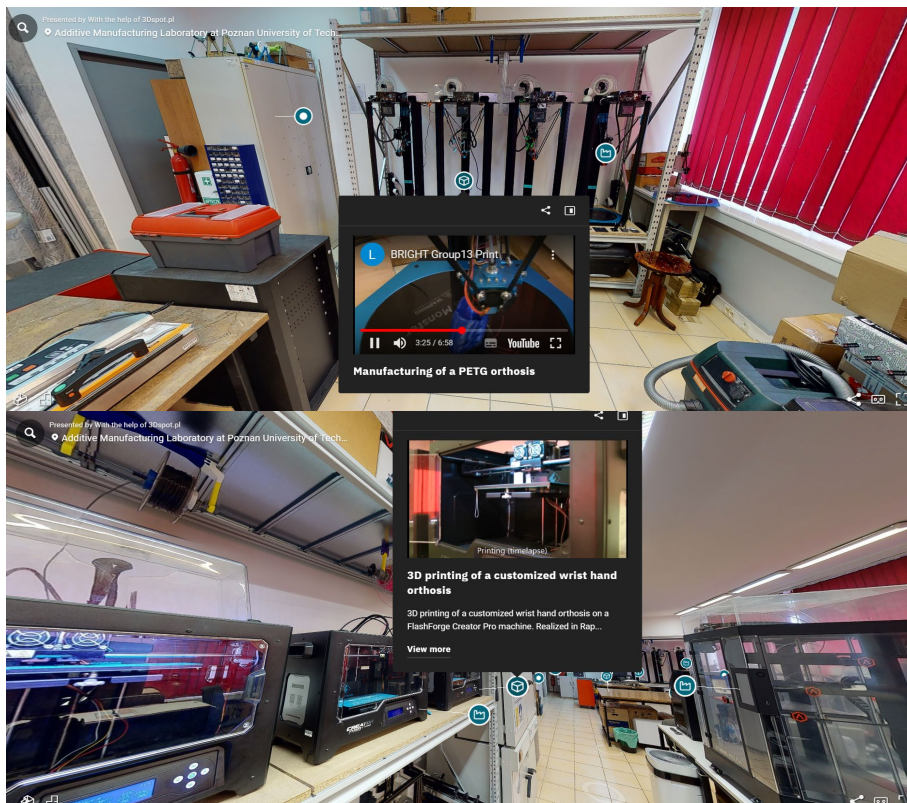


Figure 13. Educational videos of 3D printing of medical parts (BRIGHT case studies)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

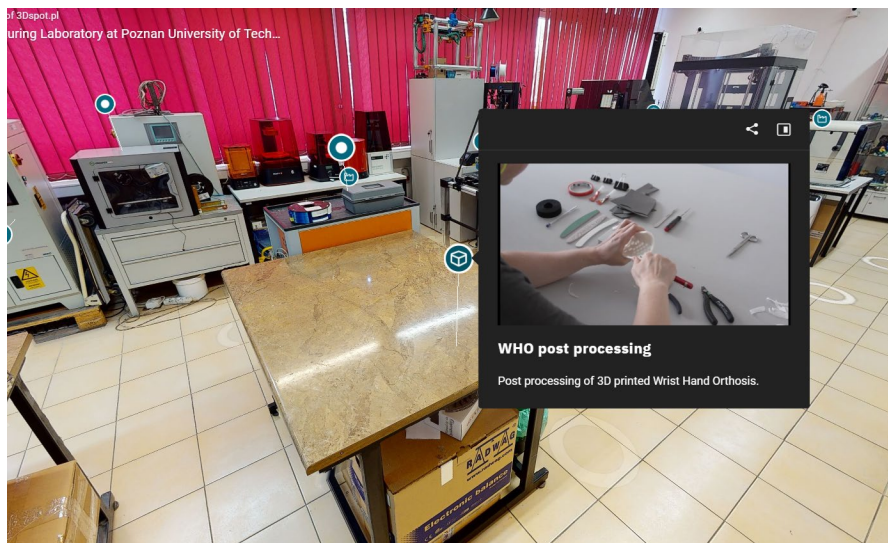


Figure 14. Educational video of post processing of medical parts

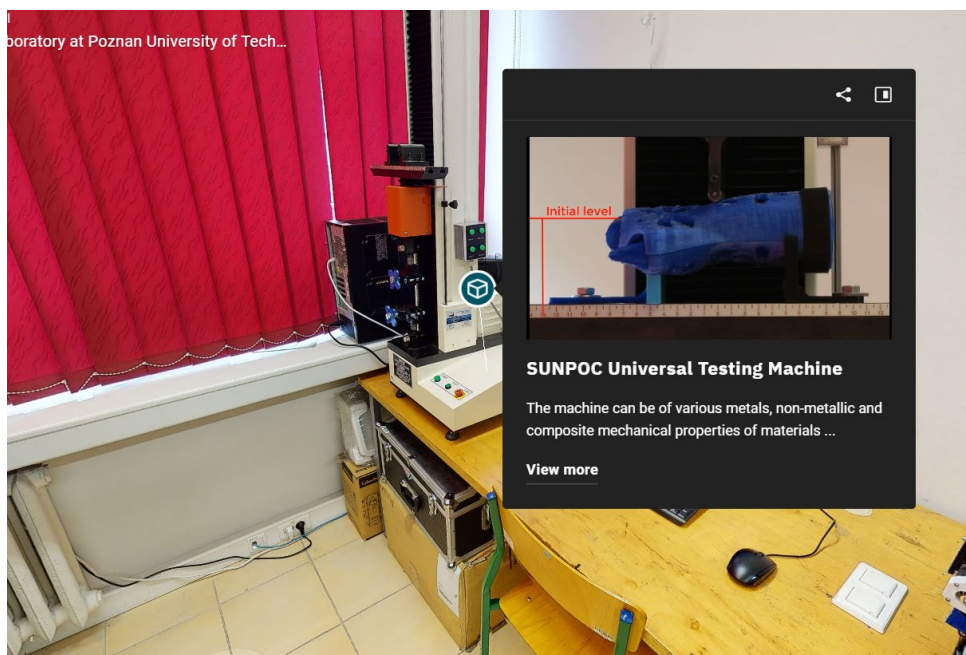


Figure 15. Educational video of testing of 3D printed medical parts

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

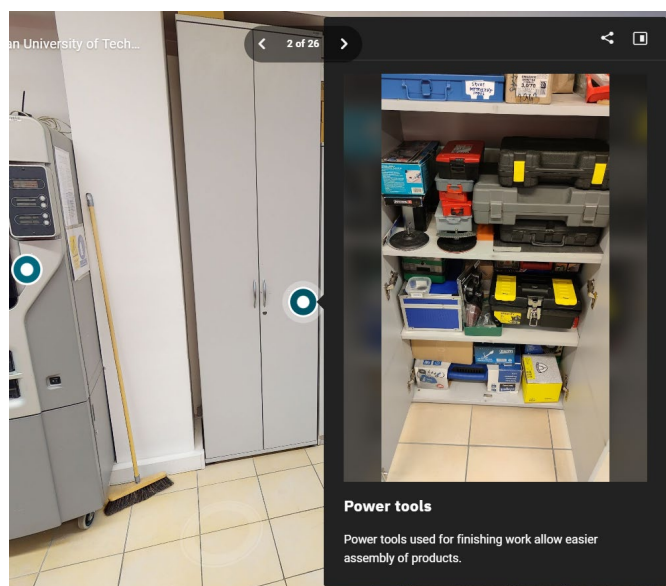


Figure 16. Photographs of laboratory equipment

3.3.3. VL Room 3 – Slovak University of Technology

The Virtual Laboratory of Slovak University of Technology is a digital representation of facility of Faculty of Materials Technology in Trnava. The starting point is a computer room (CAD/CAE simulation functionalities) – Figure 17. CAD/ CAE laboratory room of STU Trnava has been used as support to the main CAD / CAE laboratory thematic room that has been assigned to the Technical University of Cluj-Napoca. The laboratory is accessible directly by the following link:

<https://nessy2022.viewin360.co/share/collection/7vd6F>

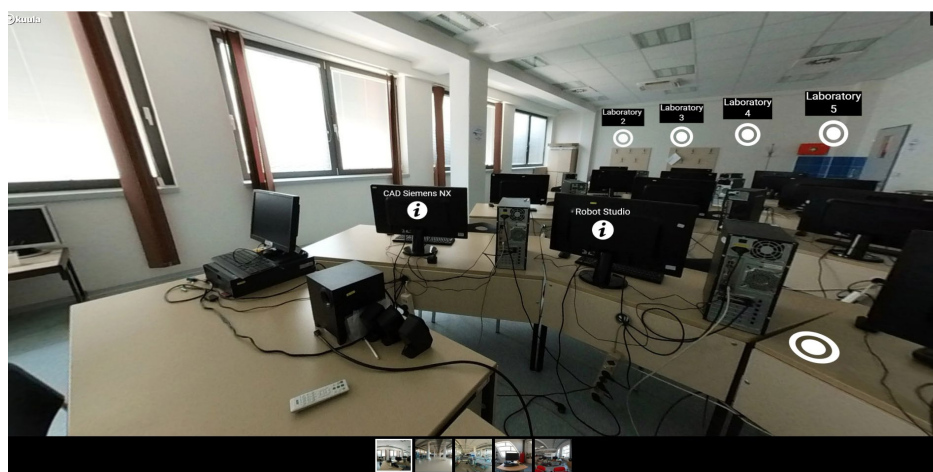


Figure 17. Starting point of STU virtual laboratory – CAD/CAE/simulation laboratory

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The whole laboratory contains the following rooms:

