EMERALD

The Education, Scholarships, Apprenticeships and Youth Entrepreneurship

EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS

EMERALD Dissemination

Key action: 2021 Cooperation Projects in Higher Education Area

Start date: 15.02.2022

End date: 30.09.2023

Total duration: 19.5 months

European Network For 3D Printing of Biomimetic Mechatronic Systems – EMERALD Project Reference: 21-COP-0019 is part of The Education, Scholarships, Apprenticeships and Youth Entrepreneurship Programme – EEA Grants 2014-2021 which was funded within the key action "2021 Cooperation Projects in Higher Education Area".

Technical University of Cluj-Napoca is Lead coordinator of the EMERALD project and the consortium is comprised by Technical Universities and SMEs partners that are coming from Norway, Romania, Poland and Slovakia. The main objective of the EMERALD project consists in providing teaching resources and methods for professors and students that are coming from the Higher Education institutions and are interested in getting relevant knowledge, skills and competences in the field of 3D printing methods used for realizing of bio-mechatronic systems for people with special needs (amputated arms).

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Content

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1. Introduction

The EMERALD project, with the reference code 21-COP-0019, was realized under The Education, Scholarships, Apprenticeships, and Youth Entrepreneurship Programme of the EEA Grants 2014-2021 framework, providing teaching resources and methodologies in the field of 3D printing for bio-mechatronic systems that are aiming to support people with special needs (with amputated arms). The EMERALD project is particularly significant for the students and professors coming from higher education institutions who are keen on acquiring in-depth knowledge and skills in 3D printing techniques focused on creating bio-mechatronic systems, especially for individuals with special needs, such as those with amputated arms as it was mentioned before.

One of the most important elements of the EMERALD project consisted in the commitment of all the involved institutions of the EMERALD consortium on disseminating knowledge and achievements to a broader audience. This included not only the direct participants, such as students and professors within the EMERALD consortium, but also small and medium-sized industrial companies (SMEs representatives), medical institutions and the general public. By ensuring a constant flow of information and updates throughout the project's lifecycle, EMERALD project aimed to maximize its impact to ensure that its achievements are widely recognized and utilized.

The higher educational institution partners in the EMERALD consortium played a crucial role in this process in this context. They have been actively involved in developing teaching resources and also participate in various activities such as workshops, meetings and conferences events which have been provided excellent opportunities to integrate and discuss the perspectives and insights gained from the EMERALD project, ensuring that its principles and methodologies were broadly disseminated, used and implemented in a way or another on these institution to whom the results have been shared in this way.

In terms of tangible outputs, the EMERALD project had overcome with lot of teaching resources, including e-course modules, e-toolkit modules for a laboratory manual and an e-learning virtual platform in which there have been integrated lot of supplementary educational documents, tools and applications that can be used by anyone who is interested on getting knowledge and skills for producing bio-mechatronic systems for people with amputated arms using 3D printing technologies. Additionally, the EMERALD project included a set of case studies, which were instrumental in developing, producing, and testing of new bio-mechatronic systems for people with amputated arms,

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using the resources of the e-learning platform that have been produced by the EMERALD consortium partners in the end. These initiatives have been particularly beneficial for the students and professors involved, providing them with hands-on experience and practical knowledge in the field, along with the possibility of realizing jointly diploma projects in this context.

Each partner in the EMERALD consortium has actively contributed to the promoting of the EMERALD project results. This was realized through various channels, including institutional websites, social media, press articles and publications such as articles and books. Furthermore, the EMERALD consortium has organized and has been participating in different types of events like workshops, conferences, summer school events, and multiplier events. These activities were not only highly important for sharing knowledge, but also for encouraging collaboration and networking among participants to these events. The dissemination of these results has been systematically documented and shared on the EMERALD project website, ensuring that all interested parties have access to the valuable resources and insights generated by this innovative project.

2. Dissemination strategy of the EMERALD consortium

The EMERALD project that has been focused besides the realizing of teaching resources in the field of 3D printing for Bio-mechatronics systems to be used for people with amputated arms, also on the conceiving of a European Network for 3D Printing of Biomimetic Mechatronic Systems, has developed an elaborated communication and dissemination plan (like shown in Figure 1) to effectively share its results and advancements. This plan encompasses a wide range of activities and initiatives, each designed to target specific aspects of the EMERALD project's outreach and impact.

As one may notice from Figure 1, one highly consistent part of this strategy has been represented by the organizing of online and offline events, such as international workshops, conferences, and multiplier events. These gatherings have been crucial for directly engaging with the EMERALD project’s stakeholders, including academic peers, industry representatives, and the broader public. These events have constituted the right context and framework for constituting the EMERALD network in the end.

In addition, the EMERALD project emphasizes the importance of academic publications. By preparing and submitting manuscripts to high-impact journals and conferences, the EMERALD project has aimed to ensure that its scientific contributions are disseminated within the academic community.

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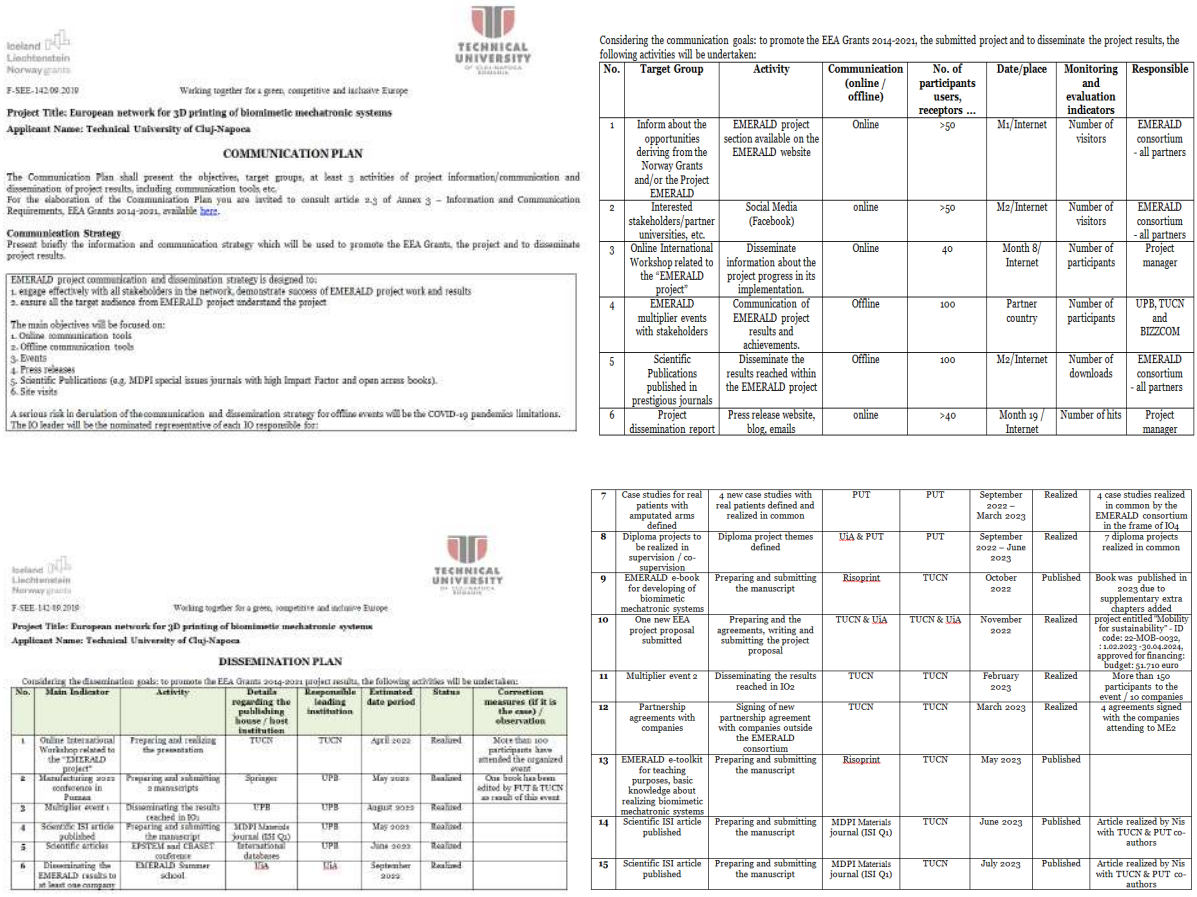
This approach not only enhanced finally the EMERALD project's visibility in academic context, but also has contributed in providing of broader knowledge base in the field of 3D printing and bio-mechatronic systems. In addition to this, the EMERALD consortium has realized prioritized activities in trying to engage as much as possible on the organized events or the events to which the EMERALD partners have participated to, with industrial companies (stakeholders) that are interested about the topic of the EMERALD project (3D printing / bio-mechatronic systems for people with amputated arms) and are interested to be part of the EMERALD network and bring contributions in this field.



F-SEE-142.09.2019 Working together for a green, competitive and inclusive Europe

Project Title: European network for 3D printing of biomimetic mechatronic systems
Applicant Name: Technical University of Cluj-Napoca

COMMUNICATION PLAN

The Communication Plan shall present the objectives, target groups, at least 3 activities of project information/communication and dissemination of project results, including communication tools, etc.
For the elaboration of the Communication Plan you are invited to consult article 2.3 of Annex 3 – Information and Communication Requirements, EEA Grants 2014-2021, available here.

Communication Strategy
Present briefly the information and communication strategy which will be used to promote the EEA Grants, the project and to disseminate project results.

EMERALD project communication and dissemination strategy is designed to:
1. engage effectively with all stakeholders in the network, demonstrate success of EMERALD project work and results
2. ensure all the target audience from EMERALD project understand the project

The main objectives will be focused on:
1. Online communication tools
2. Offline communication tools
3. Events
4. Press releases
5. Scientific Publications (e.g. MDPI special issues journals with high Impact Factor and open acess books).
6. Site visits

A serious risk in deviation of the communication and dissemination strategy for offline events will be the COVID-19 pandemics limitations.
The IO leader will be the nominated representative of each IO responsible for:

Considering the communication goals: to promote the EEA Grants 2014-2021, the submitted project and to disseminate the project results, the following activities will be undertaken:

No.	Target Group	Activity	Communication (online / offline)	No. of participants users, receptors ...	Date/place	Monitoring and evaluation indicators	Responsible
1	Inform about the opportunities deriving from the Norway Grants and/or the Project EMERALD	EMERALD project section available on the EMERALD website	Online	>50	M1/Internet	Number of visitors	EMERALD consortium - all partners
2	Interested stakeholders/partner universities, etc.	Social Media (Facebook)	online	>50	M2/Internet	Number of visitors	EMERALD consortium - all partners
3	Online International Workshop related to the "EMERALD project"	Disseminate information about the project progress in its implementation.	Online	40	Month 8/ Internet	Number of participants	Project manager
4	EMERALD multiplier events with stakeholders	Communication of EMERALD project results and achievements.	Offline	100	Partner country	Number of participants	UPB, TUCN and BIZZCOM
5	Scientific Publications published in prestigious journals	Disseminate the results reached within the EMERALD project	Offline	100	M2/Internet	Number of downloads	EMERALD consortium - all partners
6	Project dissemination report	Press release website, blog, emails	online	>40	Month 19 / Internet	Number of hits	Project manager

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DISSEMINATION PLAN

Considering the dissemination goals: to promote the EEA Grants 2014-2021 project results, the following activities will be undertaken:

No.	Main Indicator	Activity	Details regarding the publishing house / host institution	Responsible leading institution	Estimated date period	Status	Correction measures (if it is the case) / observation
1	Online International Workshop related to the "EMERALD project"	Preparing and realizing the presentation	TUCN	TUCN	April 2022	Realized	More than 100 participants have attended the organized event
2	Manufacturing 2022 conferens in Poznan	Preparing and submitting 2 manuscripts	Springer	UPB	May 2022	Realized	One book has been edited by PUT & TUCN as result of this event
3	Multiplier event 1	Disseminating the results reached in IO2	UPB	UPB	August 2022	Realized	
4	Scientific ISI article published	Preparing and submitting the manuscript	MDPI Materials journal (ISI Q2)	UPB	May 2022	Realized	
5	Scientific articles	EPSTEM and CBASET conferens	International databases	UPB	June 2022	Realized	
6	Disseminating the EMERALD results to at least one company	EMERALD Summer school	UiA	UiA	September 2022	Realized	
7	Case studies for real patients with amputated arms defined	4 new case studies with real patients defined and realized in common	PUT	PUT	September 2022 – March 2023	Realized	4 case studies realized in common by the EMERALD consortium in the frame of IO4
8	Diploma projects to be realized in supervision / co-supervision	Diploma project themes defined	UiA & PUT	PUT	September 2022 – June 2023	Realized	7 diploma projects realized in common
9	EMERALD e-book for developing of biomimetic mechatronic systems	Preparing and submitting the manuscript	Risoprint	TUCN	October 2022	Published	Book was published in 2023 due to supplementary extra chapters added
10	One new EEA project proposal submitted	Preparing and the agreements, writing and submitting the project proposal	TUCN & UiA	TUCN & UiA	November 2022	Realized	project entitled "Mobility for sustainability" - ID code: 22-MOB-0032, : 1.02.2023 -30.04.2024, approved for financing: budget: 51.710 euro
11	Multiplier event 2	Disseminating the results reached in IO2	TUCN	TUCN	February 2023	Realized	More than 150 participants to the event / 10 companies
12	Partnership agreements with companies	Signing of new partnership agreement with companies outside the EMERALD consortium	TUCN	TUCN	March 2023	Realized	4 agreements signed with the companies attending to ME2
13	EMERALD e-toolkit for teaching purposes, basic knowledge about realizing biomimetic mechatronic systems	Preparing and submitting the manuscript	Risoprint	TUCN	May 2023	Published	
14	Scientific ISI article published	Preparing and submitting the manuscript	MDPI Materials journal (ISI Q1)	TUCN	June 2023	Published	Article realized by Nis with TUCN & PUT co-authors
15	Scientific ISI article published	Preparing and submitting the manuscript	MDPI Materials journal (ISI Q1)	TUCN	July 2023	Published	Article realized by Nis with TUCN & PUT co-authors

Figure 1. Communication / dissemination strategy plan established with specific targets and concrete responsibilities / dealines / ouctomes (expected KPIs and results)

The dissemination plan constituted by the EMERALD consortium also involved regular communication through press releases, blogs, emails and permanent updates on the EMERALD project website. These ongoing efforts ensured that the EMERALD project maintains constant visibility and keeps the stakeholders informed about its progress and achievements during the whole period of its implementation.

