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BRIGHT

Erasmus+ strategic partnership for Higher Education

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

O1 - BRIGHT course modules REPORT

Project Title	**Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517**
Output	**O1 - BRIGHT course-modules**
Date of Delivery	**July 2021**
Authors	**Răzvan Păcurar**
Version	**Final**

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Content

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1 Introduction, objectives and tasks of O1

In the last decade, 3D printing technologies become a solution for developing applications in medicine. This domain is very dynamic, challenging and attractive in terms of new types of 3D printing methods, materials, software programs or applications. In the context of the pandemic, especially when new medical parts are required to be designed, developed, produced and tested in the health sector, there is a strong demand of involving people from different sectors that have high level of expertise in complementary field. New curriculum, proposed by the BRIGHT consortium is innovative, since it involves not only experts from the manufacturing engineering domain or experts from science of strength materials that are required to be strategically involved in this context, but also experts in medicine. The involvement of these experts is not foreseen just to provide basic knowledge in their field of expertise (there are books available on the internet about most of the methods), but knowledge and experience from their point of view, so as they can transfer the know how to professors coming from Higher Education Institutes and students that should be able to get skills competences in producing parts that could really be a support to the hospitals in the context of the pandemic.

Based on the experience that the BRIGHT consortium had in previous EU projects and in collaboration with several medical institutions based on several research activities that have been realized before with the main aim of saving lives of the patients, one curriculum was built based on this experience & with the support of medical institutions involved in other EU projects in developing new products/ testing new materials by 3D printing for developing medical products to support hospitals in time of pandemic.

The curriculum proposed by BRIGHT consortium comprise 7 modules (CAD / CAE / Materials Science and Strength of Materials / Flexible manufacturing systems/ 3D printing and Rapid Tooling methods for medicine / Process optimization and software control / Medical Engineering standards and tests) + Practical Activity (innovative case study) along 1 year with 60 ECTS credits. Starting from the common curriculum which was constituted in the BRIGHT project in cooperation with medical institutes, which was assumed by the BRIGHT consortium and has been considered proper in providing not only knowledge, but also practical skills and modern methods of teaching in developing and producing of medical parts made by 3D printing, in the context of the pandemic, sustaining courses that have been

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mentioned in the previous paragraph have been prepared in O1 under the coordinating of the University of Nis (Serbia).

7 course modules were therefore produced by the University partners of BRIGHT project, the solutions presented / included in the modules being not just theoretical, the solutions presented / included in the modules being not just theoretical, but filled with many practical examples that have been explained and introduced in the realized modules, as they were realized based on the reach experience and expertise that the BRIGHT project consortium has in the developing, producing and testing of medical products in the last 20 years. (e.g. examples of conceiving and producing of medical implants, bone structures, orthoses, face shields, etc. have been included in the course modules). All prepared courses were inter-correlated in between them around specific medical examples that have been identified in common, each course being realized according to the previous experience and expertise each institution has in specific fields. Therefore CAD module was realized by the Poznan University of Technology (PUT) partner, since they have been used lot of programs in segmenting, scanning and designing of different implants that are related to the medical field. In the same way, CAE module and 3D printing and Rapid Tooling methods module were prepared by TUCN in which lot of experience gained in previous research projects done at national and international level (e.g. Horizon projects) were presented / included and shared in very professional manner as well. The rest of the course modules namely Strength of Materials and Science of Materials module was prepared by PUT Poznan, Process optimization and software control module has prepared by University of Nis (Serbia), Flexible manufacturing systems course module was prepared by STU Trnava (Slovakia) and Medical testing standards and tests course module has been prepared by Juraj Dobrila University of Croatia, the responsible partner coming from this institution, being partially employed also in one Medical institution from outside the BRIGHT consortium, being able in this way to provide the point of view / feedbacks on behalf of Medical institutions to the solutions that have been presented and developed in BRIGHT course modules, including related to the important aspect of standardization.

All 7 course modules written & prepared at the level of BRIGHT consortium were presented and shared with the participants that were involved at the BRIGHT International summer school event that was organized in „online" mode by the Technical University of Cluj-Napoca (TUCN) in July 2022 and important feedbacks were collected also on behalf of

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the participants regarding the innovative aspects, originality, scientific content, usefulness of the presented information, level of novelty, etc. All 7 course modules were strictly checked from the similarity point of view using Ithenticate anti-plagiarism application and level of originality was excellent, the content and the scientific level being on very high standard limits as collected feedbacks have confirmed this highly important aspect. The course modules were shared and are available on the BRIGHT project website to be accessed in open access mode or to be downloaded as they can be found on the following link: https://bright-project.eu/?cat=16 (see Figure 1).

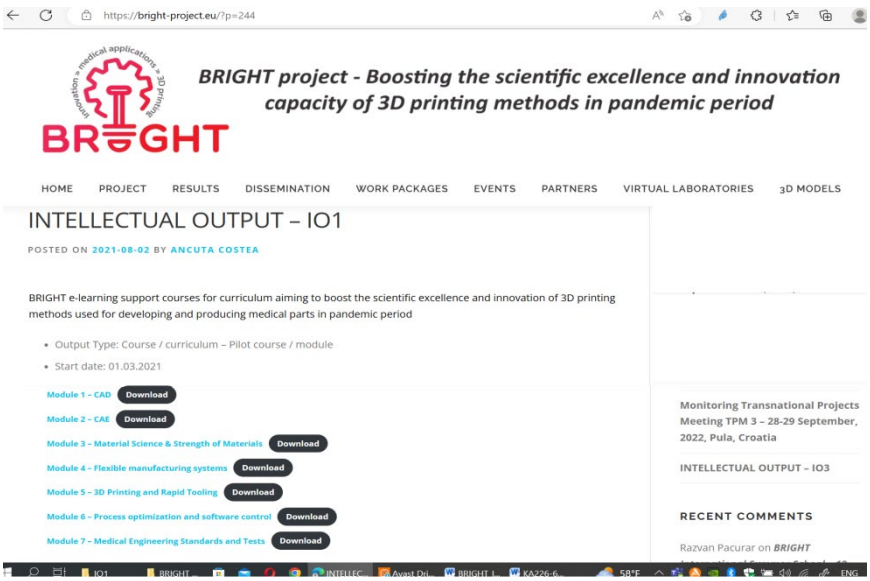

Figure 1. BRIGHT course modules shared on the BRIGHT project website, available to be "freely" accessed in open access mode and to be downloaded