- the starting room – computer simulation laboratory (Fig. 17)
- the factory hall with flexible manufacturing system (Fig. 18)
- the assembly and quality control hall (Fig. 19)
- the 3D scanning workplace for testing and control (Fig. 20)
- the workplace for metrologic measurements, with coordinate measurement machine and a tomograph (Fig. 21)

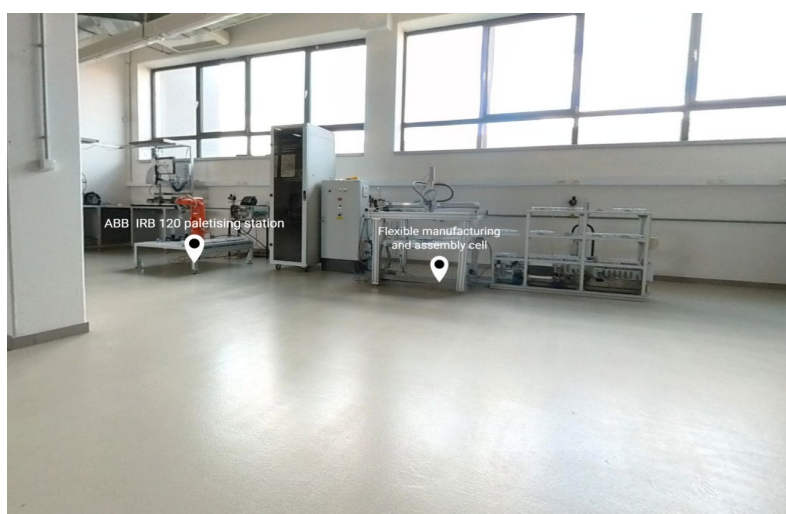


Figure 18. Virtual factory hall with the flexible manufacturing system

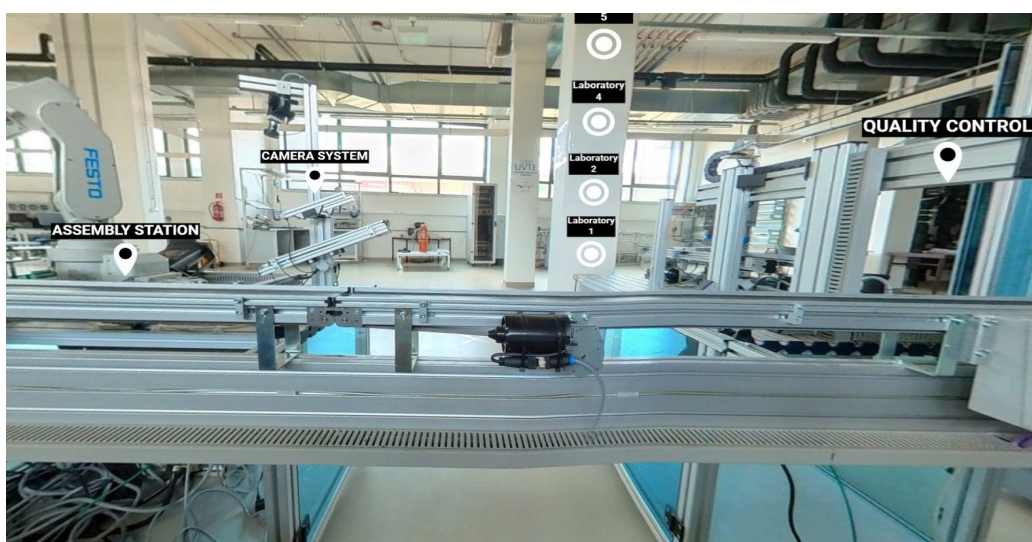


Figure 19. Virtual hall for assembly and quality testing

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

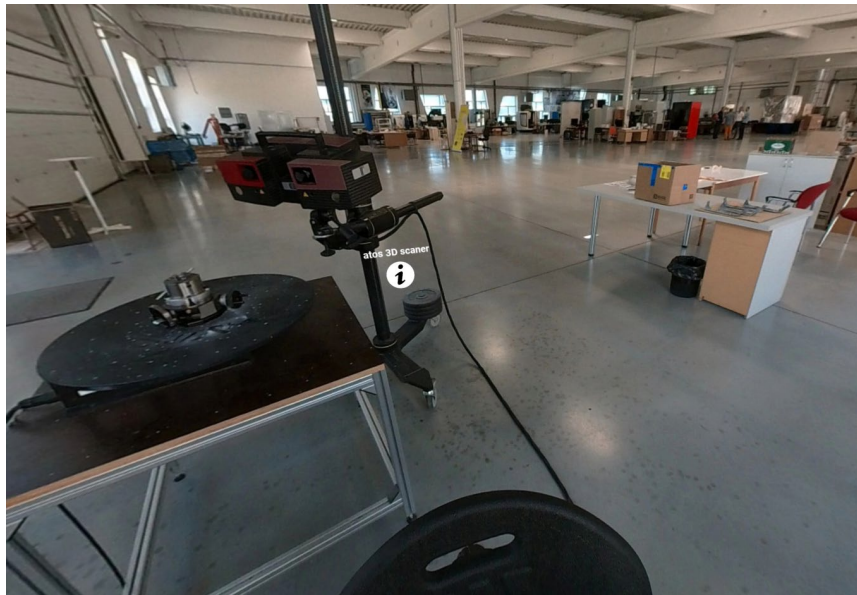


Figure 20. Virtual workplace for 3D scanning



Figure 21. Virtual coordinate measurement machine workplace

The educational content contained in the rooms contains, but is not limited to: Videos, documents, tutorials, etc. which were complementary used as support for the main thematic room (testing room) which was assigned to University of Nis partner (see Figure 2)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

3.3.4. VL Room 4 – University of Nis

The Virtual Laboratory of University of Nis is a digital representation of certain facilities of Faculty of Mechanical Engineering of this university, namely – materials testing and CAD. The laboratory is accessible directly by the following link:

<https://nessy2022.viewin360.co/share/collection/7vT3c>

Starting point of the laboratory is inside the building, where there is possibility to either select the CAD route or the material testing route (Figure 22). CAD room has been used as support to main thematic CAD room that was assigned to Technical University of Cluj-Napoca according to Figure 2, while the main functionality and purpose of the University of Nis VL is material and parts testing due to existing facilities. This was the reason why in terms of thematic rooms University of Nis was responsible partner in providing teaching resources and applications directly linked to this topic, as shown in Figure 2

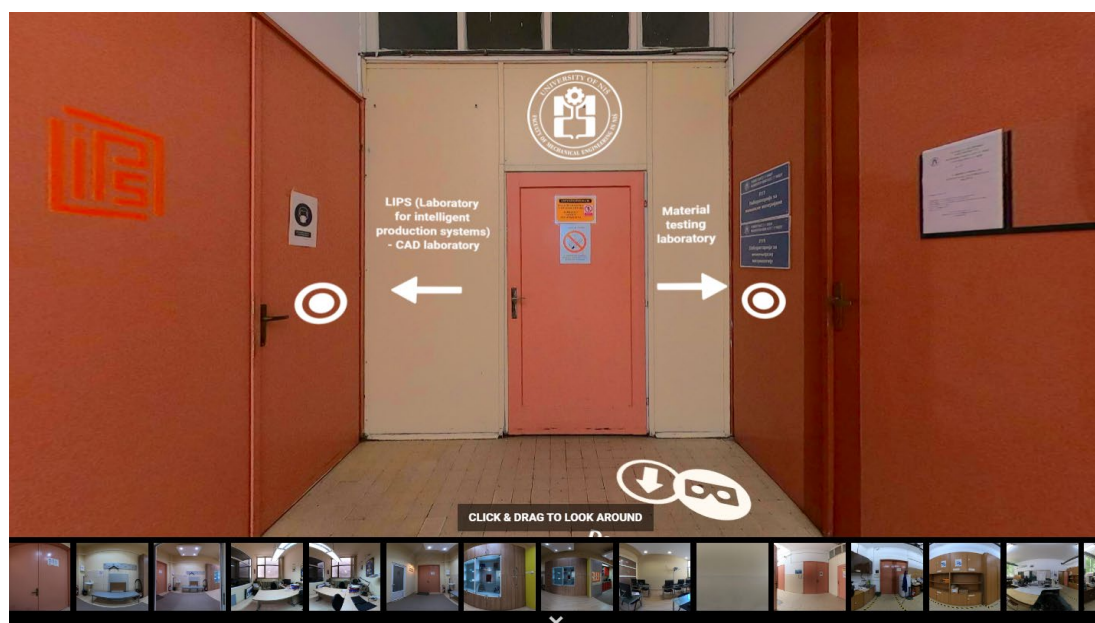


Figure 22. Virtual Laboratory of University of Nis – starting point

The laboratory contains the following locations:

- the CAD/CAE laboratory (Figure 23)
- the Universal Testing Machine room (Figure 24)
- the material testing laboratory, with multiple locations (Figure 25)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