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Each activity within the EMERALD project's dissemination / communication plan was carefully monitored and evaluated, ensuring that the goals of the planned activities and KPI actions were met and that the dissemination efforts concerning the EMERALD project results were effective and highly impactful in the end. This comprehensive and multifaceted approach reflects the EMERALD consortium commitment to not only advancing scientific knowledge but also ensuring that these advancements were accessible and beneficial to a wide array of audiences in the end.

3. The EMERALD project webpage (EN & RO)

One highly important way on realizing dissemination of the results reached in the EMERALD project has been realized through the EMERALD project website - https://project-emerald.eu (available in dual languages – English and Romanian as one may notice in Figure 2), the website serving as a dynamic and informative tool for effectively and clearly communicating the EMERALD project objectives, achievements, and ongoing activities to a broad audience (more than 2000 people have accessed the EMERALD project website only in 2023 – see Figure 2). Through the EMERALD project website, the EMERALD consortium has permanently and constantly ensured that the EMERALD project results are accessible to anyone interested in getting right knowledge and skills in the field of 3D printing for bio-mechatronic systems destined to support people with amputated arms.

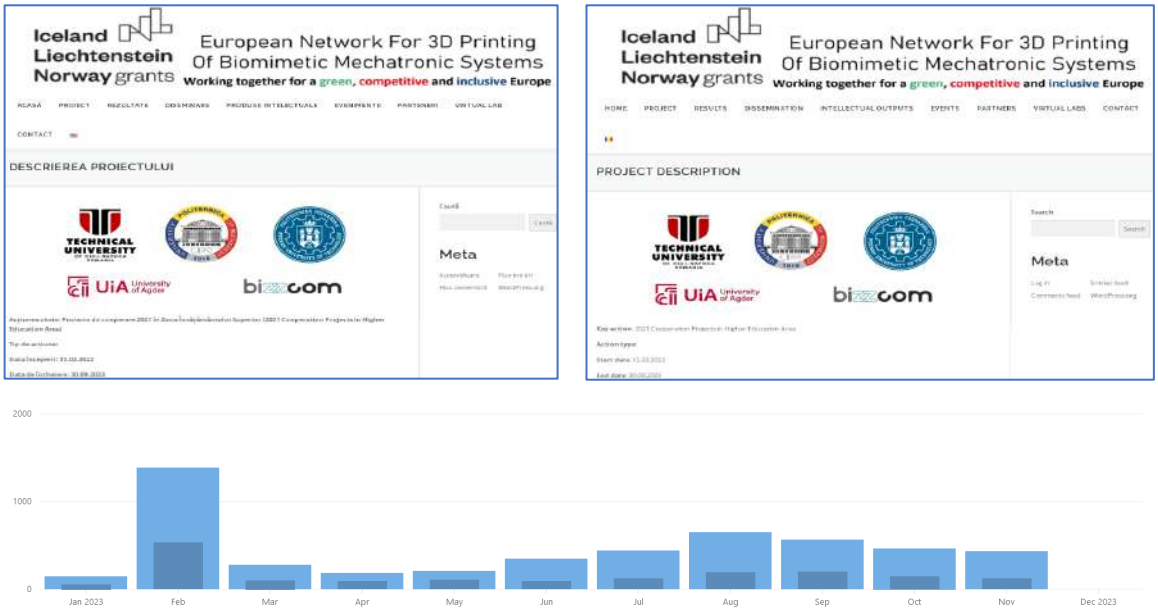

Figure 2. EMERALD project website available in dual languages (English and Romanian)

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The EMERALD project website ensures that all the communicating elements required by the EEA grants, like disclaimer, logo of “Iceland, Lichtenstein, Norway grants” and motto “Working together for a green, competitive and inclusive Europe” are visible and placed as requested on the website and all documents communicated through the EMERALD website.

In terms of content and organizing sections, the EMERALD project website is thoughtfully designed, encompassing various sections that provide comprehensive information about the EMERALD project.

At the core of the EMERALD project website detailed sections that outline the EMERALD project aims and objectives, giving visitors a clear understanding of what EMERALD project is referring to is provided as shown in Figure 3. The EMERALD partners of the consortium, involved in the EMERALD project are also well provided and emphasized on the EMERALD project website along with links that are leading on the official websites of these institutions.

Figure 3. EMERALD project description (main aims and objectives) along with the EMERALD partners involved in the consortium

A significant feature of the EMERALD website is the section dedicated to the intellectual outputs of the EMERALD project (see Figure 4). This section has been regularly updated, showcasing the latest results and developments (freely and in open access regime) as soon as they have been finalized. Such timely updates that were realized ensured that the EMERALD website remained as a current and reliable source of information about the EMERALD project advancements on the entire period of its implementation.

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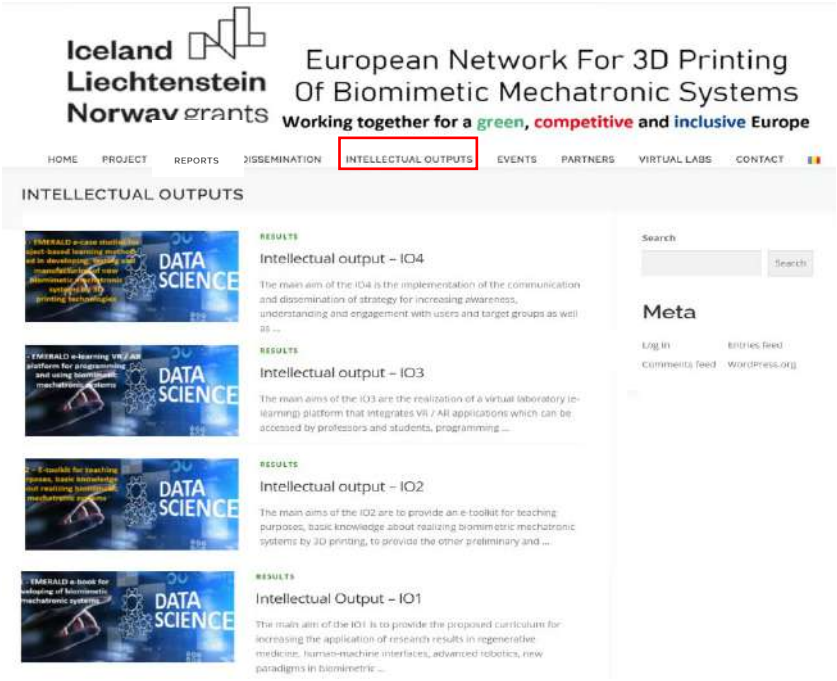

Figure 4. Intellectual outputs section of the EMERALD project

Additionally, the EMERALD project website highlights the various events organized in the frame of the EMERALD project. These include Transnational Project Meetings (TPM), Multiplier Events, and Learning, Teaching, and Training Activities (see Figure 5). Each event has represented an opportunity to share knowledge, collaborate, and engage with stakeholders and the EMERALD project website served as a record of these important events that were organized in the frame of the EMERALD project.

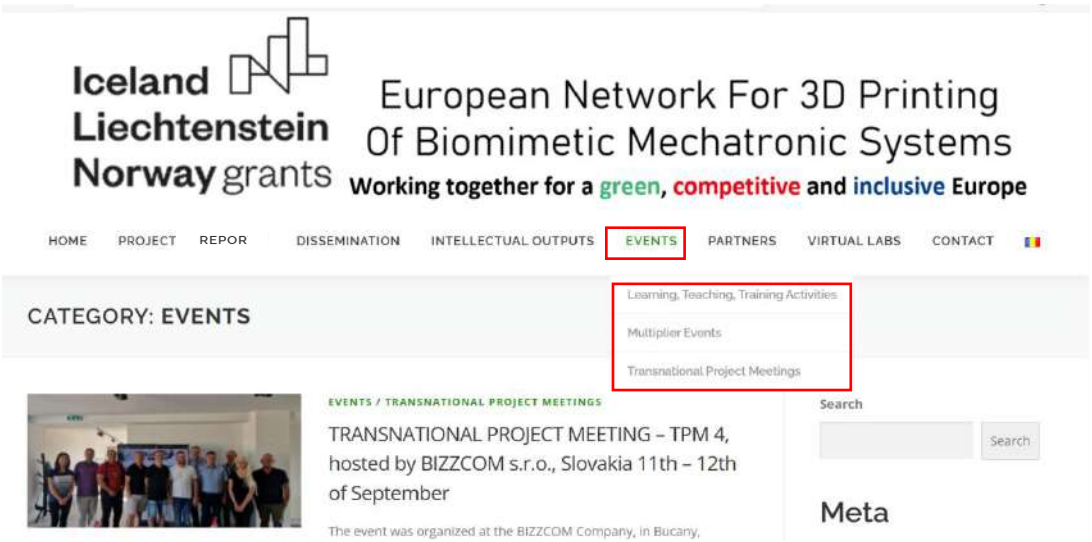

Figure 5. Events (TPM, Multiplier Evets, LTT activities) organized in the frame of the EMERALD project

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Another highly important section of the EMERALD website consists in the EMERALD e-learning virtual laboratory platform (see Figure 6). This innovative feature is briefly introduced in a dedicated section, offering visitors the chance to have access to a waste category of teaching resources with highly practical applications and educational tools that have been developed by the EMERALD consortium partners in the frame of the EMERALD project (see Figure 7).

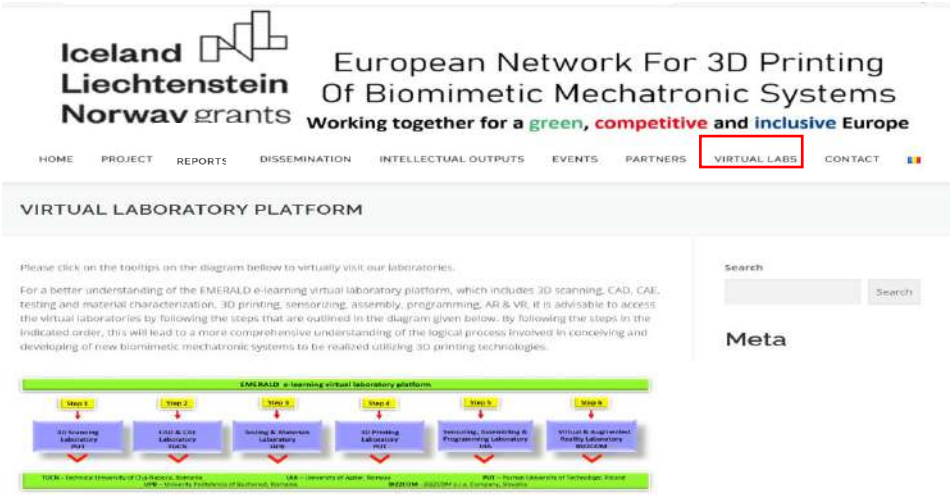

Figure 6. e-learning virtual laboratory platform realized in the frame of the EMERALD project

Figure 7. Examples of practical applications and educational tools integrated into the e-learning virtual laboratory platform realized by the EMERALD consortium partners

The EMERALD project website also includes one special dedicated section for dissemination. Here, visitors can find detailed information about the materials used for the EMERALD project dissemination efforts. This includes details about published articles, books supported by EMERALD resources, press release articles, reports on various events where the EMERALD project results were shared and also the final report of dissemination. In addition to these features, the EMERALD project website provides a contact section, making it easy for interested parties to reach out and engage with the EMERALD partners of the consortium.