2. Requirements, according to target groups

The target group of the activities that have been addressed with the course modules that have been realized were addressed to specific groups, like the following ones:

- The primary target group was represented by the teaching professors of the BRIGHT consortium. These professors were required to develop high-quality teaching materials that incorporate innovations, challenges & active involvement of their students in the teaching process. This became even more crucial during the pandemic when the methods of teaching had to be completely changed due to restrictions that limited physical contact between professors & students. Therefore the professors

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were asked to include in their courses, very practical and challenging examples of medical parts that are needed to be realized in time of pandemic and to change / adapt their way of teaching from the level of just providing information realized by Power point presentations, to try to include challenges, other type of applications, etc. in order to engage and motivate the students that were forced for a period to stay at home and follow lectures through their laptop screens. It was really one big plus for all BRIGHT professors that they had the chance to receive valuable feedback from their students & colleagues (professors) within the BRIGHT consortium, particularly during the organized events such as summer schools, related to the content of the course modules that they have been working with, novelty, innovation in terms of teaching methods, digitalization, applicability & active engagement of students in the teaching process, inter-correlation with the other courses in the curriculum presented by other professors of BRIGHT consortium. These aspects were highly important for professors involved in the BRIGHT consortium, who faced numerous challenges caused by the pandemic in relation to their students.

- Second important target group has been constituted by the students (especially the students that have been engaged in the International summer school organized by the BRIGHT consortium & students which will work on their courses in direct relation with professors of the BRIGHT consortium in their home institutions).There were tens of students which on behalf of each university involved in the consortium were interested about the resources of the BRIGHT consortium / were very interested about the particularities of the topic of BRIGHT project, which was related to the developing, producing & testing of case studies made by 3D printing technologies to support hospitals in the time of pandemic. Professors of BRIGHT consortium were actively engaged in the process of promoting the activities & share the resources provided by the BRIGHT project (course modules) in relation with their students. Many of these students have been actively involved in other activities that have been developed at the level of BRIGHT consortium or they have been engaged in developing and realizing of their diploma projects at BSc / MSc / PhD level using the BRIGHT resources and with the support of BRIGHT professors who were acting as supervisors / co-supervisors for their theses

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- In addition to professors & students within the BRIGHT consortium, targeted professors & students were also from outside the consortium and have been participated in the organized events, such as summer schools & multiplier events. It was surprising to see the high level of interest in these events, particularly in the first edition of the BRIGHT summer school, which was held online due to pandemic-related restrictions. More than 300 participants, mostly professors & students, from over 20 EU countries registered for the event organized by TUCN. The details of the event can be found in the links provided (https://bright-project.eu/wpcontent/uploads/2021/08/PRESENTATION_BRIGHT_30_07_2021_2.pdf & https://bright-project.eu/wp-content/uploads/2021/08/BRIGHT-extended-version.pdf). All of them had the chance to benefit by the BRIGHT course modules / lectures presentations and support that was offered to them "free of charge" and with "open access" during the organized events, but also post-events
- One category of target groups to whom the BRIGHT consortium has been addressed to through the realized course modules were represented by SMEs and medical institutions. Results that were reached within O1 about course modules have been disseminated at the Multiplier Event that has been organized at University of Nis (Serbia) in September 2021 (see: https://bright-project.eu/?p=221) through which over sixty participants from nearly 30 different institutions and companies have attended the event in time of pandemic (see Figure 2). Press release communicate and agenda of the event, together with the realized report after the organized event are available on the BRIGHT project website on the following addresses: https://bright-project.eu/wp-content/uploads/2022/04/Press_release_ME1-1.pdf; https://bright-project.eu/wp-content/uploads/2022/04/Agenda_Flyer_ME1.pdf and https://bright-project.eu/wp-content/uploads/2022/04/Report-ME1.pdf)

Figure 2. Multiplier event organized in Nis in September 2021 to disseminate results reached within O1

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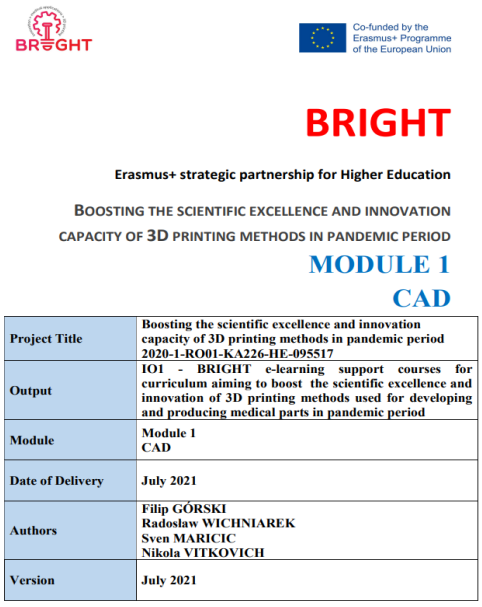
3. BRIGHT course modules

As it was mentioned before in the previous chapters, 7 course modules have been prepared by the BRIGHT project consortium, going through the logical chain of developing, producing and testing of medical products made by 3D printing, to support hospitals in time of pandemic.