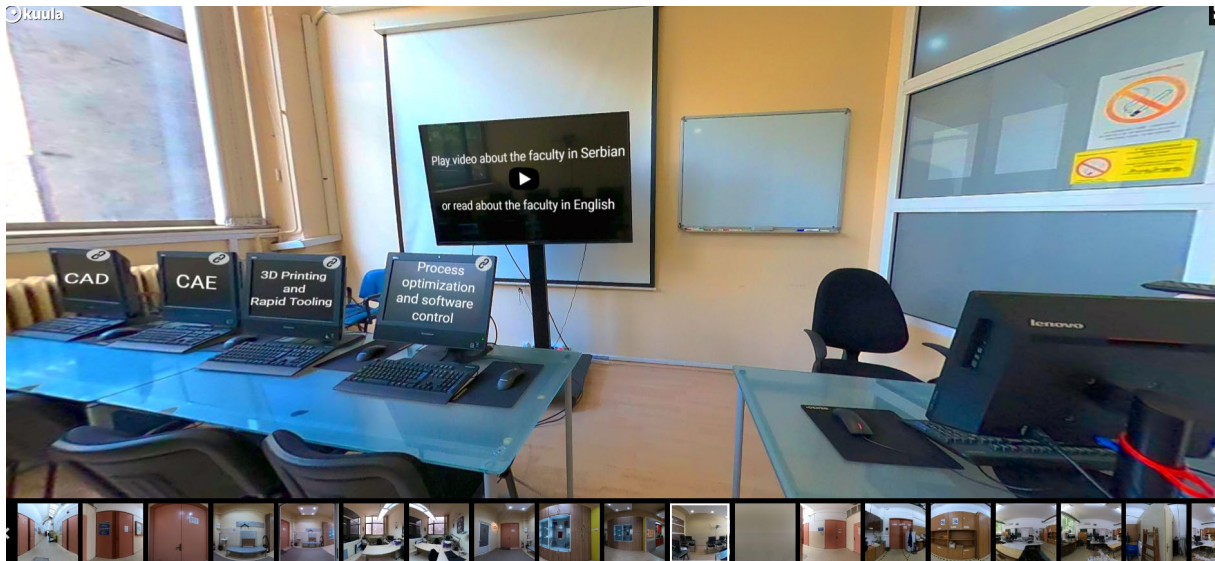


Figure 23. CAD/CAE laboratory at VL of University of Nis

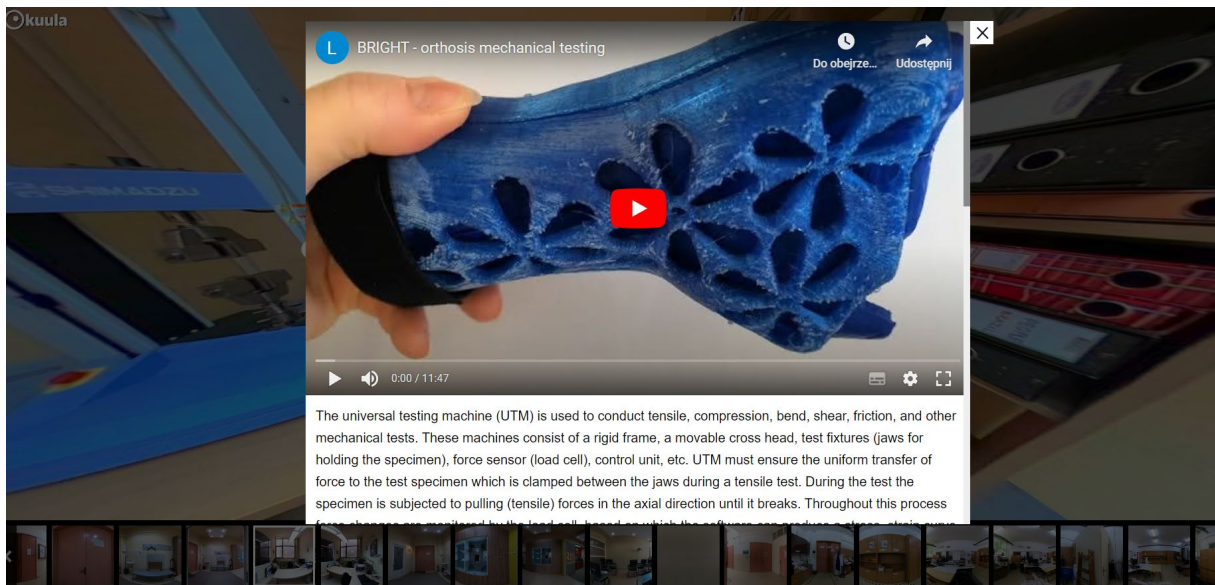


Figure 24. Universal Testing Machine room at VL of University of Nis

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

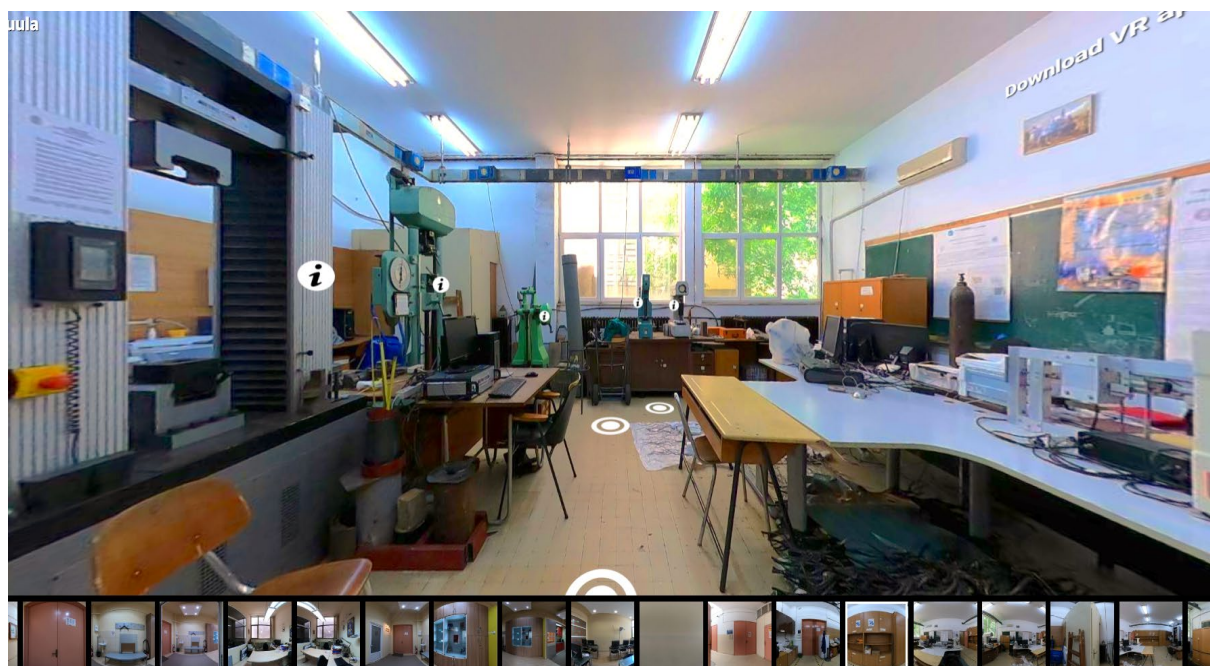


Figure 25. Material testing laboratory at VL of University of Nis

The educational content available at the laboratory contains the following:

- educational videos of testing of medical parts,
- educational descriptions of most basic material testing procedures, such as Charpy impact test or hardness test (Figure 26),
- link to BRIGHT webinar #4 on testing,
- links to some BRIGHT IO1 modules and IO2 toolkits,
- links to selected scientific publications by the team of UNI,
- link to educational interactive Virtual Reality application made for the BRIGHT project, allowing to take part in the process of material testing of medical part (application described in another chapter)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

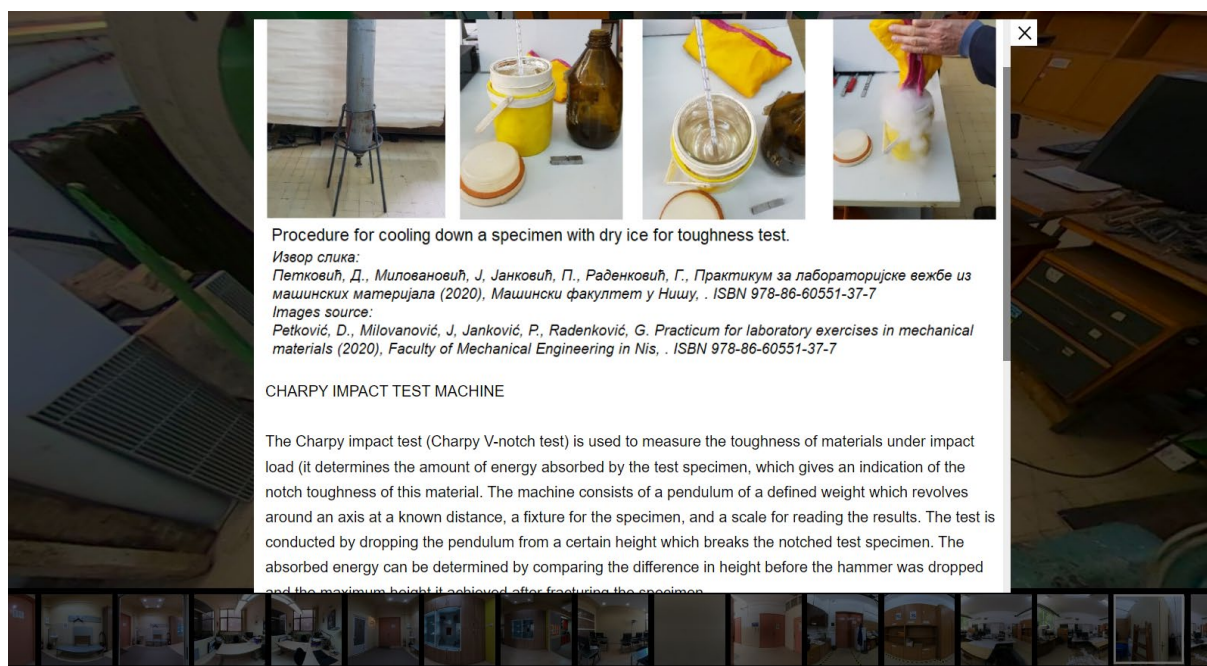


Figure 26. Description of Charpy impact test at the VL of material testing

3.3.5. VL Room 5 – Juraj Dobrila University of Pula

The VL of University of Pula presents a broader picture than the other rooms – here, overview of the whole university is presented. The virtual tour can be accessed through the following link:

<https://kuula.co/share/7sXgY/collection/7PzR7>

The actual technical laboratories that can be visited here are as following:

- laboratory of medical simulations (Figure 27),
- laboratory of programming (Figure 28),
- virtual showcase of mobile robots (Figure 29).