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4. Disseminating of the EMERALD project on institutions / social media

In terms of disseminating activities, one consistent support in communicating and promoting of the EMERALD project aims, actions and activities has come on behalf of the official institutions of the EMERALD consortium partners. Many information data have been posted on webpages on the websites of consortium partners, such as the Technical University of Cluj-Napoca – www.utcluj.ro (promoter of the EMERALD project) through official press releases and communicates on which different important announcements, achievements and results or celebrating of different milestones concerning the EMERALD project success has been realized to emphasize the importance and role of the EMERALD project in advancing technological solutions in the interest of societal benefits (see the examples provided in Figure 8 and the next following links: www.utcluj.ro/noutati and https://www.utcluj.ro/media/documents/2022/proiect_EMERALD__YHdtBS6.pdf).

Figure 8. Official press releases on the TUCN (promoter of the EMERALD project) official website

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Social media platforms, particularly Facebook has served also as dynamic forums for sharing news, updates, and engaging multimedia content related to the EMERALD project, effectively broadening all the results of the EMERALD project to a global audience (see Figure 9). Posts on these platforms frequently lead to further information, detailed articles, and videos, showcasing the EMERALD project activities, actions and achievements. These posts not only share the excitement of the EMERALD project progress but also invite the public to delve deeper into the innovative world of the EMERALD topic, often through linked content such as detailed project descriptions or reports that were made available on various media outlets.

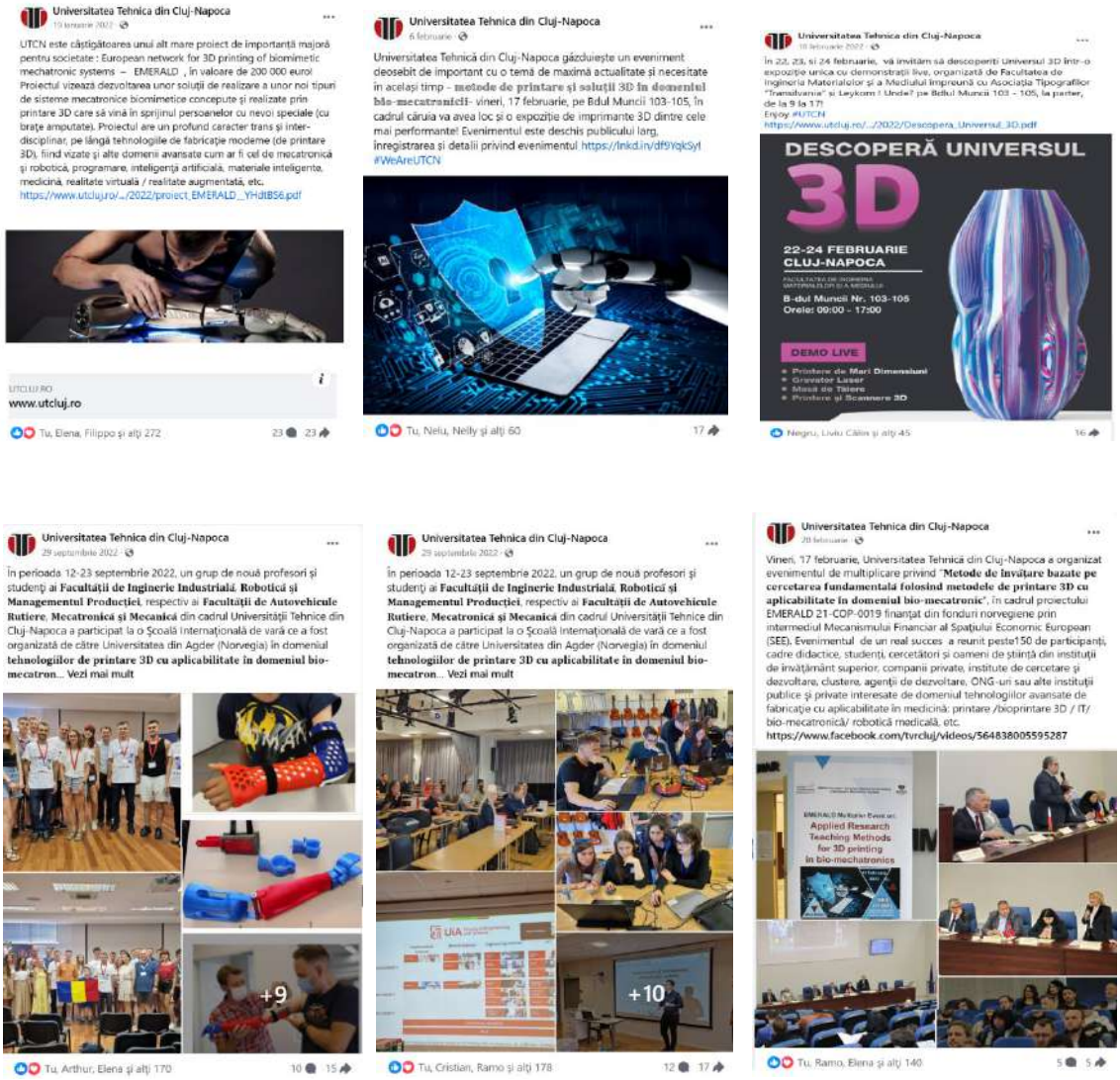

Figure 9. News about actions, activities, events and updates on the EMERALD project on the official Facebook page of TUCN

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Additionally, the EMERALD project partners have taken proactive steps in promoting the EMERALD project through different channels like personal / institutional blogs, Linkedin pages (see Figure 10 and the next following links (selection) on which they have been highlighting the collaborative nature of the EMERALD project and its integration with industry and other higher educational institutions with whom on different events they have been interacted with: https://filipposanfilippo.inspitivity.com/robotics/item/protv-news-a-popular-romanian-tv-channel-showcased-our-research-project-titled-european-network-for-3d-printing-of-biomimetic-mechatronic-systems-emerald/303; html.https://filipposanfilippo.inspitivity.com/robotics/item/european-network-for-3d-printing-of-biomimetic-mechatronic-systems/302; https://no.linkedin.com/posts/filipposanfilippo_emerald-international-summer-school-on-activity-6973569735422537729-gi9D ; https://filip.gorski.employee.put.poznan.pl/indexEN.

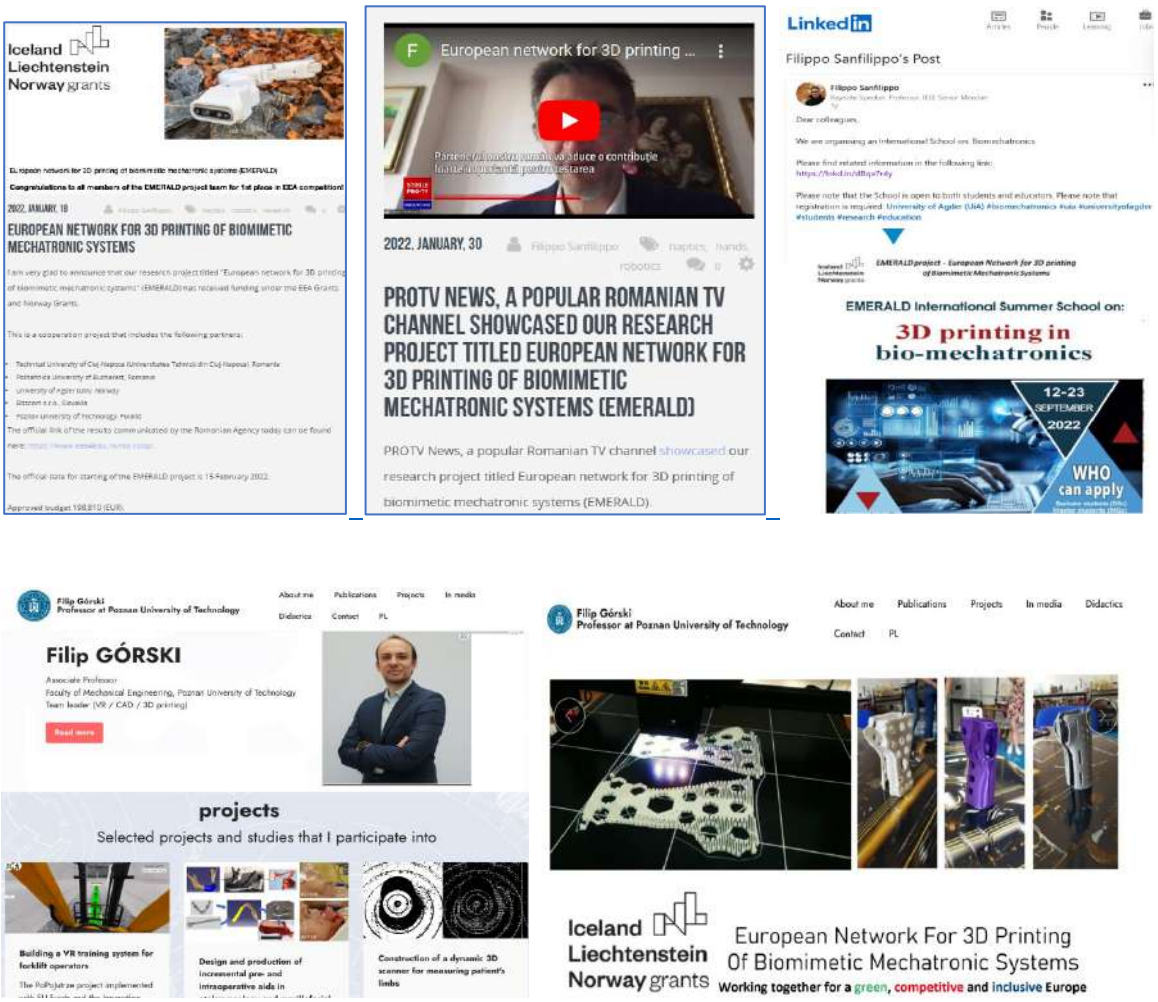

Figure 10. Promoting of the EMERALD project achievements through personal / institutional blogs and Linkedin pages

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Not only the Higher Education institutions of the EMERALD consortium have realized proactive actions in promoting of the EMERALD project results and achievements, but also industrial partner BIZZCOM, which has created a specific section on their webpage dedicated to the EMERALD project, through which there were not only emphasized the EMERALD project objectives, but also there have been shared specific contributions and expected impacts in relation with the EMERALD project for creating cutting-edge solutions for people with amputated arms (see Figure 11).

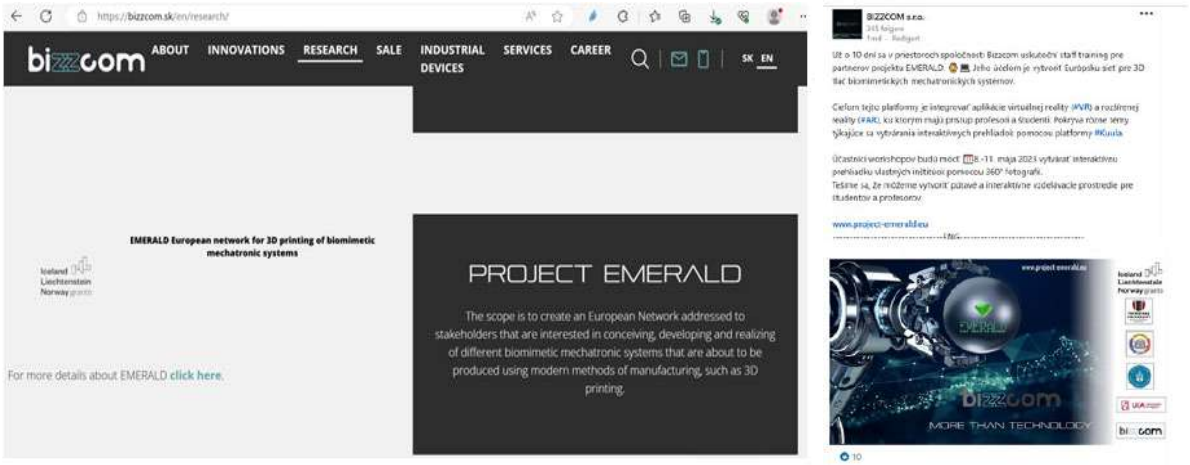

Figure 11. Promoting and disseminating of the EMERALD project results realized by BIZZCOM partner

5. Dissemination of the EMERALD project and resources in the media

Starting from the communicates and postings that have been made at the level of the EMERALD institutions involved in the EMERALD project, the media (press and TV) made a significant contribution in promoting, sharing and distributing news about the EMERALD project success and outcomes, further enhancing its visibility and impact.