3.1. BRIGHT course module 1 – Computer Aided Design (CAD)

First module that has been produced by PUT partner of BRIGHT consortium is related to Computer Aided Design (CAD) course module (see Figure 3) that is available to be accessed and downloaded for free on the next following address on the BRIGHT project website:
https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-1.pdf



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

MODULE 1

CAD

Project Title	**Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517**
Output	**IO1 - BRIGHT e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period**
Module	**Module 1 CAD**
Date of Delivery	**July 2021**
Authors	**Filip GÓRSKI Radosław WICHNIAREK Sven MARICIC Nikola VITKOVICH**
Version	**July 2021**

Figure 3. Computer Aided Design (CAD) course module realized by the PUT partner

As one may notice in the above picture this module has been realized by prof. Filip Gorski and Radoslaw Wichniarek from Poznan Univesity of Technology (PUT) in collaboration with prof. Sven Maricic (Juraj Dobrila University of Pula, Croatia) and prof. Nikola Vitkovic from University of Nis (Serbia).

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In terms of content of the module, after there are provided the basics in relation to CAD design in terms of different variants of modelling (like Wireframe Modelling, Solid Modelling, Surface Modelling, etc.) and the main software programs that can be used for realizing the CAD of the medical parts (like Autodesk, CATIA, Solidworks, etc) and their advantages / disadvantages in terms of the provided solutions, in continuing the CAD course module is focused on providing the basics related to the methodology of CAD design that can be used for medical parts to be realized by 3D printing. Starting from the basic concepts and examples for 3D printed parts realized by 3D printing and particularities of these models, there are provided in continuing the aspects related to the medical imaging techniques (like CT, MRI, etc.) and different types of data used for medical products in relation with 3D printing in time of modelling (like DICOM, STL).

Specific and particular aspects related to the designing of 3D printed mid-surgery supplies and orthopaedic and prosthetic equipment are provided in continuing, along with Good practices in preparing the medical parts in terms design for 3D printing, CAD course module being finalized with a presentation of summary of all presented methodologies in relation to CAD modelling. All aspects included in the CAD course module that are available on the BRIGHT project website in open access mode for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-1.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Filip Gorski (PUT) as shown in Figure 4.

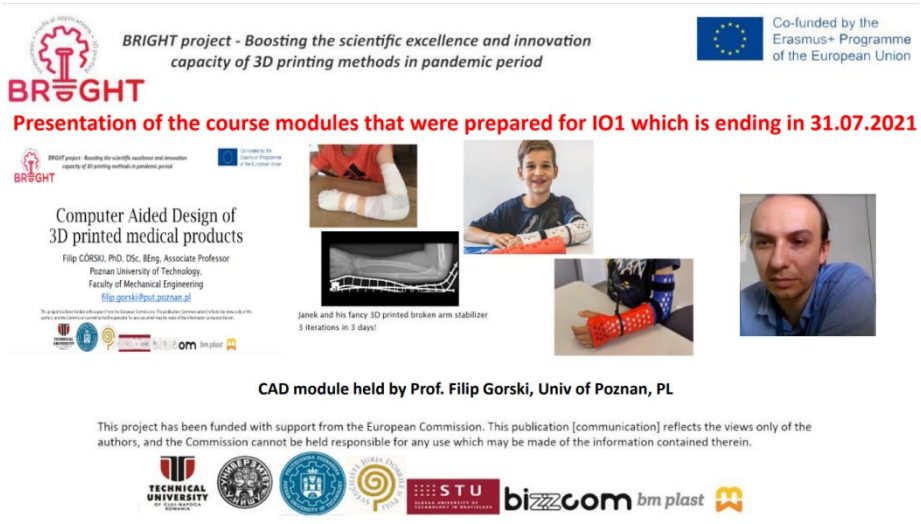
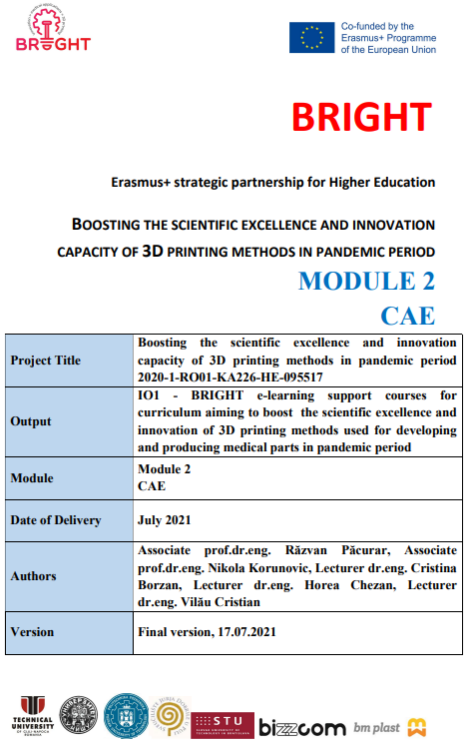


Figure 4. CAD course module presented by prof. Filip Gorski (PUT) at BRIGHT summer school edition 2021

3.2. BRIGHT course module 2 – Computer Aided Engineering (CAE)

2nd module that has been prepared by the BRIGHT consortium (TUCN partner in particular) has been related to the Computer Aided Engineering (CAE) domain, which is following the CAD step in the chain of developing of a new medical product to be made by 3D printing. CAE module (see Figure 4) is available to be accessed "free of charge" and to be downloaded from the BRIGHT project website on the following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-2.pdf)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BOOSTING THE SCIENTIFIC EXCELLENCE AND INNOVATION CAPACITY OF 3D PRINTING METHODS IN PANDEMIC PERIOD

MODULE 2

CAE

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - BRIGHT e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period
Module	Module 2 CAE
Date of Delivery	July 2021
Authors	Associate prof.dr.eng. Răzvan Păcurar, Associate prof.dr.eng. Nikola Korunovic, Lecturer dr.eng. Cristina Borzan, Lecturer dr.eng. Horea Chezan, Lecturer dr.eng. Vilău Cristian
Version	Final version, 17.07.2021

Figure 4. Computer Aided Engineering (CAE) course module realized by the TUCN partner

In terms of contributing to the CAE course module, as one may notice in the image provided above, beside the colleagues that are coming from TUCN, one specific contribution to few case studies that have been included in the CAE course module have been brought by prof. Nikola Korunovic that is coming from the University of Nis (Serbia).