These rooms were assigned as supporting facilities / complementary / additional facilities for the main testing room (thematic room) that was assigned to University of Nis as shown in Figure 2

The educational content available in this VL are mostly videos and presentations of equipment and methods available at some classes conducted at the University, with relation to medical standards.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

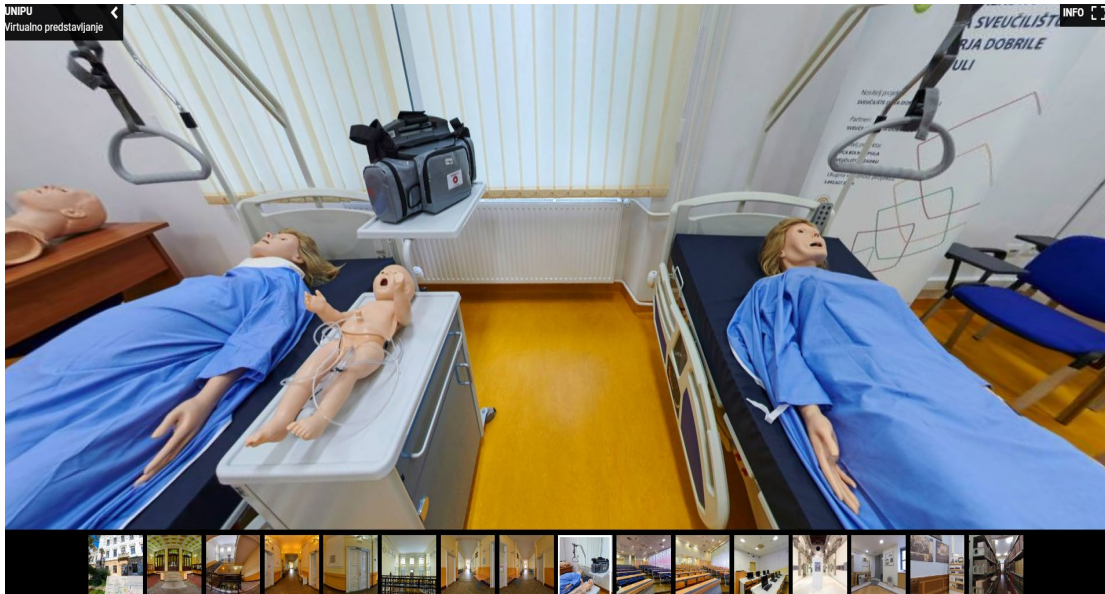


Figure 27. University of Pula – medical simulation laboratory

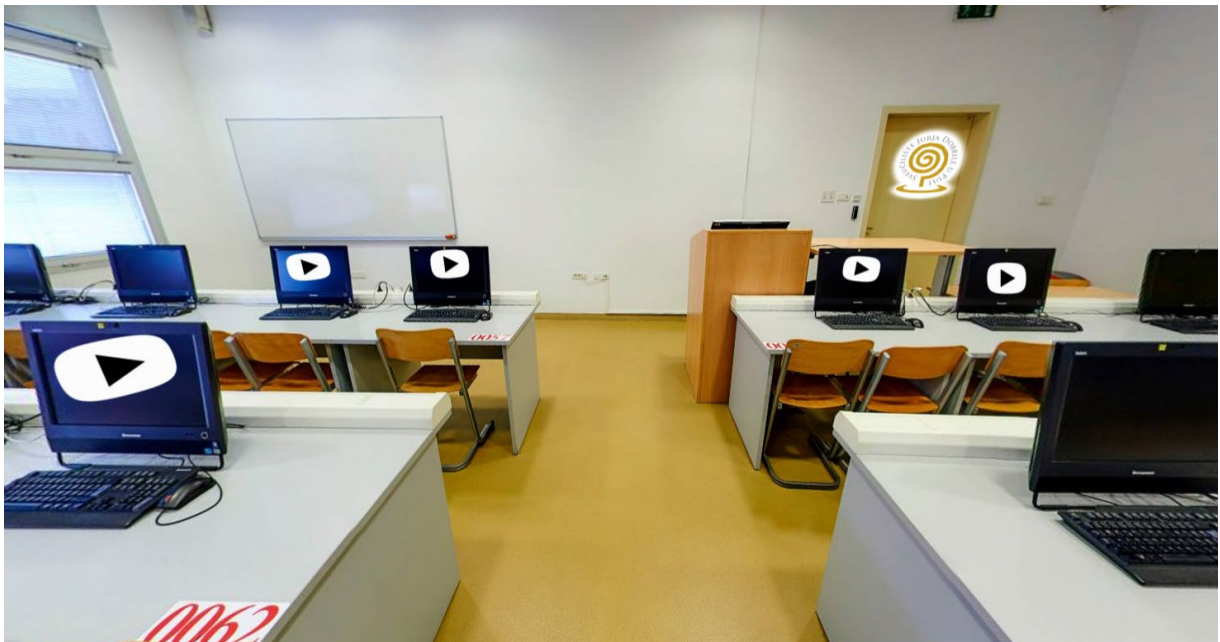


Figure 28. University of Pula – laboratory of programming

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

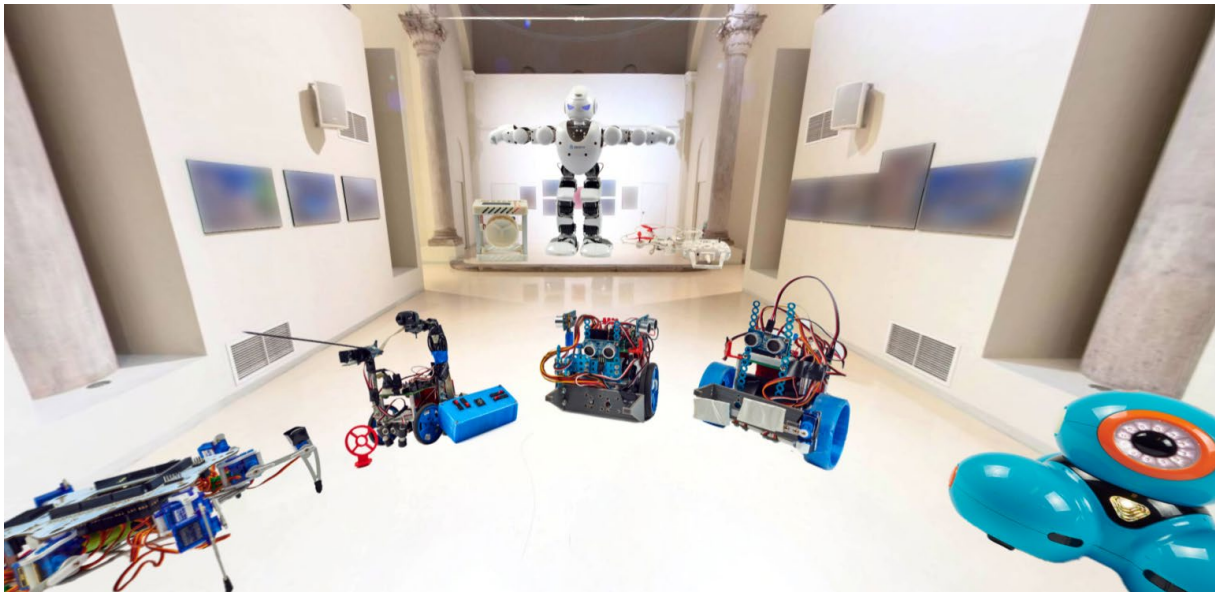


Figure 29. University of Pula – robot showcase

3.3.6. VL Room 6 – BIZZCOM s.r.o.

The VL of Bizzcom company presents unique capabilities of this industrial partner to the BRIGHT consortium. The main focus of Bizzcom VL are Augmented Reality applications, aside from prototyping, testing and transporting equipment. BIZZCOM virtual rooms have been assigned to support CAE laboratory main room of Technical University of Cluj-Napoca and testing main laboratory room realized by the University of Nis (Serbia) as one may notice in Figure 2.