Official communicate that has been released by the Technical University of Cluj-Napoca as it was shown in Figure 8 (about the EMERALD project) has been scaled up on the EduManager portal (one of the most important portals of Education with high visibility for the Higher Educational sector in Romania), but also in written press (see the next following links) and Figure 12 for more details:

- https://www.edumanager.ro/un-alt-proiect-de-anvergura-si-importanta-majora-castigat-de-universitatea-tehnica-din-cluj-napoca/
- https://foaiatransilvana.ro/un-nou-proiect-inovativ-care-va-revolutia-industria-medicinei-va-fi-realizat-la-cluj-a-castigat-o-finantare-de-200-000-euro/

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- https://cluj24.ro/proteze-printate-3d-un-proiect-premiat-al-universitatii-tehnice-din-cluj-in-sprijinul-persoanelor-cu-nevoi-speciale-100607.html
- https://romania24.ro/proteze-printate-3d-un-proiect-premiat-al-universitatii-tehnice-din-cluj-in-sprijinul-persoanelor-cu-nevoi-speciale-336687.html
- https://editiadedimineata.ro/cluj-proteze-bionice/
- https://adevarul.ro/stiri-locale/cluj-napoca/orasul-din-romania-unde-vor-fi-facute-brate-2145954.html

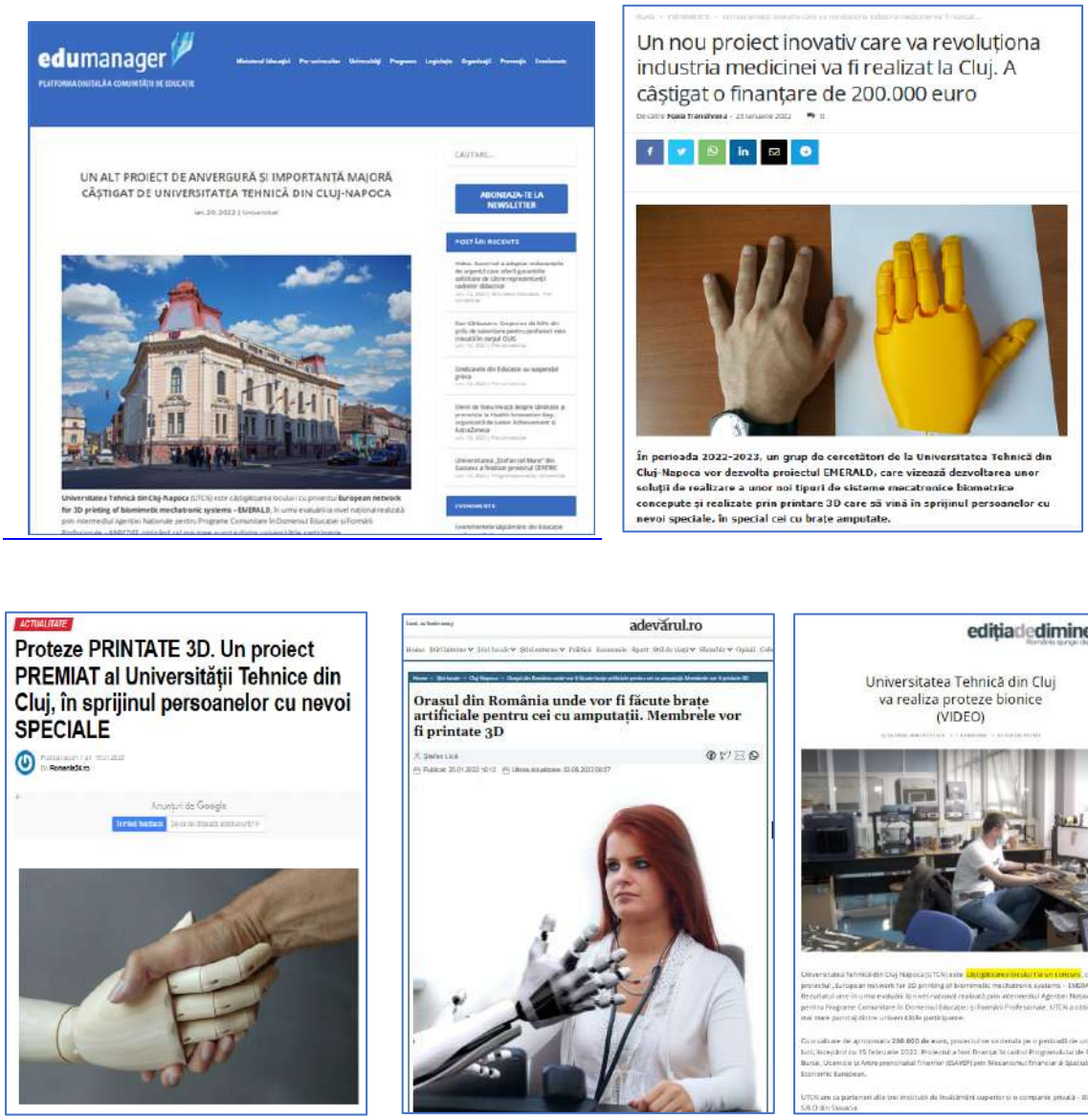

Figure 12. Information about the EMERALD project on the EduManager portal and in the press

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An important TV station in Romania (ProTV) realized one news about the EMERALD project, raising in this way the popularity of the EMERALD project and promoting of the EMERALD project aims and objectives along with the aspects related to the Norwegian grants opportunities. The official information with this news produced by ProTV station can be found on the next following link (Information has been scaled up also to University of Agder (Norway) as one may notice in Figure 13.

- https://stirileprotv.ro/stiri/stiinta/cercetatorii-romani-vor-sa-dezvolte-brate-artificiale-ce-tehnologie-folosesc-si-cum-se-realizeaza.html
- https://www.youtube.com/watch?v=cDjCcf9zD9o

Figure 13. News about the EMERALD project at TV station Pro TV Romania

Relation with media (TV) was highly important also in the case of Poznan University of Technology (PUT) partner, who has managed to disseminate locally the results about the EMERALD project by taking interviews for a local TV in Poznan (just this video had more than 300 visualizations in less than 5 months since it was launched on the YouTube – see Figure 14). Link with the video realized by PUT (interview with Prof. Filip Gorski) can be found here:

https://www.youtube.com/watch?v=F-7r9BqZBw4&t=58s

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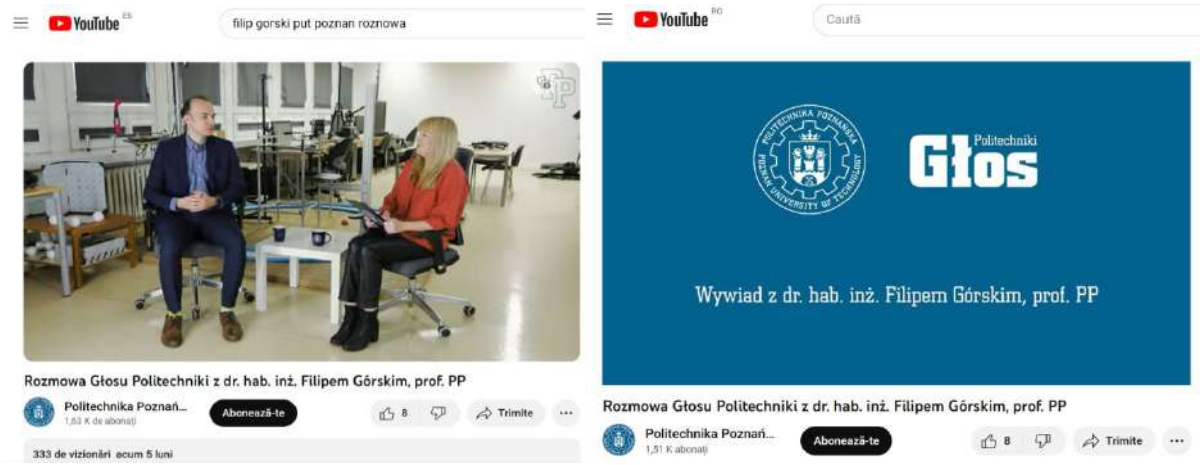

Figure 14. Interviews taken about the EMERALD project at PUT on YouTube

Filip Górski has appeared also to a nation-wide TV in live show "Dzień Dobry TVN", where he had the chance to talk about prostheses for children (real patient) for which has been produced in one case study of the EMERALD project (see Figure 15).

Figure 15. Nation-wide TV live show to present case study about prostheses for children (real patient

Details about this TV live show in which Prof. Filip Gorski (PUT) has been invited can be found on the next following links:

-https://vod.pl/shorty,130/wymarzona-proteza-zosi,7293828?fbclid=IwAR1Q68XA2UJiFfolnnaBb4V-JefE4FGVvMHJiB9Z5TkAQZi1vHzl8cvUAdE and https://www.facebook.com/permalink.php?story_fbid=pfbid0Sr4aKeU4rABvZanTajv9HQEEHYidCTqe9ARbNFH2YXeEo8vh1XLtdqWS8gTSofDGl&id=100057177441812

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Relation with media has been highly important on the entire duration of the implementing period of the EMERALD project also in terms of organized events (see for example TV news that have been produced by TV stations concerning the Multiplier Events organized in Bucany (Slovakia) at BIZZCOM and at Technical University of Cluj-Napoca (Romania) in 2023:

- https://www.facebook.com/tvrcluj/videos/564838005595287/
- https://www.youtube.com/watch?v=KHTORz_EcXk&t=32s

6. Dissemination of the results reached in the frame of EMERALD project through EMERALD organized events

The EMERALD project has been highly important in developing of the European Network for 3D Printing of Biomimetic Mechatronic Systems and part of its success can be attributed to the various events organized to disseminate project achievements. These events, including multiple Multiplier events served as platforms to share the valuable insights and results that were reached as intellectual outputs of the EMERALD project. Key developments such as e-course modules, e-toolkit laboratory manual and the e-learning virtual laboratory platform have been showcased through these organized events, highlighting the innovative results that were reached through the EMERALD project in terms of educational resources being provided. These organized events were highly important in reaching an audience beyond the EMERALD consortium, to effectively engage students and professors coming from the higher educational sector and other interested stakeholders such as industrial partners and medical institutions in the end.

The focus of the organized events was on sharing the advancements in the development, producing and testing of bio-mechatronic systems for people with amputated arms using different types of 3D printing technologies.

Moreover, the EMERALD project hosted Learning, Teaching, and Training activities, like International Summer Schools, which further emphasized the EMERALD project commitment to open-access education. Invitations to these enriching educational events were extended to all interested individuals, providing them with the opportunity to participate free of charge to these organized events. This open-access approach ensured that the knowledge and skills related to 3D printing technologies for bio-mechatronic systems were widely accessible, fostering an inclusive environment for learning and development in this cutting-edge domain.

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6.1. Multiplier Event on Research Base Learning Method for Teaching in Bio- Mechatronics – September 2022 - Bucharest, Romania

The "First Multiplier Event on Research Base Learning Method for Teaching in Bio-Mechatronics," (see figure 16 and link: https://upb.ro/calendar-evenimente/emerald-multiplier-event-on-research-base-learning-method-for-teaching-in-bio-mechatronics/) was organized by the University Politehnica of Bucharest (UPB) EMERALD partner on September 2, 2022, being focused on disseminating the educational outcomes of the EMERALD project, particularly those related to the intellectual output 1 (O1) finalized in July 2022.

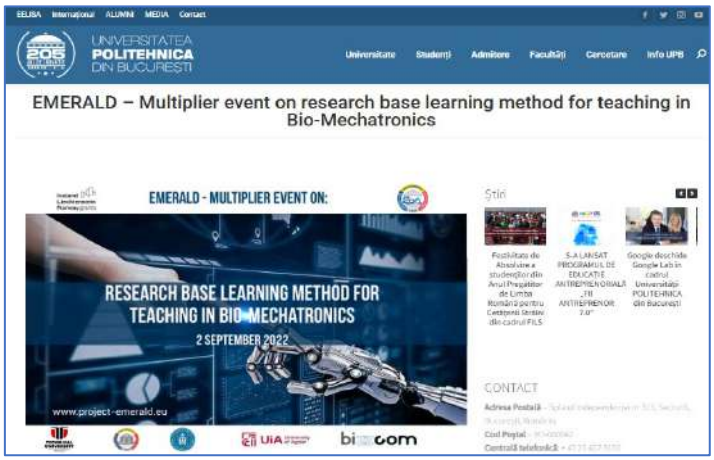

Figure 16. Multiplier Event on Research Base Learning Method for Teaching in Bio-Mechatronics organized by UPB

During the organized Multiplier Event, there have been showcased the 8 course modules that have been developed by the EMERALD partners in the consortium in the frame of O1, covering areas such as CAD, CAE, 3D printing, sensors and electronics, smart materials, bio-mechatronics, computer programming, and VR/AR technologies (see Figure 17). In addition to the presentations realized by the EMERALD partners, industry stakeholders like Leycom and Admasys, representing important 3D printing companies like Markforged and Ultimaker in Romania have participated in the event (see Figure 18). These companies have realized demonstrations concerning advanced 3D printers they have in their premises and explored potential applications in bio-mechatronic systems with the attendees. There was a particular interest expressed by these companies concerning the Fresh 3D Printing method that exists at UPB partner, solution that was highly interesting due to its non-planar, freeform layering capabilities.

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Figure 17. Revealing of the 8 course modules that have been realized by the EMERALD partners of the consortium in the frame of O1

Figure 18. Presentation realized by professors of UPB and industrial companies representatives who attended the multiplier event organized by UPB

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The Multiplier event organized by UPB facilitated a dialogue between EMERALD consortium partners and industrial company representatives, identifying common research interests. Participants to the organized event have expressed a keen interest in the EMERALD project, indicating a desire to be actively involved in future events and activities organized in the frame of the EMERALD project. Details about the agenda of the Multiplier event organized at UPB, as well as detailed report about this event & press release communicate that has been posted on the EMERALD project website can be seen on the following links: https://project-emerald.eu/?p=112 and https://project-emerald.eu/?p=243.