In terms of CAE course module content, in the introduction there are being provided important details concerning the use and role of the Finite Element Methods / Computer Aided Engineering programs for medical applications that are made by 3D printing

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technologies, in continuing of this course module being provided specific examples that have been analysed through different software programs that are available and can be used for CAE analyses, like SolidWorks simulation, ANSYS or ABAQUS. Examples provided in relation to these programs, how these examples have been defined in the program, how materials have been selected, which characteristics have been considered for the selected materials and why those characteristics in particular and no other characteristics, how analyses were performed and how reach results have been interpreted, along with the importance of these results, these aspects are being in very detail provided in CAE course modules, so anyone who will follow the steps of the CAE analyses in relation to specific examples could comprise and understand in principle how such analyses have to be made and which is the importance of these analyses especially in the case when one new medical product is needed to be developed and realized by 3D printing technologies. In terms of examples included and provided in the CAE course modules, these are variated, going from different types of implants like pelvic implants or skull implants, to lattice structures or bone structures / bone fixators, all these provided examples being previously realized for real patients that have benefit and were surgically operated using the facilities and parts that have been made by 3D printing and Rapid Tooling solutions at the level of BRIGHT higher educational institutions in the preamble. All aspects included in the CAE course module that are available on the BRIGHT project website for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-2.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Răzvan Păcurar (TUCN) as shown in Figure 5.

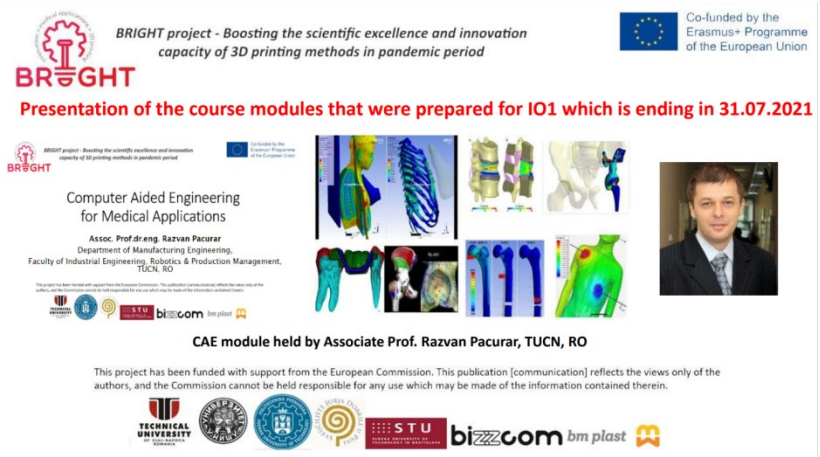

Figure 5. CAE course module presented by prof. Răzvan Păcurar (TUCN) at BRIGHT summer school edition 2021

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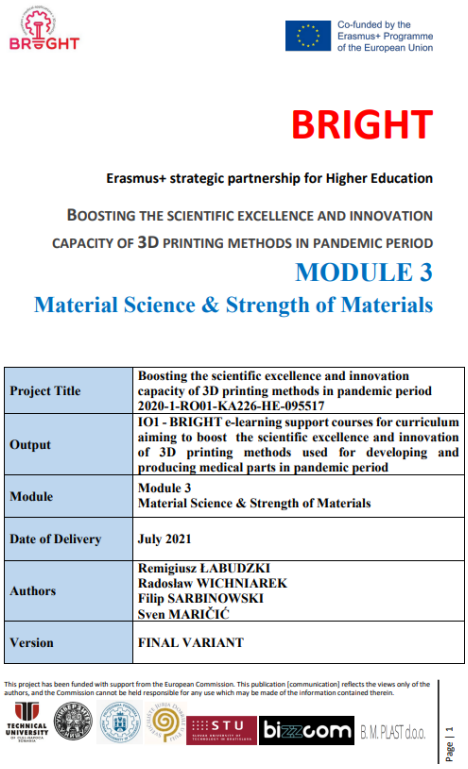
3.3. BRIGHT course module 3 – Material Science & Strength of Materials

The third module related to the Material Science & Strength of Materials (see Figure 6), which is important in providing / determining characteristics of materials that are needed for the CAE analyses (samples), but also in providing validation of real medical parts that have been realized by 3D printing has been prepared by PUT partner, this course module being available like the previous ones to be accessed “free of charge” or “downloaded” from the BRIGHT project website on the following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-3.pdf



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MODULE 3

Material Science & Strength of Materials

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - BRIGHT e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period
Module	Module 3 Material Science & Strength of Materials
Date of Delivery	July 2021
Authors	Remigiusz LABUDZKI Radoslaw WICHNIAREK Filip SARBINOWSKI Sven MARIČIĆ
Version	FINAL VARIANT

Figure 6. Material Science & Strength of Materials course module realized by the PUT partner

Also to this course module in particular, as one may notice beside the professors who have been working under coordination of prof. Remigiuzs Labudski from Poznan University of Technology (PUT), contribution to this module has been brought also on behalf of Prof.

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Sven Maricic from the University Juraj Dobrila of Pula (Croatia) which have provided examples related to samples that have been realized and tested within his university.

In the introduction of this module, at the beginning there are provided important information and review aspects in terms of biomedical requirements of 3D printing methods correlated with the biomaterials that are used for realizing specific medical products, like for surgery operations, orthopaedics, tissue engineering, dentistry, etc. In continuing the course module it is focused on providing the main technologies and methods that are used for mechanical testing of samples or of medical parts realized by 3D printing technologies. Working principles, constraints, setup details are being provided for each type of mechanical test that is described in the course, including hardness testing, tensile / compressive strength testing, impact strength tests, etc. Within the realized course there is approached also the Materials Science domain, in which methods of non-destructive testing of materials produced with 3D printing technologies, like Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Transmission Electronic Microscopy (TEM) are explained with concrete examples in details.