The laboratory is available under the following link:

<https://nessy2022.viewin360.co/share/collection/79pDP>

The VL contains the following locations:

- starting point – outside the main company headquarters (Figure 30),
- reception, allowing to check on SM profiles and various projects (Figure 31),
- showroom (Figure 32),
- engineering hall (Figure 33),
- construction hall (Figure 34),
- assembly hall.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

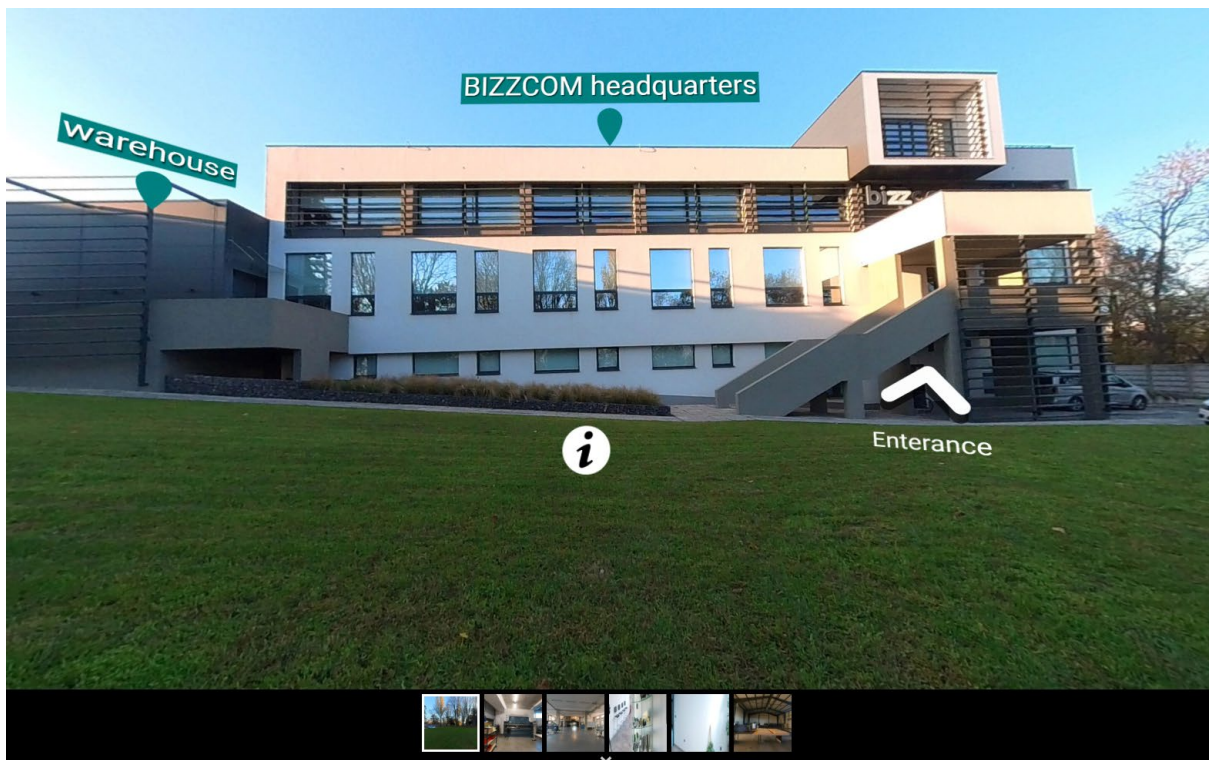


Figure 30. Bizzcom – starting point



Figure 31. Bizzcom – reception

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

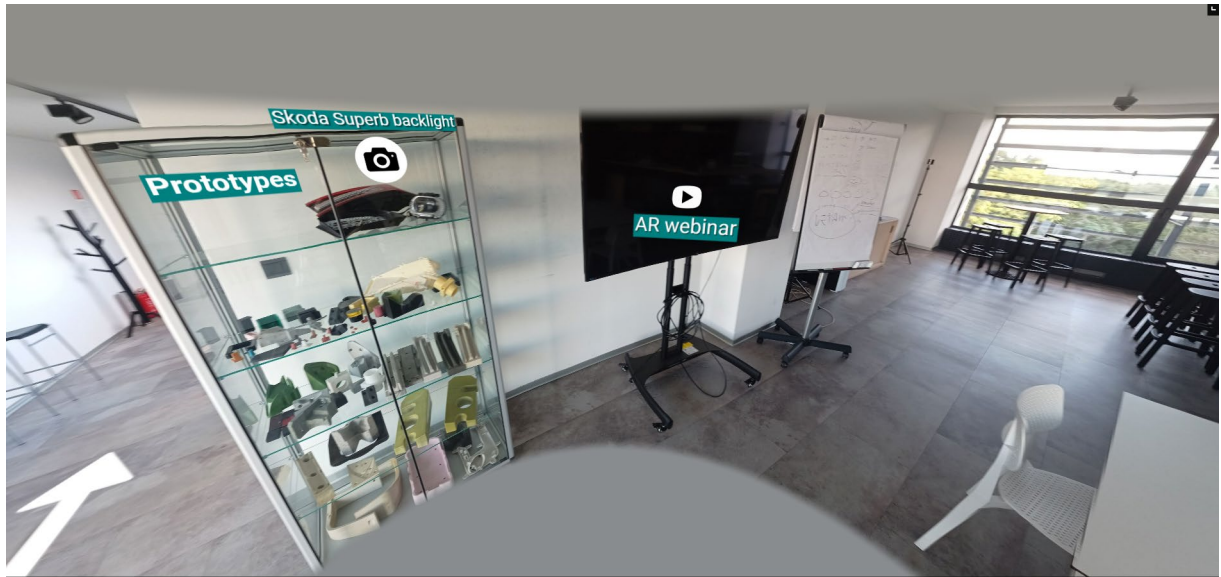


Figure 32. Bizzcom – showroom



Figure 33. Bizzcom – engineering hall (with AR marker visible)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 34. Bizzcom – construction hall

The educational contents of this VL are as following:

- educational videos of various equipment working (transporting devices, production machines etc.)
- link to Augmented Reality webinar realized in IO4,
- Augmented Reality models of medical parts (described in another chapter).

Also, as it is a real imagery of most of facilities of a specific production company, the educational value for the students comes also from getting to know the company itself. The VL represents the organizational structure of the company, processes realized there and equipment used. The students may get familiarized with how a modern, digital company focused on use of XR technologies, among other things, can be operating.

3.3.7. VL Room 7 – BM Plast d.o.o.

The virtual laboratory of the second industrial partner to the BRIGHT project – BM Plast company – is available at the following link:

<https://nessy2022.viewin360.co/share/collection/79p1c>

As in the case of Bizzcom, the VL enables students to see how a production company dealing with polymers is organized and working. The VL presents the various production processes related to polymers (useful when 3D printing prototyping stage is finished and a

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

given medical product is directed into real production), such as injection molding and extrusion processes (Figure 35) or material preparation process (Figure 36). This is the main reason why BM Plast virtual laboratory room (Figure 37) has been assigned to be one additional support to the main virtual testing laboratory room (thematic room) that was conceived by the University of Nis (Serbia) according to Figure 2. The equipment available at the production site is presented and described from educational point of view, emphasizing the most important aspects of the processes and devices.

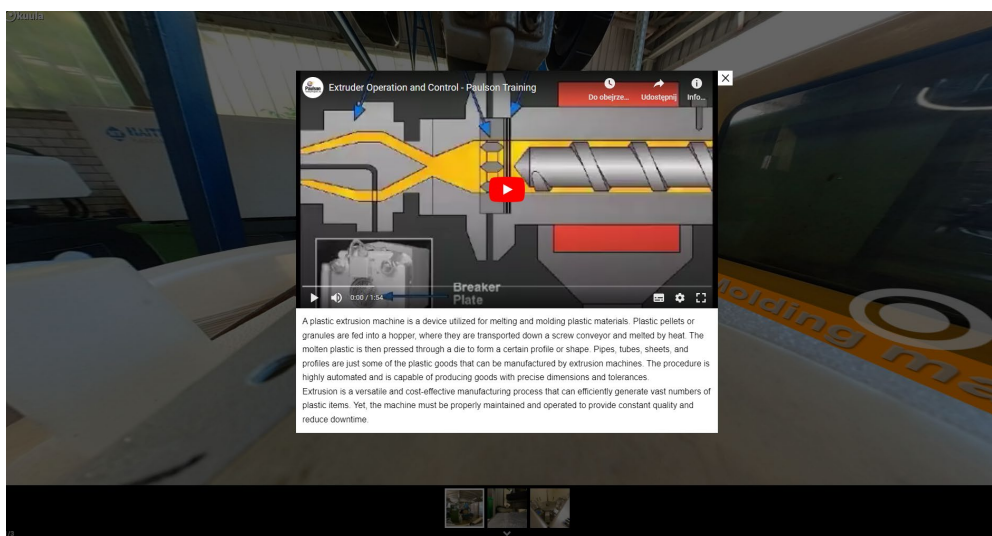


Figure 35. Polymer processing description at BM Plast Virtual Laboratory

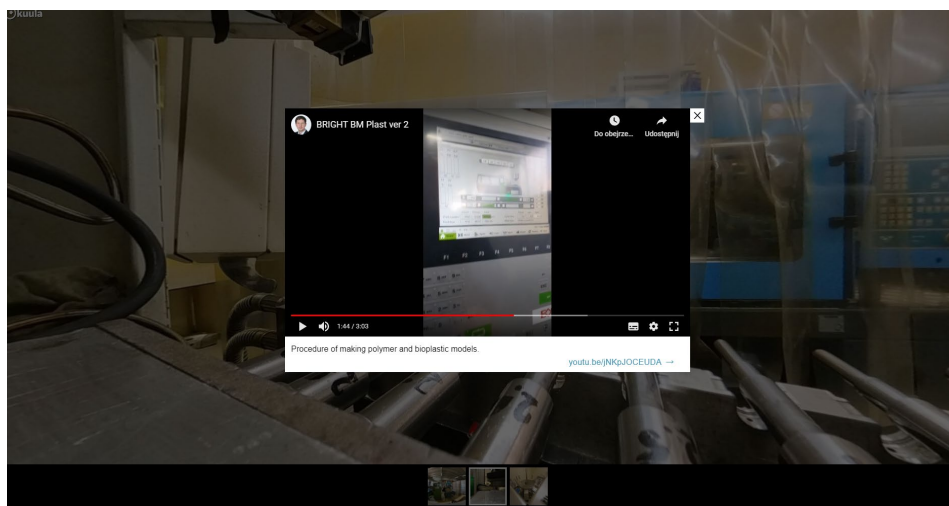


Figure 36. Material making process at BM Plast Virtual Laboratory

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 37. BM Plast Virtual Laboratory

3.4 Medical 3D models library

The library of medical parts 3D models contains all the digital representations of selected medical cases, used as educational content in the results of the BRIGHT project. The students can access, view and download 3D models of medical parts for their own educational use, as supporting materials to the instructions, modules, toolkits and movies created in other IOs of the project.