6.2. Multiplier Event on Applied Research Methods for 3D Printing in Bio-Mechatronics – February 2023 – Cluj-Napoca, Romania

The "Second Multiplier Event on Applied Research Methods for 3D Printing in Bio-Mechatronics" was organized by the Technical University of Cluj-Napoca (TUCN) on February 17, 2023, being focused on disseminating the outcomes of intellectual output 2 (O2), regarding the e-toolkit manual developed for bio-mechatronic systems using 3D printing technologies that has been finalized by the EMERALD consortium at the end of January 2023. Official press release communicate has been released on the Technical University of Cluj-Napoca (TUCN) official website as one may notice in Figure 19 and on the next following link:

https://www.utcluj.ro/media/documents/2023/EMERALD_2.pdf.

Figure 19. Multiplier Event on Applied Research Teaching Methods for 3D printing in Bio-Mechatronics organized by TUCN

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During this event, Professor Filippo Sanfilippo from the University of Agder (Norway) has presented a robotic arm that has been developed during the 2022 summer school in Norway, demonstrating the innovative capabilities of the EMERALD project consortium in conceiving bio-mechatronic systems realized by 3D printing to support people with special needs (amputated arms) – see Figure 20.

Figure 20. Robotic arm developed at University of Agder (Norway)

This robotic arm has served as a basis for the development of the e-toolkit manual that was realized in the frame of O2, but also the base of case study #5 that has been additionally realized in the frame of the EMERALD project (in O4) along with an ISI paper with open access that has been submitted in Frontiers in Materials journal in September 2023. Professor Filip Gorski from Poznan University of Technology further discussed advancements in affordable sensorized prosthetics for people with amputated arms, emphasizing the toolkit laboratory manual practical application (see Figure 21).

Figure 21. Examples of orthotic and prosthetic systems realized in the frame of O2

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The Multiplier event organized by the Technical University of Cluj-Napoca was highly attractive for the attendees, over 120 participants including professors, students and representatives from various sectors such as R&D institutes, industrial companies and NGOs, reflecting a strong interest in 3D printing and bio-mechatronics taking part on all organized activities at Technical University of Cluj-Napoca in February 2023. Structured into four sessions, the agenda catered to higher education institutions, industry professionals, live demonstrations by companies, and discussions on continuing the implementing of the results reached in the frame of EMERALD project in future projects to be realized by the EMERALD partners in the consortium and attendees to this event (industrial companies in particular). Over 15 company representatives at the event highlighted the synergy between higher educational sector and industry, offering access to advanced solutions they have in their premises (in terms of new types of 3D printing systems and new types of materials to be tested for such type of applications) expressing their interest in realizing of collaborative research with partners of the EMERALD consortium in particular in the end (including the VR and AR applications domains) (see Figure 22).

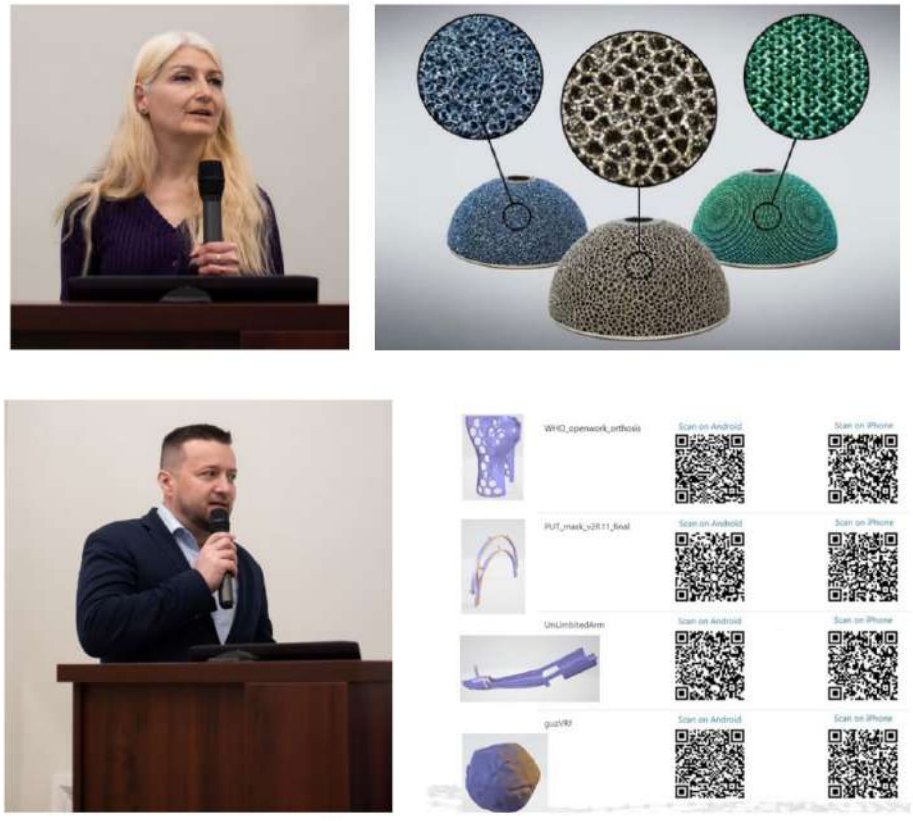

Figure 22. Sharing the results reached in the frame of O2 concerning intelligent materials and VR / AR applications by the EMERALD consortium partners

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In terms of cooperating in between higher educational institutions, Professors Roca Joaquin and Ojados González Dolores from the Polytechnic University of Cartagena (Spain) provided insights into medical applications of 3D printing and 3D bio-printing, fostering collaboration with TUCN (see Figure 23).

Figure 23. Extending the opportunities of collaborating in the field of 3D bio-printing with TUCN

The Multiplier event provided the framework for a hands-on exhibition that has been provided by more than 10 industrial companies who have taking part to this event, showcasing innovative materials and 3D printing technologies / 3D printing equipment items the companies have in their premises (see Figure 24 and Figure 25).

Professor Razvan Pacurar (coordinator of the EMERALD project) announced the ambitious plans of the EMERALD consortium for establishing a European network for 3D printing in biomimetic mechatronic systems, with many companies signing partnership agreements to join the EMERALD network (see Figure 24). 4 companies have signed such partnership agreements at the end of the Multiplier Event. The positive reception and collaborative spirit of the event were indicatives of the EMERALD project impact and its future potential in the end.

Figure 24. Live demonstrations realized by the companies during the Multiplier Event

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Figure 25. Practical exhibition realized by the industrial companies that attended the Multiplier Event

Figure 26. Plans for establishing the European network for 3D printing in biomimetic mechatronic systems (EMERALD network) in 2023

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The impact of this organized event in the local media was highly powerful, aspect proved by the next following links on which information can be found in direct relation to this organized event in particular (see also Figure 27):

http://www.marketwatch.ro/articol/18018/Eveniment_de_multiplicare__EMERALD_Metode_de_invatare_bazate_pe_cercetarea_fundamentala_folosind_metodele_de_printare_3D_cu_aplicabilitate_in_domeniul_bio-mecatronic/

https://zcj.ro/eveniment/mana-de-ajutor-pentru-pacientii-cu-brate-amputate-vine-de-la-cluj-utcn-creeaza-la-imprimante-3d-membre-artificiale-pentru-oameni-dar-si-ciocanul-lui-thor-sau-volane-de-formula-1--244180.html

https://zcj.ro/eveniment/cercetatorii-clujeni-bun-bazele-viitoarelor-brate-artificale-tehnologii-avansate-de-fabricatie-cu-aplicabilitate-in-medicina-prezentate-la-utcn--244166.html

https://iloveyoucluj.ro/eveniment/mana-de-ajutor-pentru-pacientii-cu-brate-amputate-vine-de-la-cluj-utcn-creeaza-la-imprimante-3d-membre-pentru-oameni-dar-si-axul-lui-thor-volane-de-formula-1-si-inele/19144

https://ziarulfaclia.ro/eveniment-de-multiplicare-emerald-organizat-de-utcn/

https://www.facebook.com/tvrcluj/videos/564838005595287

https://youtu.be/SsMga-kUXyo

https://youtu.be/2KlKamP0ptg

One press communicate has been released on the TUCN official website / official Facebook page of TUCN post-organized event as one may notice in Figure 28, being undertaken also by the important educational portal of Romania (EduManager) as one may notice on Figure 29 and on the next following links as well:

https://www.utcluj.ro/media/documents/2023/EMERALD_baEWFzE.pdf

https://www.facebook.com/utcluj.ro/posts/pfbid0ByrxznSr33StkTpz6H88e6jPMPAhCCcTKdSqfYy63oqyuUo1xBiHHdt6NWiSXu3kl

https://www.edumanager.ro/eveniment-de-multiplicare-emerald-metode-de-invatare-bazate-pe-cercetarea-fundamentala-folosind-metodele-de-printare-3d-cu-aplicabilitate-in-domeniul-bio-mecatronic/

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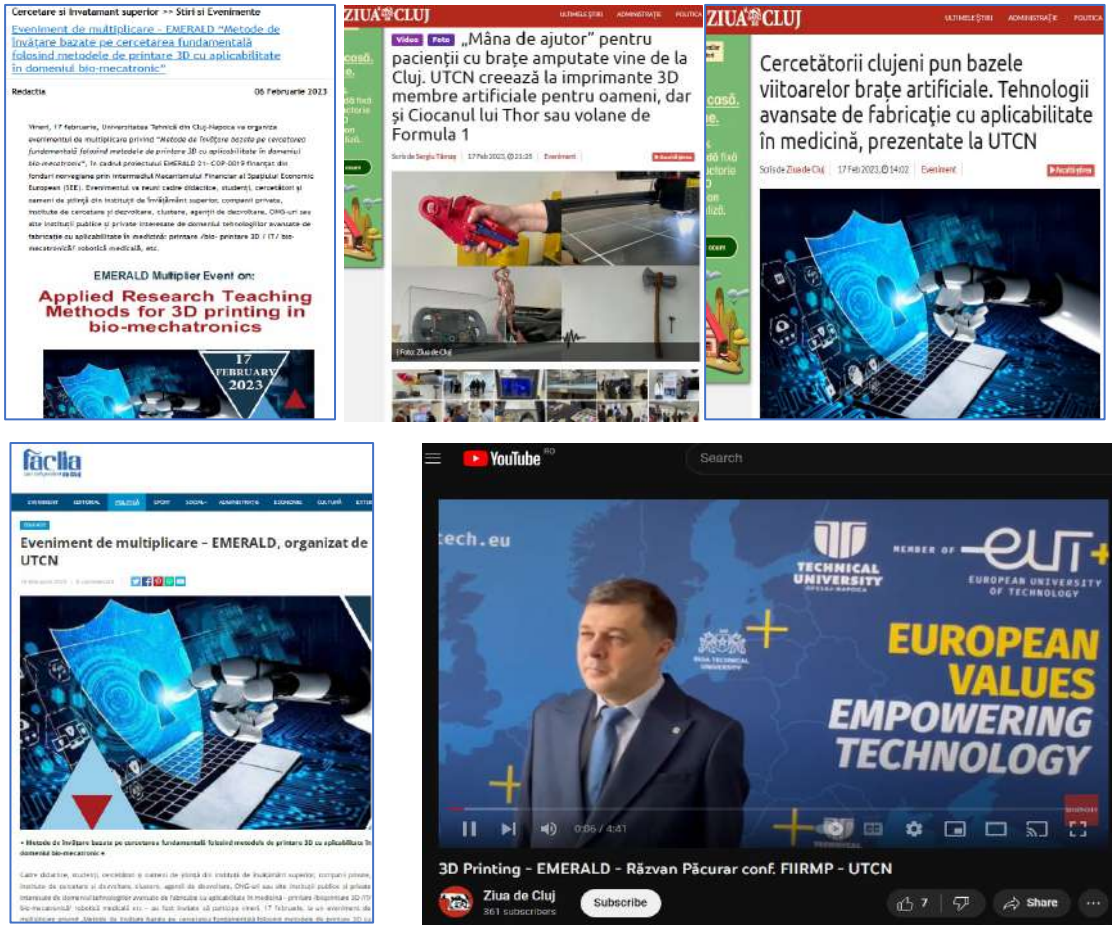

Figure 27. Powerful impact in the media during and after Multiplier Event organized at TUCN

Figure 28. EMERALD Multiplier Event press release at TUCN

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Figure 29. EMERALD Multiplier Event press release at TUCN undertaken by the EduManager platform

The Multiplier event has been disseminated also by a local TV station (TVR Cluj) as one may notice in Figure 30 and on the next following link:

https://www.facebook.com/tvrcluj/videos/564838005595287

Figure 30. Disseminating of the results reached in the frame of the EMERALD project at TVR Cluj

Further information and a detailed report on the event can be found on the EMERALD project website on the next following links: https://project-emerald.eu/?p=192 and https://project-emerald.eu/wp-content/uploads/2023/02/EMERALD_report_en.pdf).