All aspects included in the Material Science & Strength of Materials course module that are available on the BRIGHT project website in open access mode for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-3.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Remigiuz Labudski (PUT) as shown in Figure 7.

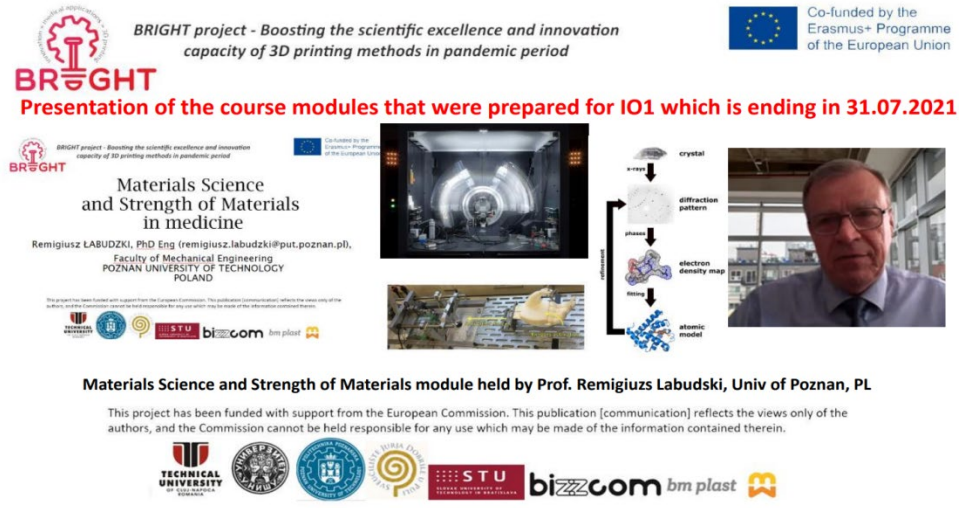

Figure 7. Material Science & Strength of Materials course module presented by prof. Remigiuz Labudski (PUT) at BRIGHT summer school edition 2021

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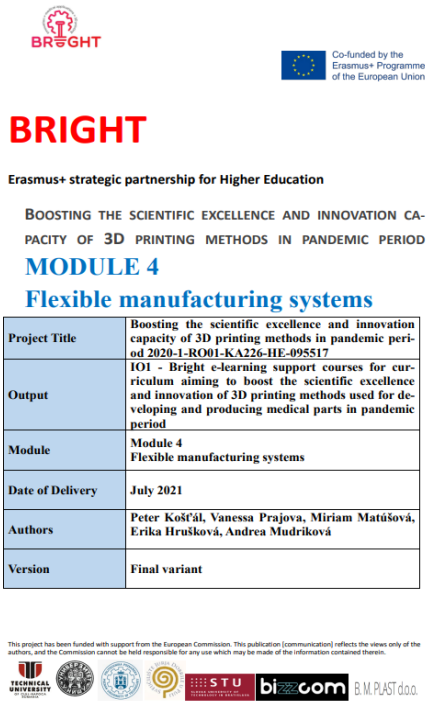
3.4. BRIGHT course module 4– Flexible manufacturing systems

The 4th course module related to Flexible manufacturing systems (Figure 8) is completing the previous course modules that have been presented by now, these course module being very important especially in the case when new types of materials that are suitable for 3D printing technologies or new types of 3D printing technologies that are particularized for specific types of medical applications that are needed to be realized and tested in concordance with specific needs / particularized needs defined by medical institutions in developing / testing of new products made by 3D printing are being required to be done. This specific module, taking into consideration the previous existing experience in this domain has been realized by the STU partner in Trnava (Slovakia), the course module being possible to be accessed like in the same of previous course modules presented, "free of charge" or "downloaded" from the BRIGHT project website on the following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-4.pdf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MODULE 4

Flexible manufacturing systems

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - Bright e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period
Module	Module 4 Flexible manufacturing systems
Date of Delivery	July 2021
Authors	Peter Košťál, Vanessa Prajova, Miriam Matúšová, Erika Hrušková, Andrea Mudriková
Version	Final variant

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Figure 8. Flexible Manufacturing systems course module realized by the STU partner

Flexible Manufacturing systems course module has been exclusively realized by the STU partner and is focused on the beginning in the introduction section on providing basic

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knowledge in defining of the advantages of flexible manufacturing systems, in increasing the level of productivity, but also on the disadvantages controlling such processes. Trends of these types of systems in medical Device Manufacturing processes, importance of integrating and using of lasers in the manufacturing, but also controlling processes, and especially the use of lasers in additive manufacturing processes, such as Laser Powder Melting or Hybrid Manufacturing methods, that are combining 3D printing with CNC machining are being explained in detail in this module, along with the challenges that exists when such type of equipment is required to be produced and controlled inter-dependently. In the end of the course module, since topic of the BRIGHT project and main aim is to develop new flexible systems for the medical sector, it is provided one last very important section, in which the specific requirements imposed by specific medical applications are needed to be imposed and clearly taken into consideration when one new type of flexible system is intended to be build. Such requirements are related to the need of sterilization, cleaning rooms, specific operations that are needed for surface treating or post-treating of medical parts that are being produced, etc. All these specific aspects included in the Flexible Manufacturing Systems course module that are available on the BRIGHT project website in open access mode for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-4.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Peter Kostal (STU) as shown in Figure 9.