The library contains more than a dozen models, with possible expanding. It has not been created entirely anew – Sketchfab platform was utilized, and the models were embedded in the project website, to be accessed directly from the WWW interface (Figure 38).

The examples of models contained in the library include, but are not limited to:

- case 1 – hand orthosis
- case 2 – tongue
- case 3 – face shield
- case 4 – robotic prosthesis (Figure 39)
- case 5 – mechanical bicycle prosthesis
- implants
- anatomical models (body parts)

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

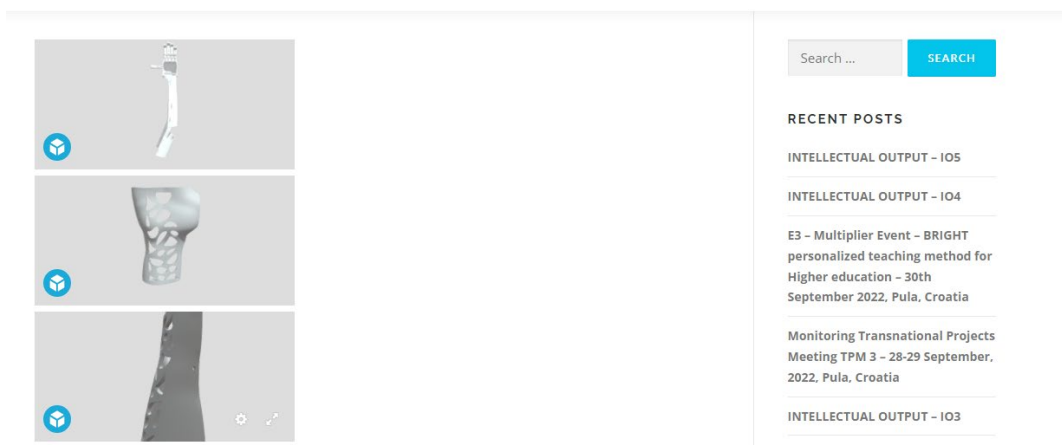


Figure 38. WWW interface of the 3D models library

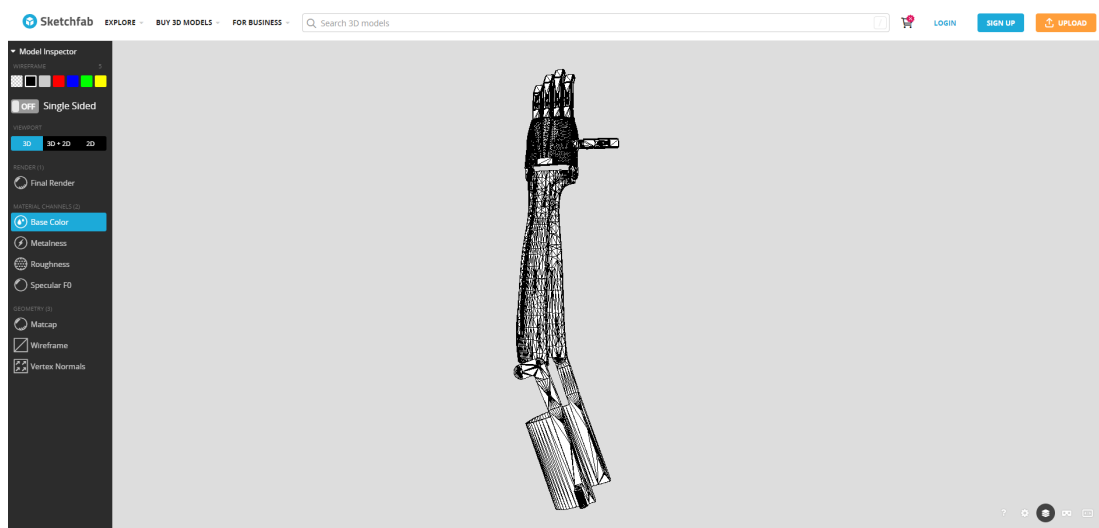


Figure 39. 3D model of a prosthesis opened in SketchFab platform

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The models can be downloaded and used for own educational processes in design, 3D printing and others. The same models are also able to be viewed through AR systems, as available in Room 6 (Bizzcom), they were also introduced in VR space, as available in Room 1 (TUCN).

Within BRIGHT virtual laboratory platform, as one may notice similar e-virtual laboratory models have been integrated within the BRIGHT virtual platform – related to CAD (e-library of CAD models – TUCN and STU, e-library of CAE models (TUCN), e-library of conventional models (STU, BIZZCOM and BM Plast) – see Figure 2.

3.5 VR/AR applications

3.5.1. Virtual Reality orthosis design and printing tutorial

This immersive Virtual Reality application has been created by team of Poznan University of Technology and it is available for download in the Virtual Laboratory of PUT (exact spot of the link is presented in Figure 40). The annotation also contains a short YouTube video presenting the functions and operation of the VR application.

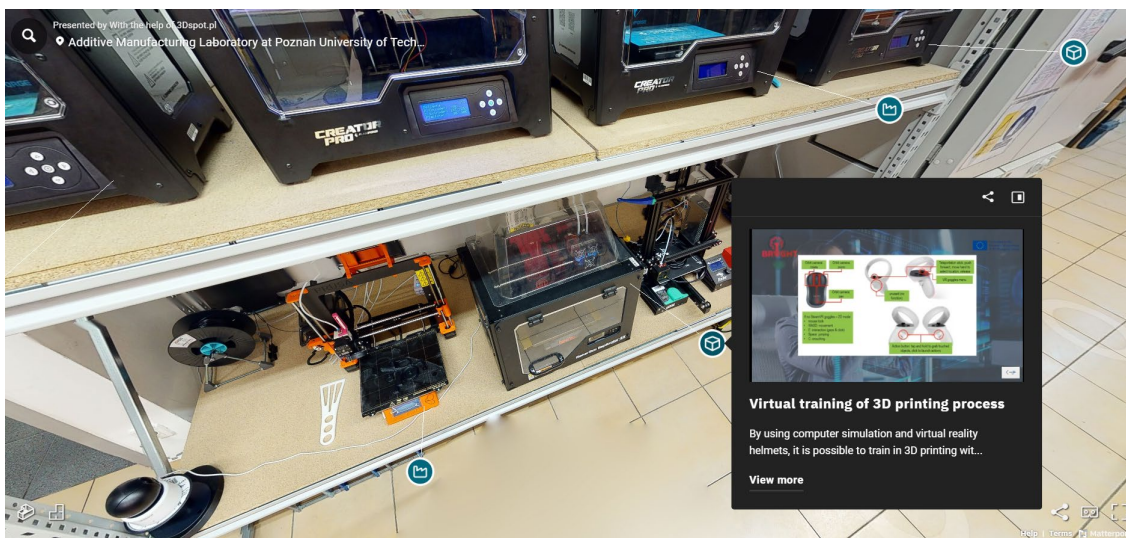


Figure 40. Virtual Reality application for design and 3D printing of a medical product available through Virtual Laboratory of Poznan University of Technology

The application is an interactive training scenario, focused on design (CAD) and manufacturing (3D printing) of one of two orthopedic products: a wrist hand orthosis (WHO) and an ankle foot orthosis (AFO). The process is based on results of AutoMedPrint project realized at PUT, and its subsequent results. It contains the following procedures:

- 1) selection of the medical product, with appropriate descriptions
- 2) 3D scanning of a patient (digital avatar of one of team members, with use of digital twin of AutoMedPrint equipment)
- 3) 3D configuration of product parameters
- 4) 3D printing (preceded by material selection and loading)
- 5) post processing of 3D printed products
- 6) try-on (assembly) with the digital patient

For both products (cases) in the application, full process can be realized.

The application is an immersive, PC VR application created in Unity software. It is compatible with the OpenVR standard, meaning that all VR goggles able to run through SteamVR software can be used with the application (this includes, but is not limited to goggles such as Meta Quest 2, HTC Vive Pro, Valve Index, HP Reverb G2, Samsung Odyssey HMD, as well as older and newer versions of these). It requires a reasonably good configuration of a computer, possibly with gaming graphics card (such as nVidia RTX 2060), at least 12 GB RAM and intel i5 processor or equivalent of.

The application can be also opened and used without VR goggles. Then, in the so-called desktop mode, it is operated similarly as typical First Person Perspective games – by using WASD keys and mouse for movement, along with space for jumping and E for using objects.

After opening the application, the initial screen is a menu, as presented in Figure 41. The menu allows to select the following options:

- start training – this loads the training scene and starts the actual simulation,
- instructions – a screen with information about controls, movement and interaction,
- project info – a board presenting information about the BRIGHT project, partners and short description of IO3,
- quit – this turns off the application.



Figure 41. Main menu of the Virtual Reality application for 3D printing teaching

After launching the training, the student is placed in a simulated environment – a large room, with AutoMedPrint scanning equipment in the middle, also containing a TV model (for displaying instructions) and some laboratory equipment (3D printer, cabinet with materials, working table with manual tools etc.). In the VR mode, movement around the environment is realized partially on user’s own legs (on a short distance) and by teleporting (Figure 42). In desktop mode (without goggles) movement is smooth, using WASD keys.

In the main window, there is a basic user interface with text windows and buttons. This is not visible to the student who has VR goggles, but can be operated by the instructor. The UI contains buttons for two camera modes (first-person which is preview of what user in VR goggles sees and orbit, which allows rotating and zooming to various places, independently on movements of the user). It also contains a text box with current instruction, and the quit button.