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6.3. Multiplier Event on the Experiencing of e-Learning Platform for Biomechatronics – September 2023 – Bucany, Slovakia

The "Third Multiplier Event on the Experiencing of e-Learning Platform for Biomechatronics" was organized by Bizzcom s.r.o. in Bucany, Slovakia, on September 2023 (see Figure 31). This event attracted 40 external participants from various institutions, including the Slovak University of Technology in Trnava (Slovakia) and industry representatives, alongside 15 members from the EMERALD project consortium. The focus of the Multiplier Event organized by Bizzcom in Slovakia was on the EMERALD e-learning virtual laboratory platform that has been developed by the EMERALD consortium to guide users to go through the process of conceiving, realizing and testing of new biomimetic mechatronic systems for people with amputated arms that were produced using 3D printing technologies.

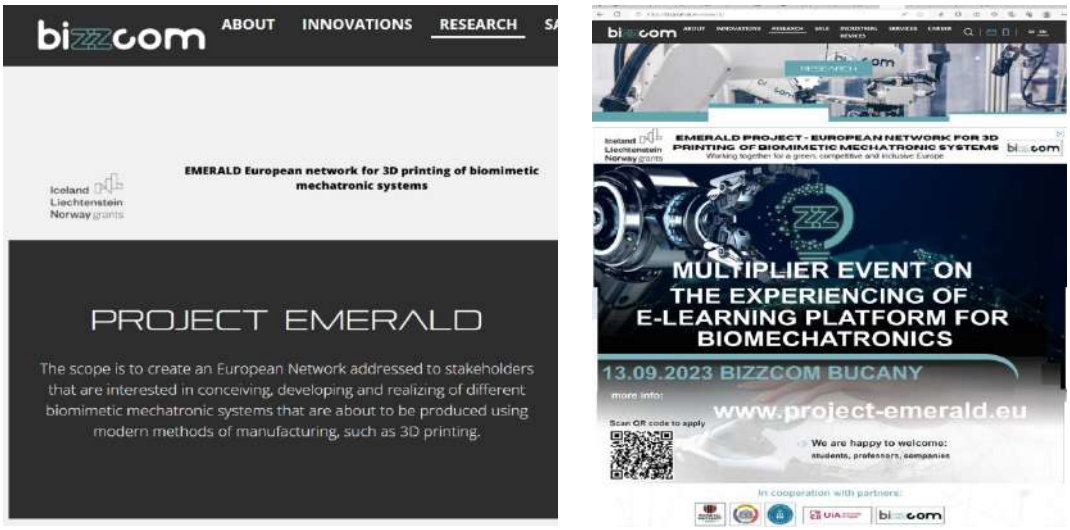

Figure 31. Multiplier Event of EMERALD project posted on BIZZCOM website

Professors Razvan Pacurar (TUCN), Filippo Sanfilippo (UiA), Filip Gorski (PUT), Diana Baila (UPB), and Martin Zelenay from Bizzcom s.r.o delivered presentations on e-learning platform focusing on the educational tools and resources that are included in virtual laboratory rooms of the EMERALD partners of the consortium (see Figure 32).

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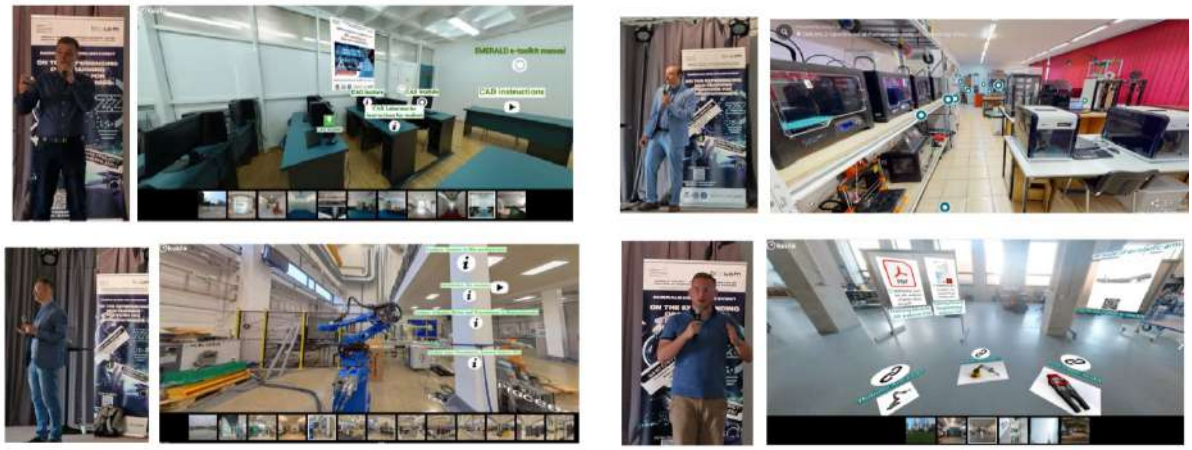

Figure 32. EMERALD partners sharing the educational resources included in e-learning platform virtual laboratory rooms

Attendees had the opportunity to interact with the e-learning platform using computers and mobile devices, providing feedback on the educational resources offered by the EMERALD partners of the consortium (see Figure 33).

Figure 33. Attendees experiencing the facilities offered by the e-learning virtual laboratory platform

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As one may notice in Figure 34, a unique aspect of the Multiplier event was constituted by the hands-on experience with VR/AR/Mixed Reality applications that have been integrated into the e-learning platform, enhancing in this way the learning experience of the users. Round table discussions led by the EMERALD consortium partners have been realized with the attendees to the Multiplier event, focusing on the received feedbacks, along with potential improvements that can be brought in the future to the e-learning platform that has been conceived by the EMERALD partners of the consortium. Important discussions were held also on the use of the e-learning platform facilities for future diploma theses that can be realized by the students under supervision of the EMERALD professors coming from the higher educational institutions of the EMERALD consortium (see Figure 31).

Figure 34. Round table discussions led by the EMERALD partners of the consortium during the Multiplier event

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The event also has opened new ways for collaboration with industry representatives from Slovakia, such as CTRL, GoSpace, and Seiteq, as a result of the Multiplier Event organized these companies signing Partnership cooperation agreements through which they have been expressing their will to join the EMERALD network. This underlines the project's successful outreach and its potential for fostering future research and educational initiatives in the fields of 3D printing and biomechatronics to support people with special needs (people with amputated arms) on a larger scale in the end.

An important highlight of the Multiplier Event was the attendance of Hlohovská televízia, a Slovakian TV station, which conducted interviews with EMERALD consortium representatives and attendees (see Figure 35). The coverage provided by the TV station which can be watched by accessing the next following link: https://www.youtube.com/watch?v=KHTORz_EcXk played a crucial role in broadening the reach of the EMERALD project achievements, particularly the virtual e-learning platform for bio-mechatronics, broadcasting news of the Multiplier event and the EMERALD project achievements across Slovakia.

Figure 35. Interviews in the media (Hlohovská televízia, a Slovakian TV station) with the EMERALD partners in the consortium during the organized Multiplier event

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The EMERALD e-learning platform that has been developed in the frame of the EMERALD project is set to remain freely accessible, ensuring the sustainability of the project's educational resources in the future as well. The e-learning platform is aimed to remain a valuable resource to be exploited with the aim of finding new needs and challenges in the bio-mechatronics field in the future, targeting meanwhile to continue the EMERALD consortium dedication to ongoing research to be done in collaboration by higher educational institution and industry partners that are interested in furthering the research initiatives that have been reached in the EMERALD project (Figure 36).

Figure 36. Ending of the EMERALD Multiplier Event organized at Bizzcom Slovakia in September 2023

6.4. EMERALD International Summer School events organized at University of Agder (Grimstad, Norway) on September 2022 and September 2023

The EMERALD consortium partners successfully organized two editions of International Summer Schools at the University of Agder in Grimstad, Norway, in 2022 and 2023. The 2022 summer school has been focused on developing constructive and manufacturing solutions for medical products like orthoses, prostheses and robotic arms, customized for people with special needs (with amputated arms) – see Figure 37. This International Summer school 2022 edition event was notable from the dissemination point of view by the involvement of the Blatchford Ortopedi A.S. company from Norway, a prominent company in the field of 3D printing and mechatronics which has been provided their insights of a practical dimension to the theoretical knowledge provided by the EMERALD partners in the consortium (professors) during the organized event, fostering a collaborative environment for future research concerning bio-mechatronic components and product testing (see Figure 38).

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Figure 37. International summer school 2022 edition focused on developing constructive and manufacturing solutions for medical products

Figure 38. Insights provided by Blatchford Ortopedi A.S. company from Norway

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The International summer school 2023 edition broadened its scope to include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality applications, integrating these cutting-edge technologies into the EMERALD project's e-learning platform.

This platform was specially designed to share comprehensive knowledge and offer the skills necessary for developing, manufacturing, and testing bio-mechatronic systems for people with amputated arms in the end (see Figure 39).

Figure 39. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality applications integrated into the e-learning platform as they were developed at summer school 2023.

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Fluicell from Sweden, a leader in 3D bio-printing, made significant contributions by sharing advancements in printing human tissues and potential integrations into bio-mechatronic systems (see Figure 40).

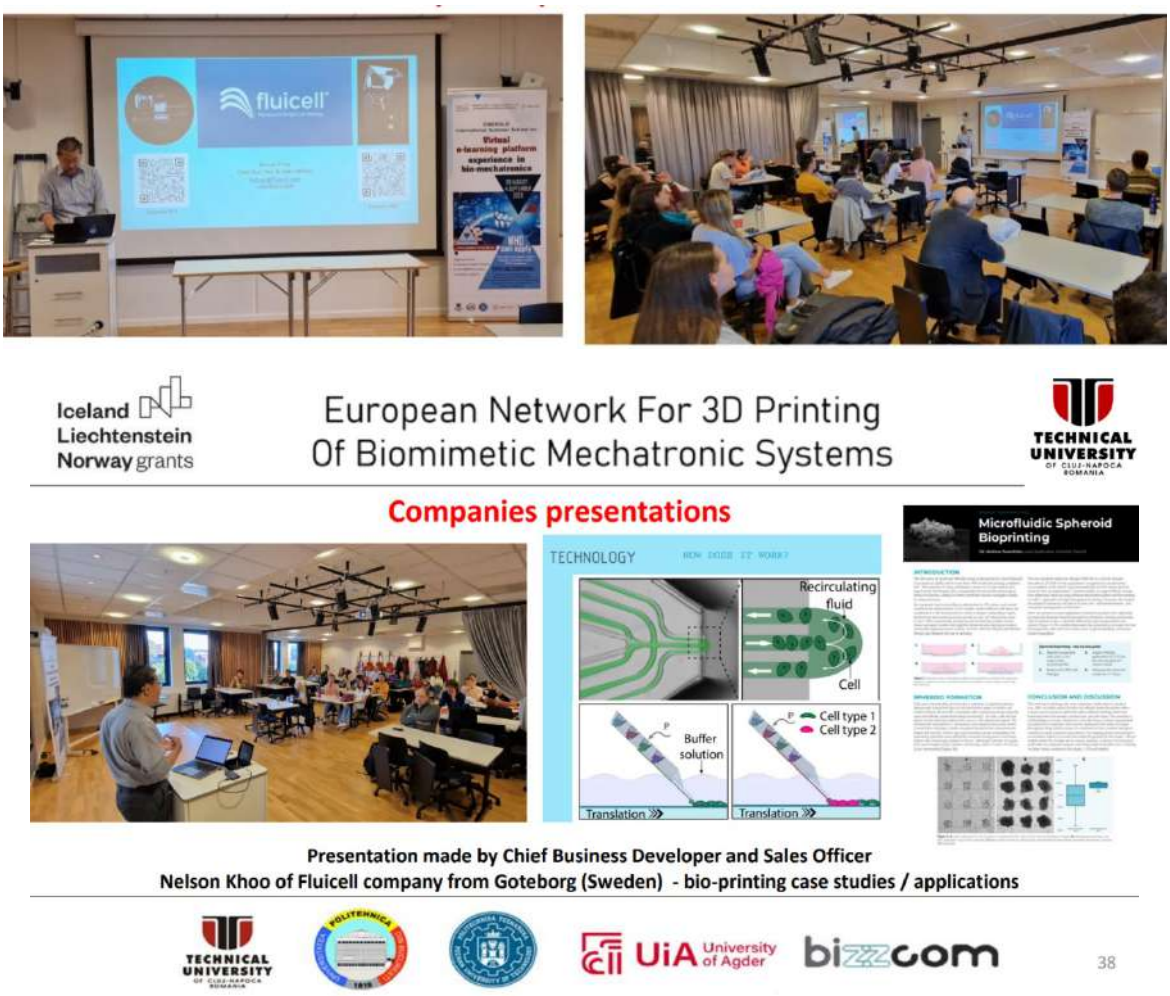

Figure 40. Insights provided by Fluicell company of Sweden in the field of 3D bio-printing

Both summer school events (2022 and 2023 editions) were characterized by a series of lectures and hands-on workshops covering diverse topics such as Computer Aided Design (CAD), Computer Aided Engineering (CAE), 3D printing, programming, VR/AR applications, etc., these sessions being organized both for participants of the EMERALD consortium and outside the consortium. In this context, in terms of disseminating activities it is to be noted that among the participants to both editions of organized summer schools there have been participating professors and students coming from higher educational institutions (outside the EMERALD consortium) like the Juraj Dobrila

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University of Pula, Croatia and Riga Technical University, Latvia with whom the teaching methods and educational tools have been shared with in the end.