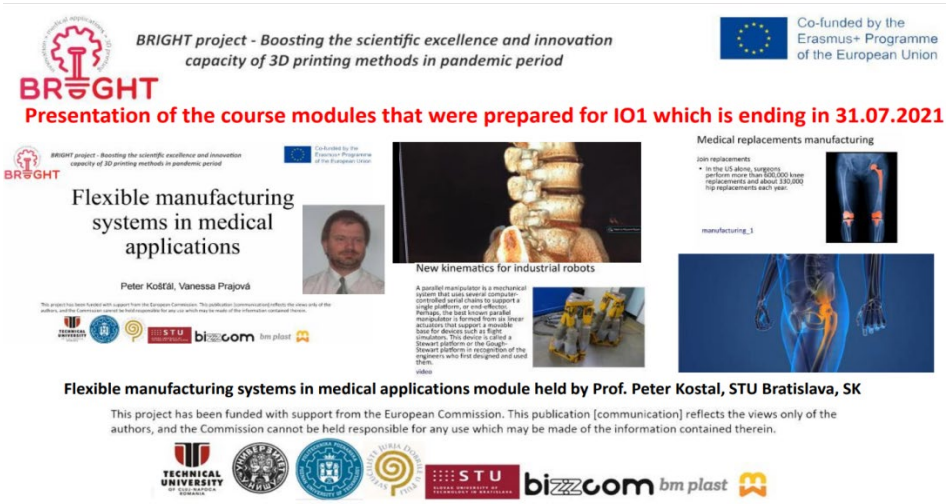

Figure 9. Flexible Manufacturing Systems course module presented by prof. Peter Kostal (STU) at BRIGHT summer school edition 2021

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3.5. BRIGHT course module 5– 3D printing and Rapid Tooling technologies

The 5th course module realized within O1 of the BRIGHT project was related to the main 3D printing and Rapid Tooling technologies (Figure 10) that can be used for realizing of medical parts. Since TUCN has the reachest experience and expertise in this field with more than 25 years in producing medical parts for specific patients, TUCN has been the main partner that has been designated in producing this specific course module, which is possible to be accessed “free of charge” and “downloaded” from the BRIGHT project website on the following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-5.pdf


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MODULE 5

3D PRINTING AND RAPID TOOLING

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - Mapping and scientific literature review on the mechatronics skills for Industry 4.0
Module	Module 5 3D Printing and Rapid Tooling
Date of Delivery	July 2021
Authors	Associate prof. dr.eng. Răzvan Păcurar, Associate Prof.dr.eng. Nikola Vitkovic Associate prof.dr.eng. Aleksandar Mltenovic
Version	Final variant, 18.07.2021

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Figure 10. 3D printing and Rapid Tooling course module realized by the TUCN partner

Beside TUCN partner, in producing of this course module, partners coming from University of Nis (Serbia) brought also their contribution with regards to specific cases that they have been working on with the aim of realizing bone structures by 3D printing.

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In terms of the content of the course module, in the introduction there are provided main advantages of using 3D printing / Rapid Tooling methods for medical applications, especially in the case when new types of materials are required to be tested or new customized medical parts are needed to be produced using these types of technologies for specific patients. In continuing, in the course module there are presented the main 3D printing and Rapid Tooling technologies that are used for realizing of medical parts (like Fused Deposition Modelling, Selective Laser Sintering, Selective Laser Melting, Stereolitography / Digital Light Processing, etc.), by providing in case of each technology details about working principle of specific 3D printing type of technology that is being analysed in the chapter along with presentation of main 3D companies and equipment items that are used in relation with the specific 3D printing that is presented / analysed and ending with the examples of medical parts that can be produced using each of the analysed / presented 3D printing and Rapid Tooling technology (parts to support hospitals in time of pandemic (face masks, respiratory valves etc.), but also implants, medical orthoses, bone structures, etc. All these specific examples provided in the 3D printing and Rapid Tooling module that is available on the BRIGHT project website for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-5.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Răzvan Păcurar (TUCN) as shown in Figure 11.

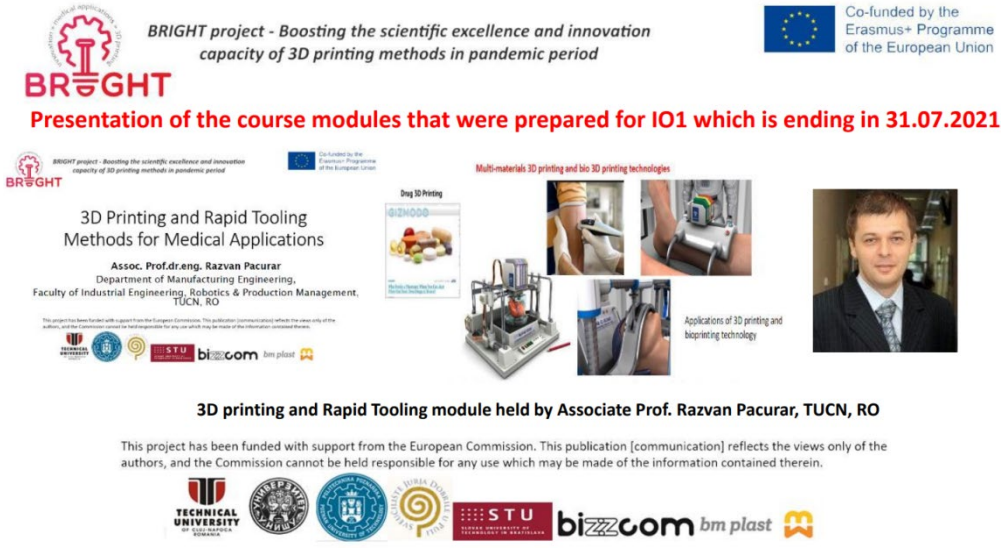

Figure 11. 3D printing and Rapid Tooling course module presented by prof. Răzvan Păcurar (TUCN) at BRIGHT summer school edition 2021

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3.6. BRIGHT course module 6– Process optimization and software control