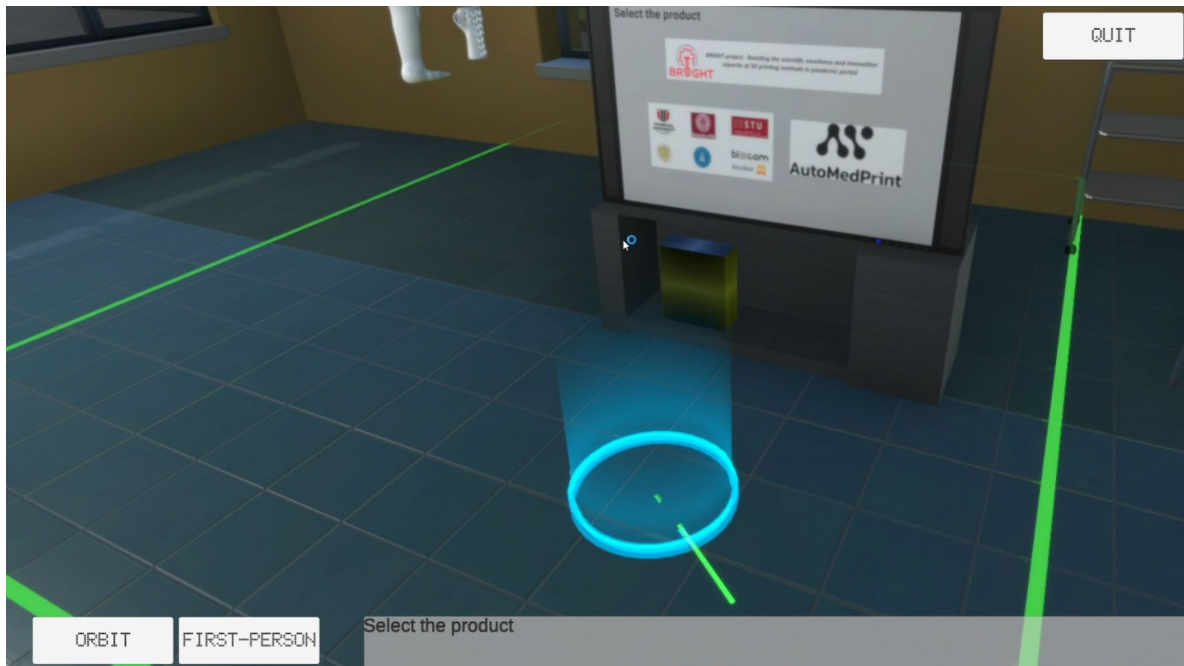


Figure 42. Movement on a distance in VR - teleporting

The initial step is product selection. After touching or clicking on a product, its description will be presented on the TV. Then, using a blue box with arrow, student can proceed to the further step (Figure 43).



Figure 43. The initial step – product selection

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The second step is patient scanning. The digital avatar is shown and the student must first invite the patient to the chair (Figure 44) and then start the scanning by clicking on the laptop at the scanning workplace (Figure 45).



Figure 44. Patient invited to the scanning workplace



Figure 45. Activation of 3D scanning procedure

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

As in the real AutoMedPrint system, the scanning is realized automatically (Figure 46). The user must wait for the process to finish, which takes approximately half a minute (the process is sped up in relation to the real scanning). After the process, the student must ask the patient to get off the chair and next task begins.

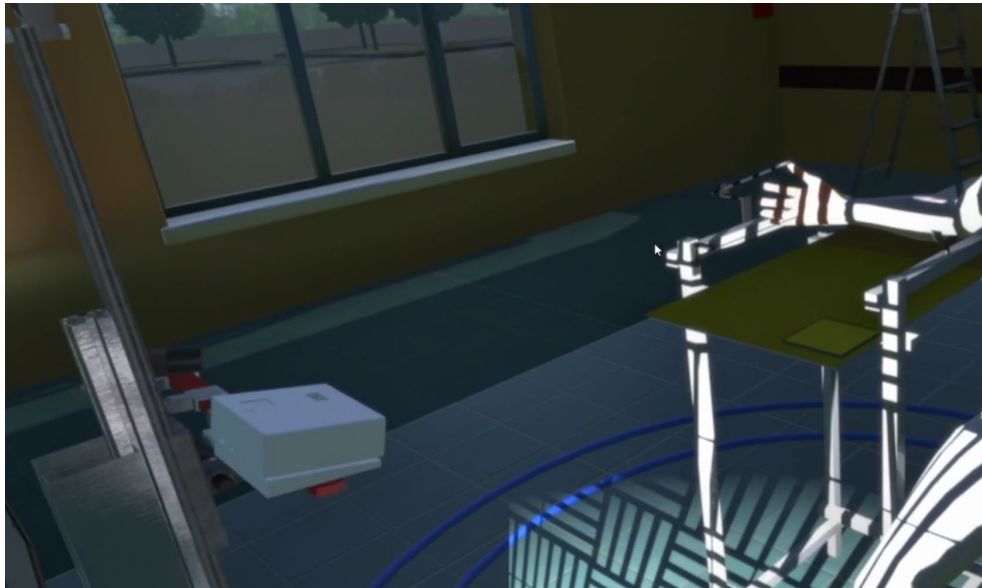


Figure 46. Simulated 3D scanning of patient's upper limb

The next stage is configuration of the variant of the selected orthopedic product. Some design features may be selected by the student, along with material, in the first step. In the second step, 3D printing process parameters can be selected (Figure 47).

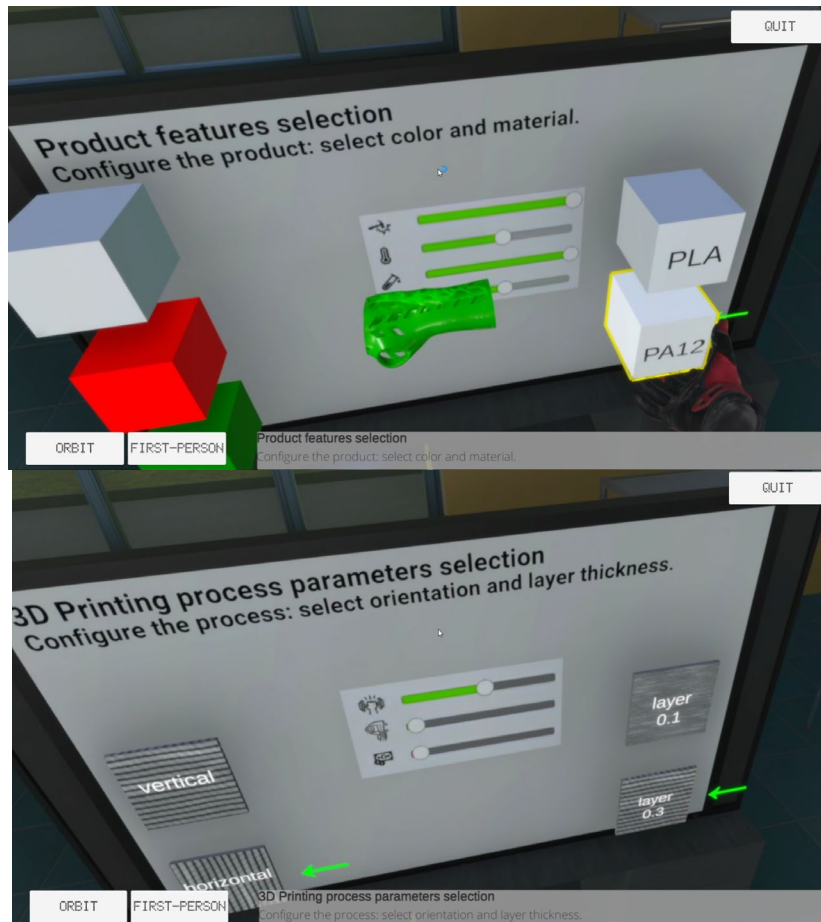


Figure 47. Configuration of the product (top) and process (bottom)

Next couple of steps are dedicated to the manufacturing process. The student must pick a specific roll of polymer filament, in a selected color, from the cabinet in the room and install it in the machine (Figure 48). Then, 3D printing (Fused Deposition Modelling) process can begin. The layer deposition is simulated, again it is sped up (normally, the process takes several hours) – Figure 49.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 48. Installing the material and turning on the machine

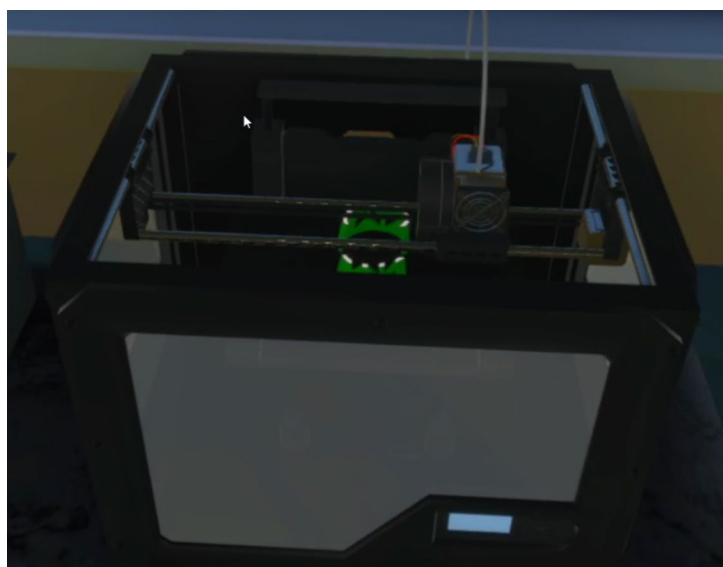


Figure 49. Simulation of 3D printing process

Another stage of the whole process of manufacturing of medical devices simulated in the VR application is post processing. The student must remove all parts from the machine and then manually polish them at the working table (Figure 50).

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 50. Post processing of simulated 3D printed parts

Final stage is assembling the orthosis on patient's limb – the student needs to bring the parts to the patient (who is present again in the scene) and assemble them (Figure 51). This finalizes the whole scenario.