Summer school events were intensively promoted and results have been disseminated through official press release communicates on the website of the promoter of the EMERALD project (TUCN), official announcements on the EMERALD institutions of the consortium, social media and blogs of the institutional partners, etc. as one may notice on the following links (selection) and on Figure 41:

- https://www.utcluj.ro/media/notices/2022/Universitatea_Tehnica_din_Cluj-Napoca_EMERALD_2022.pdf
- https://www.utcluj.ro/media/documents/2023/Scoala_de_vara_EMERALD.pdf
- https://no.linkedin.com/posts/filipposanfilippo_emerald-international-summer-school-on-activity-6973569735422537729-gi9D
- https://dmef.put.poznan.pl/artykul/szkola-letnia-w-temacie-druk-3d-w-bio-mechatronice
- https://upb.ro/selectie-pentru-scoala-de-vara-din-norvegia/
- https://www.facebook.com/permalink.php?story_fbid=pfbid02kvbq5SPZMiGhCn7PybyLuXQMpixhMed71HAguMQD8K3pQHyx4VuUeVvkapUKQv6ul&id=100057177441812
- https://www.facebook.com/permalink.php?story_fbid=pfbid02wtRTmNTSKoNNHkfAj4MqnvdMrqNWYD8VdGJmL5pj2kdhEtMDeswyEnENtbqEJf9zl&id=100057177441812
- https://www.facebook.com/utcluj.ro/posts/pfbid032YbCZDfQ42nHdF4WtWWXGMLpkwuMFDc6cHBVf2vNWfZqdp4bg1SAvkQCCBd6Nvtvl?__cft__[0]=AZUoLlIlouNTB4l2mXPrp31byrH9F0EjR6YTty7ePCbNI7eYo0PeVm2J7ux8rjwyhkmE3bU010kPRcdTUeiDgStprvvcXCMu1A9w7p-C7fEZJ3MhnZC29h9WbI305ES7NFwdtoYJVI8QaQum6OW_qPlA&__tn__=%2CO%2CP-R
- https://www.facebook.com/sanfifili/posts/pfbid02W8jnKAaVoAYtypdizv5GxgYdgHnCmTfbrb2aEwiEohRgEXiTSnN6Ak1jRF2QR2tGl?__cft__[0]=AZUHXpstc7R-4qCn0Dtl_WSp31FLG7yL4pQX1g-CwkykwkTZDLSkZTjqfCgPaXSDEJsxLh-HKPPBbvZ5W73GeEZPPSRcc1my1-y3NSyU_FDJ4vnMhI7vnsrp_V-_-QlhYHkxS1C_UY7YvTkG3EtT53zakdGXDUP-mTR3dzqsB6xXZPwIGnUaVmW11uDP2SR1fTk&__tn__=%2CO%2CP-R
- https://www.facebook.com/razvan.pacurar.2013/posts/pfbid02HZL865JGoneD8vantfuro4z8AVZsH26k2LqCKXRho5xEiXpvpnnYrrvTch1a9fyXl and https://www.facebook.com/razvan.pacurar.2013/posts/pfbid02LcoB9Qk3QjSz6n4QNwA5NBcu54zYUnKccx7K6cs3bhmif47R9Kjdr2WCDFrKYhfMl

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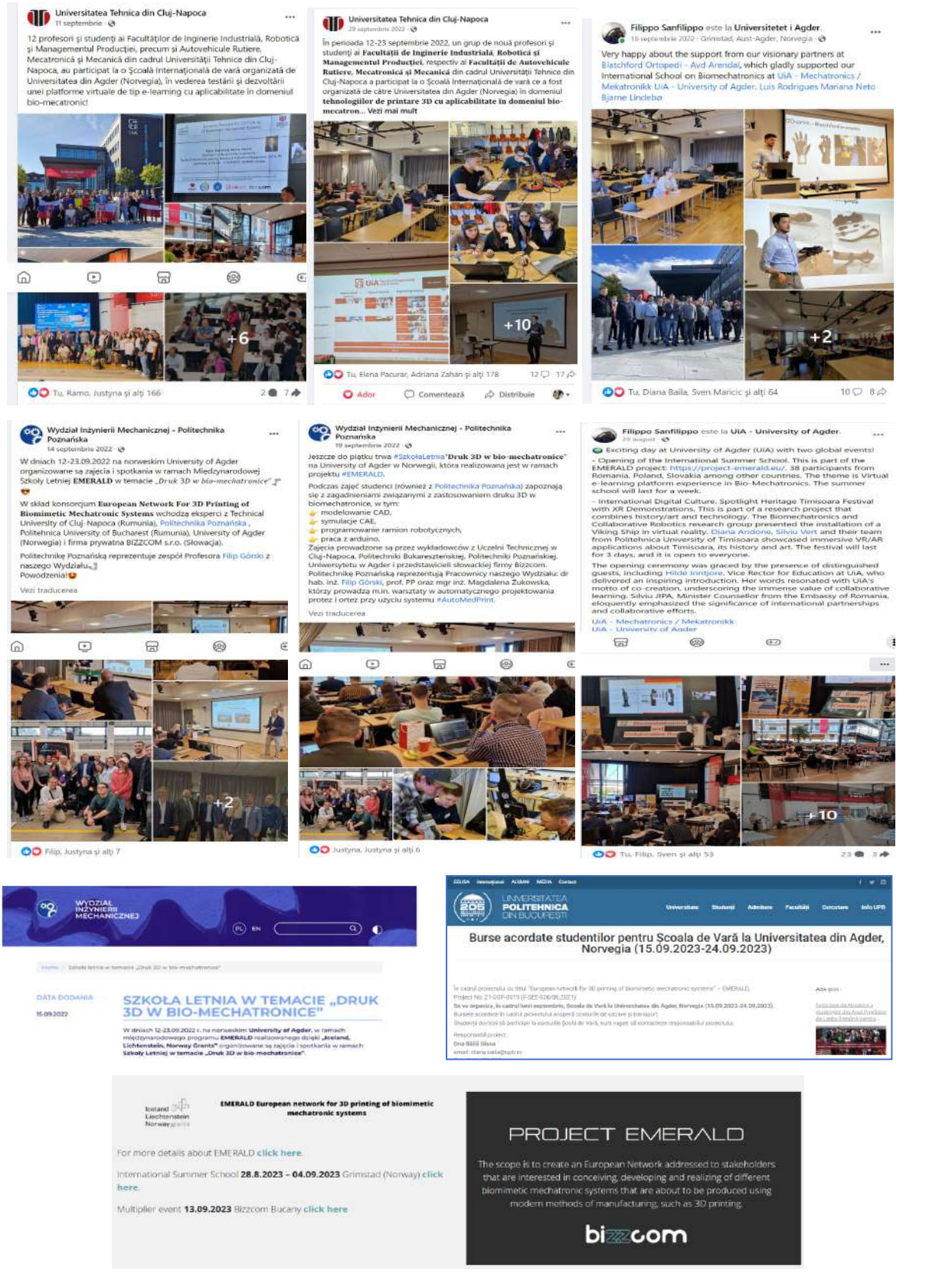

Figure 41. EMERALD Summer school events promoted by the EMERALD institutions

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7. EMERALD case studies, theses, publications and presentations to the events

7.1. EMERALD case studies

In the frame of the EMERALD project, the EMERALD consortium had brought significant contribution in the advancements of bio-mechatronics, particularly for people with amputated arms. In the frame of the Intellectual Output (O4), using the customized innovative teaching resources tools and methods developed in the frame of the EMERALD project, four case studies have been realized for real patients with amputated arms by using 3D printing methods. This project not only integrated project-based learning with modern educational approaches but also facilitated the development, producing and testing of new mechatronic systems using 3D printing technologies.

The EMERALD project Case Study #1 that has been realized by the EMERALD consortium partners has been focused on the developing of biomechatronic upper limb prosthesis for patients with transhumeral amputations (see Figure 42). The EMERALD project intelligent upper limb prosthesis design was characterized by its innovative modular structure. This design, conceived in Autodesk Inventor, is an integrated whole composed of numerous elements with unified connections. Its ground-breaking feature is the ability to load anthropometric and configuration data directly from an external Excel file. This functionality enables the generation of anatomically matched prosthesis components and the manipulation of various configurations, allowing for the quick and fully automated production of individualized prostheses for different patients.

Figure 42. Developing of biomechatronic upper limb prosthesis for patients with transhumeral amputations

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The initial phase of the project involved using a CAD design to create a basic prosthesis variant, which included a compressive-release socket, a forearm with an elbow joint and a C-shaped end effector with a Cardan joint at the wrist. The prosthesis was specifically adapted for an adult patient born without a functioning right forearm. Both of the patient's upper limbs were 3D scanned, and the resulting data was automatically processed using the AutoMedPrint system (a designing system that has been originally produced at Poznan University of Technology) (see Figure 43).

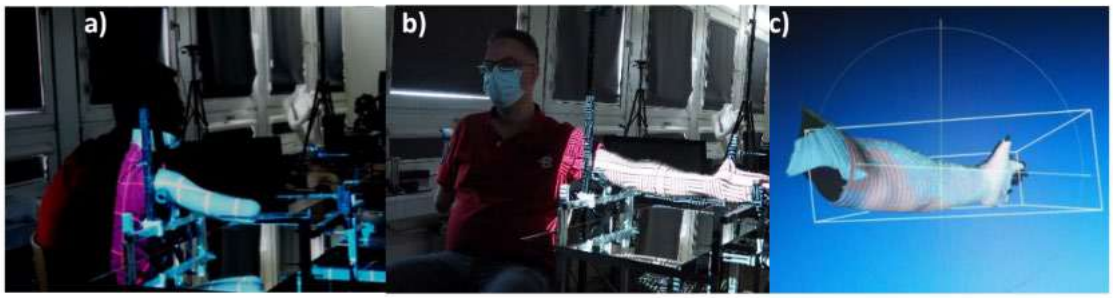

Figure 43. 3D scanning process of the patient with amputated arm

In the preliminary studies, the initial version of the prosthesis was manufactured and tested by the patient. After minor strength improvements, it was tested in real conditions, such as cycling. The feedback from these tests led to several modifications in the mechanical part of the prosthesis, including changes to the CRS socket, forearm model, and C-handle, to enhance stability and comfort during use. These developments formed the basis for research on a sensor-equipped prosthesis, which represents a significant advancement in the field of biomechatronics (see Figure 44). The EMERALD project focus on creating a customizable, automated solution for prosthesis manufacturing reflects a deep commitment to enhancing the quality of life for patients with limb differences.

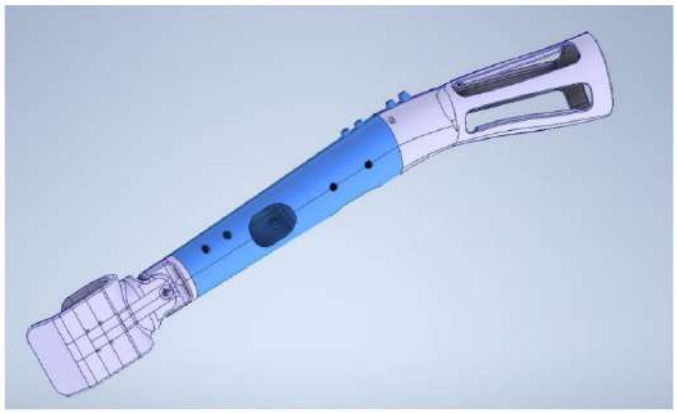

Figure 44. Realizing of a sensor-equipped prosthesis in the frame of the EMERALD project

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The final version of the EMERALD project prosthetic parts was manufactured using the Zortrax M300 Dual 3D printer (Figure 45). This semi-professional printer, known for its dual extrusion capabilities and large build volume, is compatible with a variety of materials, including ABS filament used in this project. The parts were printed in two batches: first, the prosthetic socket for optimal inner surface quality, and then the remaining elements like the forearm and C-handle. Manufacturing parameters such as layer thickness, internal filling, extrusion temperature, and velocity were carefully selected based on material specifications and prior experience to ensure stability and avoid common 3D printing errors.