Having the highest experience and expertise in the field of Process optimization and software control (Figure 12) that is needed to be realized when customized characteristics are needed for producing medical parts by 3D printing or when technological parameters used in specific 3D printing processes are needed to be optimized to improve the outcome results related to the realized parts (like accuracy, roughness, mechanical characteristics, etc.), this particular module (6th course module of BRIGHT) has been assigned to University of Nis, who have been working on it exclusively and have finally produced the course module which can be freely opened or downloaded from the BRIGHT project website on the next following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-6.pdf

BRIGHT

Erasmus+ strategic partnership for Higher Education

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

MODULE 6

Process optimization and software control

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - BRIGHT e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period
Module	Module 6 Process optimization and software control
Date of Delivery	July 2021
Authors	Nikola Vitković Jovan Arandelović Miloš Stojković Aleksandar Miltenović Miloš Simonović
Version	V1.0, 17.06.2021

Figure 12. Process optimization and software control course module realized by the University of Nis partner

Within its content, in the introduction section it is explained the importance of optimizing of the specific technological parameters in close correlation with the

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particularities of the medical part that it is needed to be realized, customized and in concordance with the shape features, size of the part, type of technology through which the medical part will be realized, functional role of the part and patient specific needs. In continuing within the realized module there are provided important information in terms of geometrical constraints and topological optimization that has to be implemented / realized in concordance with the anatomical requirements, 3D data information collected, type of the stress to which the part is going to be subjected to later on, etc. but also there are provided specific and important information on how an optimizing process of technological parameters have to be done in concordance to the expected outcomes and particularities of the medical parts that are needed to be produced. In order to exemplify better the approached methodologies for the topological and technological optimization, two examples are being presented in detail within this course module in the end, like bone model made by 3D printing and Reverse modelling procedure that has been applied at the University of Nis concerning the humerus bone and plate customization. All these examples and methods that are included within the Process optimization and software control module that is available on the BRIGHT project website for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-6.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Nikola Vitkovis (Univ. of Nis) as shown in Figure 13.

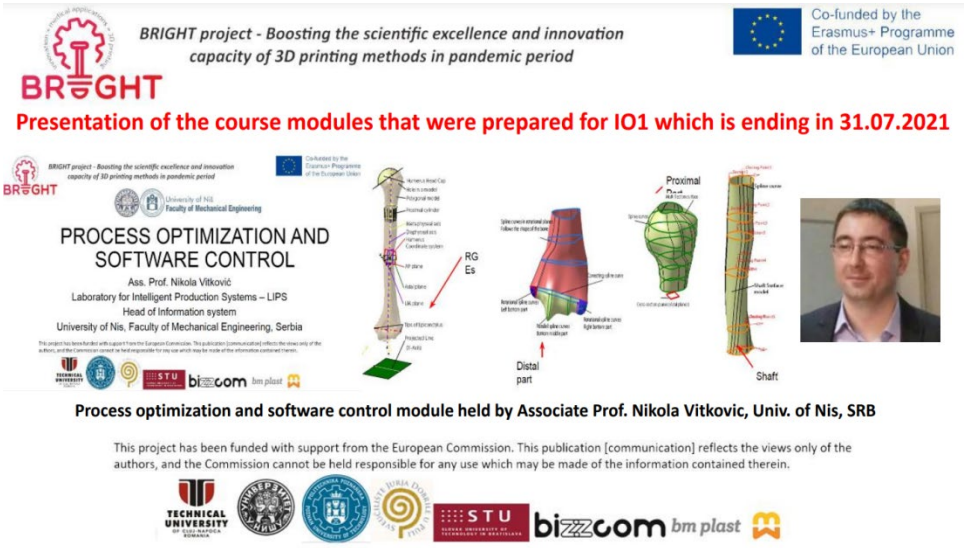

Figure 13. Process optimization and software control course module presented by prof. Nikola Vitkovis (Univ. of Nis, Serbia) at BRIGHT summer school edition 2021

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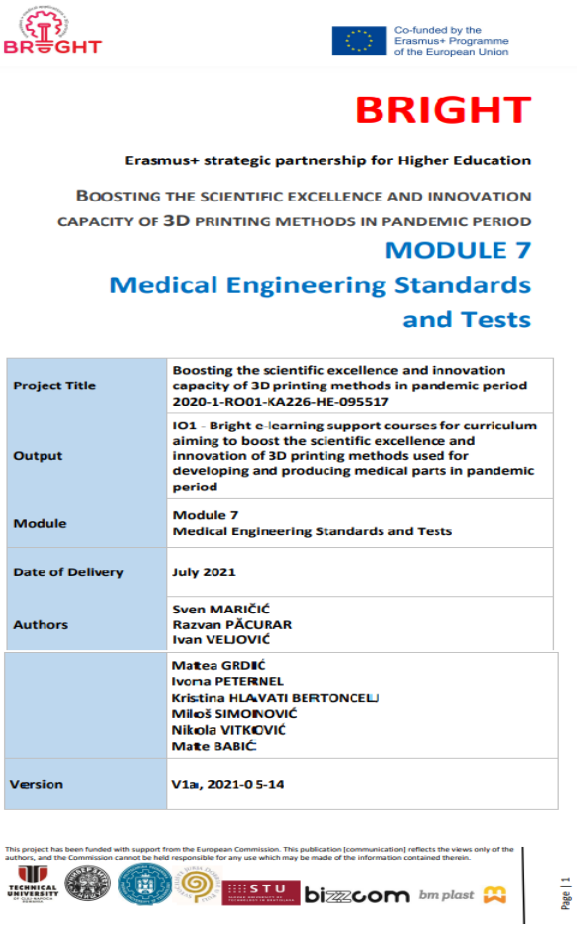
3.7. BRIGHT course module 7– Medical Engineering Standards and Tests