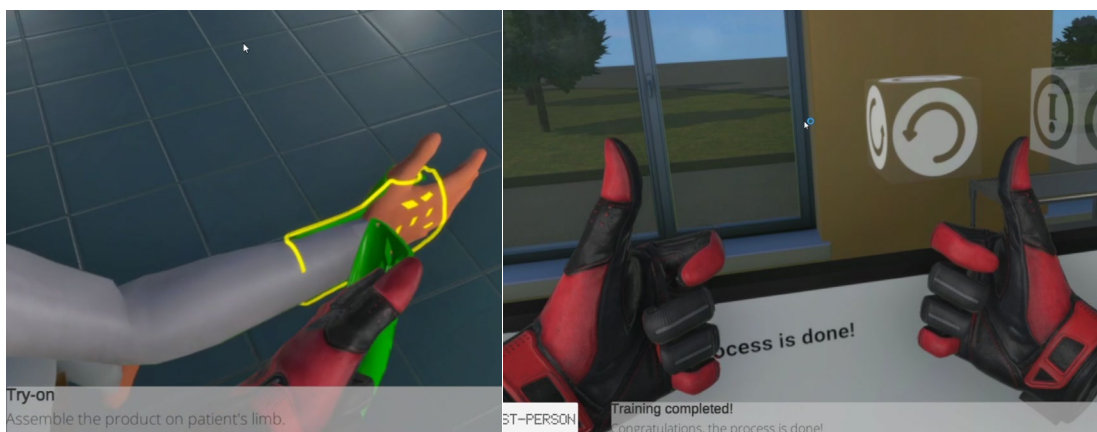


Figure 51. Assembling the product and finalizing the scenario

Virtual Reality is a technology that has been known to be used for effective education since the beginning of its conception. As such, the technology itself with its benefits will not be described here. To highlight the obtained objectives – the main benefits of the created VR application are:

- showing complete, innovative, digital process of manufacturing customized medical devices to the students,
- learning in an immersive environment – “learning-by-doing”,

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

- realistic simulation of 3D scanning and 3D printing process.

The application and its parts were used during BRIGHT project second summer school and further events. It is also used as a teaching tool at Poznan University of Technology, in at least two subjects realized at the Biomedical engineering study programme.

3.5.2. Virtual Reality product testing tutorial

The second fully immersive Virtual Reality training application has been created by team of University of Nis and it is available for download in the Virtual Laboratory of UNI, at several spots in the laboratory.

The application has similar method of creation and operation as in the case of the previous Virtual Reality application. It has been created also using the Unity engine and a similar set of plugins and scripts. It contains a single procedure, presenting mechanical testing of a medical part in a virtual laboratory setting, for teaching purposes.

The laboratory is a simplified representation (“digital twin”) of a real material testing laboratory at University of Nis. When starting the application, the user is placed directly inside the laboratory and is able to walk around and explore all the machines (Figure 52).

The interactive part is the tensile test. A specimen can be placed inside jaws of the universal testing machine and the process can be started by using a red button. Then, an animation is played and the process is simulated (Figure 53).



Figure 52. Material testing room in Virtual Reality

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

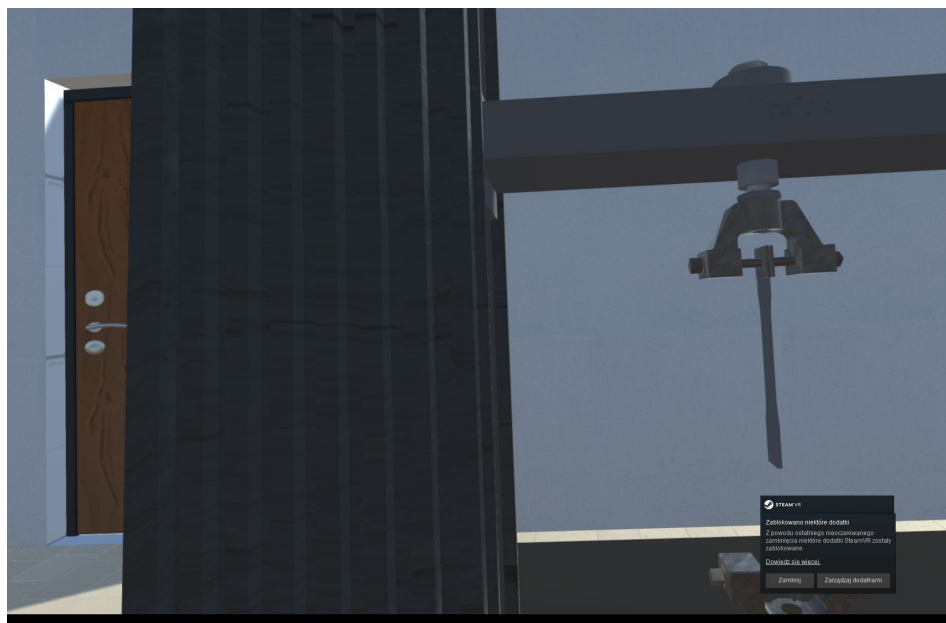


Figure 53. Simulation of tensile test in the VR testing application

As the previous application, this one also has a teaching advantage – it allows students to explore the virtual lab, see real testing machines and use them in the “learn by doing” manner. As such, it is an important asset and extension of the platform.

3.5.3. Augmented Reality 3D models

The Augmented Reality experience has been created by the Bizzcom company, in cooperation with the other partners. The Augmented Reality models can be viewed and interacted with using any mobile device (cellphone, or smartphone) with capability of recognizing QR codes.

The AR models are accessible from Room 7, belonging to Bizzcom company. In the Engineering Hall, it is possible to find a white board, with a marker named “AR models”. Opening this marker enables user to perceive a number of 3D models, corresponding mostly with BRIGHT case studies, and their respective QR codes (Figure 54). Each model can be clicked and opened and it will be available for simple interaction at the screen of computer or any other device (Figure 55). Certain models are animated, e.g. wrist hand orthosis has an exploding view, enabling to view its parts separately.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

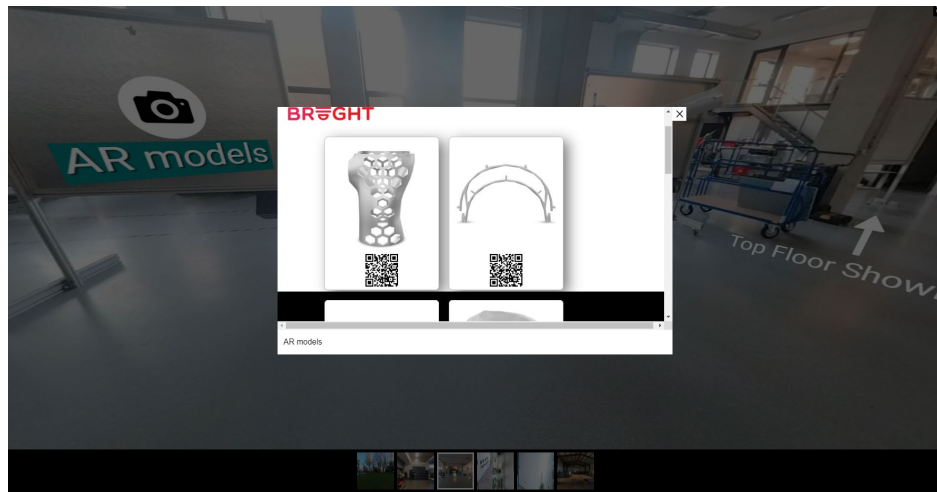


Figure 54. Interface for opening the AR models



Figure 55. View of a specific model

Using the QR codes, user will be transferred to a web application, where AR capabilities are used. The whole experience was developed on the basis of freely available toolkits, such as “model viewer” provided by the Smithsonian Digitization Programs Office (modelviewer.dev).

Through smart device (cellphone / tablet) camera, real world is visible. Then, the 3D model of a medical part can be superimposed on it, enabling the user to take part in Augmented Reality experience (Figure 56). The model can be freely transported around and simple interactions can be done with it, such as rotating, scaling and exploding (in selected cases).

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Figure 56. Augmented Reality experience – prosthesis model

The Augmented Reality experience with medical 3D models is a compelling way to get students familiarized with certain shapes and designs. It allows simple, everyday use device (smartphone) to be utilized as a 3D model viewer, also enabling smooth mixing of the model with real environment. These models, part of interactive experience in the BRIGHT VL platform, have very high importance in teaching, what is proven by their use in the BRIGHT project itself – they were used by the students of the summer school, with great fun, interest and to a great educational effect. The base of models can be further developed and more interactions can be also added, enabling to expand the educational effect.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

4 Conclusions

The Virtual Laboratory platform developed in scope of the Intellectual Output 3 of the BRIGHT project contains most of knowledge developed during the project presented in an accessible, interactive way. It has been also extensively used during the BRIGHT project activities, including the summer school and Multiplier Event carried out after the platform was finished.

The platform is a very important tool for teaching purposes and will be an important asset at partner institutions during the bioengineering courses and other educational activities, such as projects realized by students research groups. It was and is crucial in any form of remote learning, when access to laboratory is restricted or anyhow unavailable (e.g. when conducting remote classes for international students). It gives a new insight to the students that can remotely visit a number of laboratories and production facilities across Europe and get familiarized with how it's done using various, state-of-the-art equipment.

The platform's content, although finished considering the BRIGHT project assumptions and requirements, is not completely closed. The educational content can and will still be added, even after conclusion of BRIGHT project, adding or updating materials, expanding it with results of student diploma theses for further reference etc. The platform will be also developed in other EU funded projects realized together by the consortium members and its use as a teaching tool will be continued.

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.