Last, but not least, the last course module (7th course module) realized within O1 of the BRIGHT project entitled "Medical Engineering Standards and Tests" (Figure 14) has been assigned to be coordinated by Juraj Dobrila University of Pula (Croatia) who has been identified as being the BRIGHT partner having the highest experience and expertise in this field. BRIGHT course module on "Medical Engineering Standards and Tests" is available to be freely accessed and downloaded from the BRIGHT project website, on the following link: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-7.pdf



BRIGHT

Erasmus+ strategic partnership for Higher Education

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

MODULE 7

Medical Engineering Standards and Tests

Project Title	Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517
Output	IO1 - Bright e-learning support courses for curriculum aiming to boost the scientific excellence and innovation of 3D printing methods used for developing and producing medical parts in pandemic period
Module	Module 7 Medical Engineering Standards and Tests
Date of Delivery	July 2021
Authors	Sven MARIČIĆ Razvan PĂCURAR Ivan VELJOVIĆ
	Matea GRDIĆ Ivona PETERNEL Kristina HLAVATI BERTONCELJ Miloš SIMONOVIĆ Nikola VITKOVIĆ Mate BABIĆ
Version	V1a, 2021-05-14

Figure 14. Medical Engineering Standards and Tests course module realized by the University Juraj Dobrila of Pula (Croatia) partner

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Besides colleagues coming from Juraj Dobrila University of Pula (Croatia), contribution to this module has been brought also from TUCN, University of Nis and BM Plast partners who had previous experience in working with medical products realized for specific patients and needs in cooperation with medical institutions, like universities, clinics or hospitals. In terms of content of the module, in the Introduction are presented the main steps that are needed in terms of standardizing of a product to be made by 3D printing for medical purposes. In continuing are provided examples of how these steps have been applied in the case of one medical shield that has been realized by 3D printing to support hospitals in the time of pandemic, but also the importance of performing of additional tests that are important for the standardization process and test of medical products (describing in detail the procedures that are needed to be followed in this case) regarding tolerances, dimensional control, metrology, but also new methods that are important for testing of medical products in clinical environment using modern methods of evaluating / analysing like Artificial Intelligence (AI), Virtual Reality (VR), etc. All these examples and methods for standardization and testing of the medical products that are included within the Medical Engineering Standards and Tests module that is available on the BRIGHT project website for downloading (see: https://bright-project.eu/wp-content/uploads/2022/04/BRIGHT_IO1_module-7.pdf) have been presented to the BRIGHT summer school 2021 edition by prof. Sven Maricic (Juraj Dobrila University of Pula, Croatia) as shown in Figure 15.

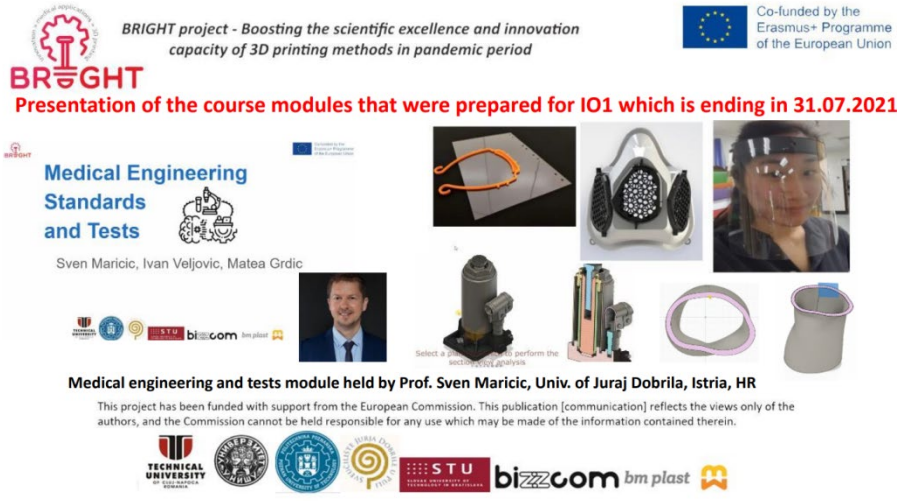

Figure 15. Medical Engineering Standards and Tests course module presented by prof. Sven Maricic (Juraj Dobrila University of Pula, Croatia)at BRIGHT summer school edition 2021

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4. Conclusions

As it was mentioned in the introductive chapter, the curriculum proposed by BRIGHT consortium comprise 7 modules (CAD / CAE / Materials Science and Strength of Materials / Flexible manufacturing systems/ 3D printing and Rapid Tooling methods for medicine / Process optimization and software control / Medical Engineering standards and tests) that have been prepared by the BRIGHT consortium in the frame of O1 under the coordinating of the University of Nis (Serbia). The above mentioned 7 course modules were therefore produced by the University partners of BRIGHT project, the solutions presented / included in the modules being not just theoretical, but filled with many practical examples that have been explained and introduced in the realized modules, as they were realized based on the reach experience and expertise that the BRIGHT project consortium has in the developing, producing and testing of medical products in the last 20 years. All 7 course modules written & prepared at the level of BRIGHT consortium were presented and shared with the participants that were involved at the BRIGHT International summer school event that was organized in „online" mode by the Technical University of Cluj-Napoca (TUCN) in July 2022 and important feedbacks were collected also on behalf of the participants regarding the innovative aspects, originality, scientific content, usefulness of the presented information, level of novelty, etc. Results that were reached within O1 about course modules have been also disseminated at the Multiplier Event that has been organized at University of Nis (Serbia) in September 2021, and the realized course modules were further on used also by the professors of BRIGHT consortium in relation with their students in time of pandemic. Many of these students have been actively involved in other activities that have been developed at the level of BRIGHT consortium or they have been engaged in developing and realizing of their diploma projects at BSc / MSc / PhD level using the BRIGHT resources and with the support of BRIGHT professors who were acting as supervisors / co-supervisors for their theses. Results reached within O1 in terms of course modules have been further on used and integrated within the virtual laboratory platform that has been realized by the BRIGHT consortium in the frame of O3 in the end.

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