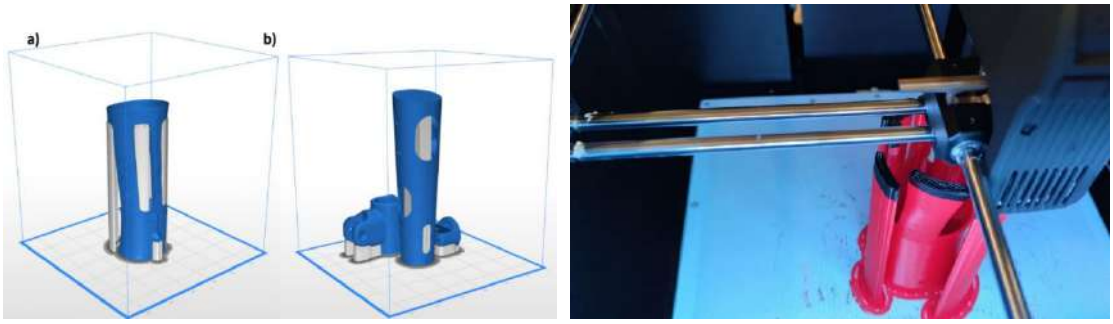

Figure 45. Components of the prosthesis realized by 3D printing

Post-processing operations involved basic manual processes like support removal, grinding, and thermal treatment to remove excess material. Each part was visually inspected during and after printing to identify and rectify any major or minor defects. These steps ensured that the prosthetic parts were functional, comfortable, and ready for assembly into the complete prosthesis.

The assembly of the biomechatronic prosthesis involved both mechanical and electronic components. The mechanical parts, created using additive manufacturing, were assembled using standard tools and connecting elements like screws and nuts. The electronic assembly, more complex and time-consuming, used cost-effective components. These included a microcontroller, accelerometer, gyroscope, magnetometer, and a force sensor, all interconnected according to a specific wiring diagram. The electronic parts were then integrated into the mechanical structure of the prosthesis, ensuring a compact fit within the forearm cavities. The programming of the prosthetic's electronic system was carried out in the Arduino programming environment, utilizing pre-existing libraries for efficient data collection from the sensors.

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Testing of the prosthesis was conducted in two phases. Initially, laboratory tests were performed without a patient to record sample data and ensure proper sensor functioning. Subsequently, patient tests were conducted to assess comfort, weight, fit, and functionality. The prosthesis was tested on an electric scooter, simulating various movements and recording data for analysis (see Figure 46). These tests aimed to validate the prosthesis's performance in real-life scenarios.

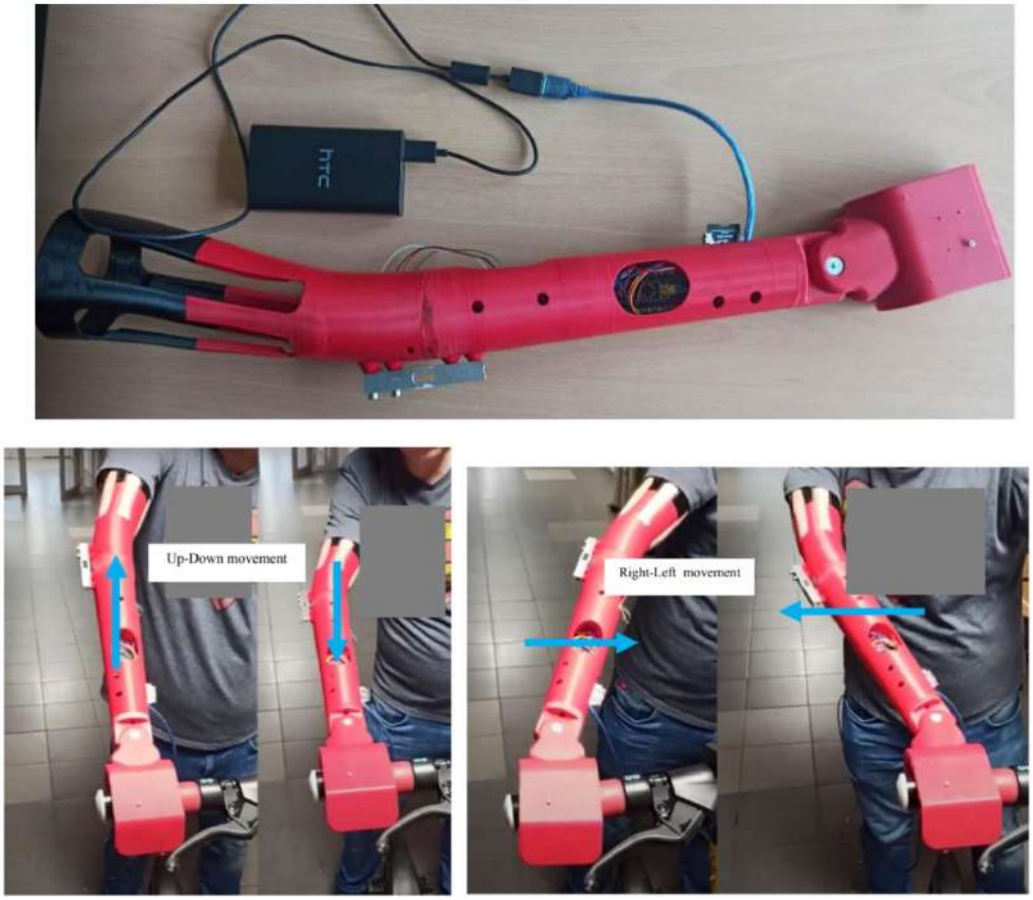

Figure 46. Laboratory and real-life testing scenarios performed by the patient with realized prosthesis

Going further, the EMERALD Case Study #2 has come up with remarkable progress in the field of prosthetic development, primarily focused on upper limb prosthesis (see Figure 47). Two unique concepts for the prosthesis were highlighted concerning this particular case study developed. This initial stage was critical in setting the direction related to the case study. Following the design phase, the prototypes of the end effectors – a key component of the prosthetic limb – were not just designed but also brought into physical form through advanced 3D printing methods (see Figure 48).

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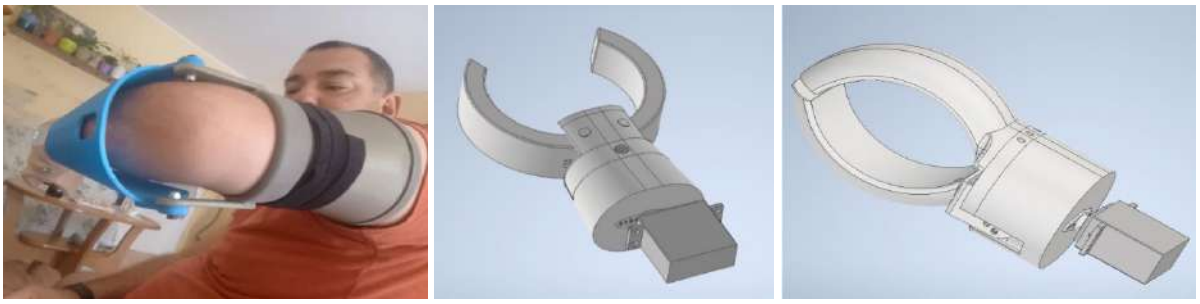

Figure 47. Case study of patients needing upper limb prosthesis and designed concepts considered for this case study

Figure 48. Prototype concepts realized by 3D printing technologies

The EMERALD Case Study #3 showcased in continuing the developing of an innovative rehabilitation application designed to enhance patient engagement and exercise regularity. This application, tailored for upper limb exercises, leverages the power of virtual reality, integrating movement-tracking sensors and a dedicated sensor for recording precise hand positions. The primary goal was to transform rehabilitation into an engaging experience, thereby increasing the user's motivation to participate in treatments. The aspects related to this particular case study were methodically divided into four main stages. The first stage involved designing and creating a specialized controller, an essential component for interacting within the virtual environment (see Figure 49). Next, an orthosis was adapted to work seamlessly with the application, ensuring that the physical movements of the user were accurately captured and reflected in the virtual space. The third stage was dedicated to scripting the game. This crucial phase brought the application to life, utilizing the Unity program to implement an immersive, interactive experience. The resulting application is a bilingual escape room-type game, consisting of four distinct rooms. In each room, users are prompted to perform exercises targeting the movement of specific joints, blending physical rehabilitation with the engaging mechanics of a game. The final stage involved the integration of all these elements into a coherent system, ensuring a seamless user experience. The application, as it currently stands offers a unique approach to rehabilitation, making it more appealing and interactive for users.

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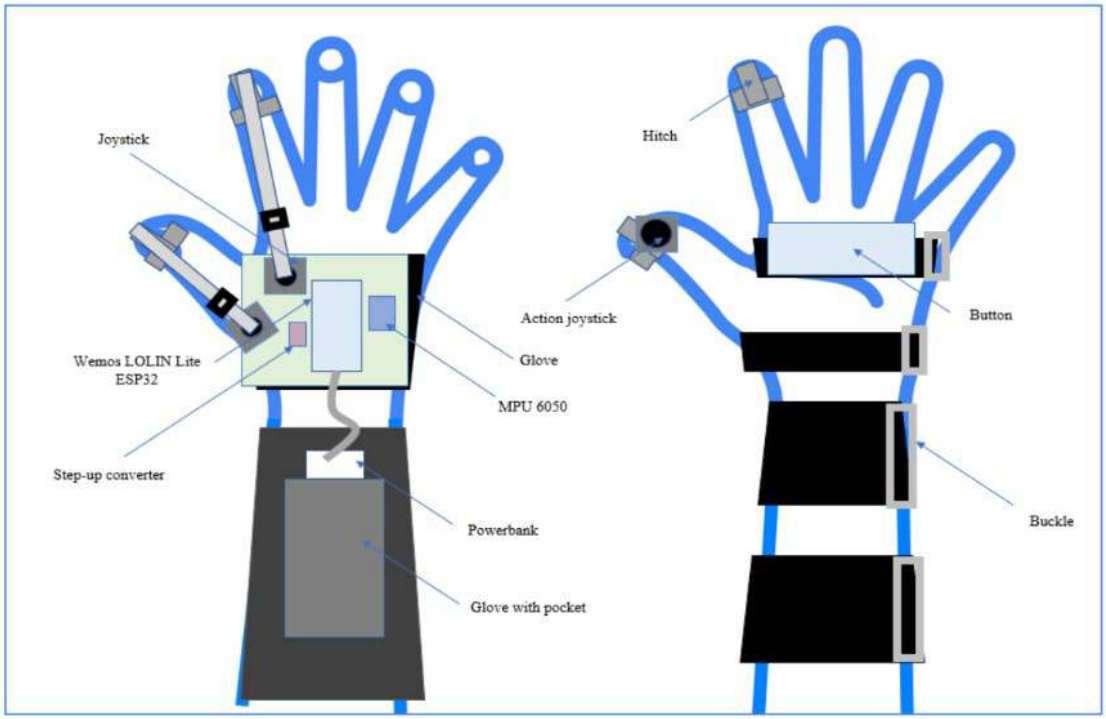

Figure 49. Designing of the controller for the patients with upper limb orthosis

The controller, equipped with a gyroscope and accelerometer, accurately measures the angular position of the hand. It also features flexible ties for index finger and thumb flexion, a selection button, and an analogue resistive joystick on the thumb for nuanced control. The orthosis shown in Figure 50, which was generated using the AutoMedPrint system, was refined to increase the range of motion, particularly in hand bending and thumb movement.

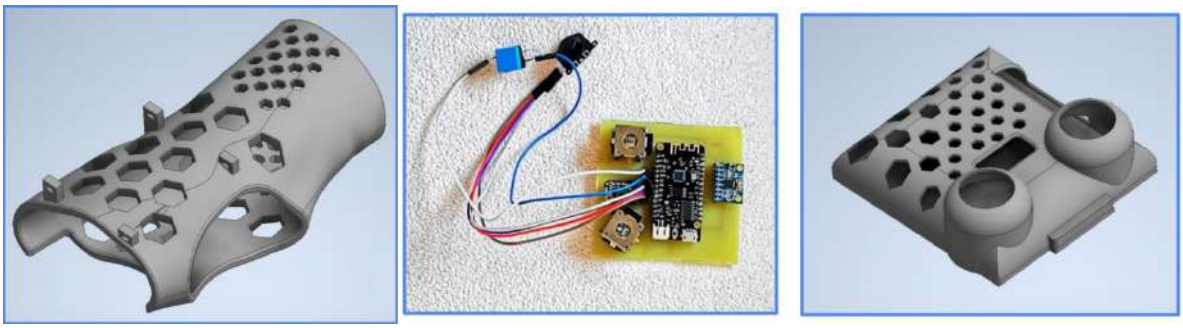

Figure 50. Orthosis and interior / exterior housing part of the controller

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Modifications included attaching points for the controller housing and redesigning the closure system, inspired by Xkelet's solutions. Future enhancements will add an attachment site for the HTC Vive's position sensor, further integrating the physical and virtual components.

The application itself is a multi-level experience, beginning with a tutorial and leading into various themed rooms, each targeting specific joint movements (see Figure 51).

Figure 51. Exercises in VR for hand therapy

Exercises range from shoulder movements in a house setting, where users pull down ropes, to elbow joint exercises in a dungeon environment, mimicking a bowling action to knock down virtual enemies. Wrist exercises are set in a garden, involving fruit picking and throwing, while finger exercises occur in a museum setting, where users interact with moving candles.

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Last, but not least, case Study #4, realized in the frame of the EMERALD project has presented a novel approach in the developing of biomechatronic lower limb orthosis, specifically targeting patients with ankle-foot area conditions such as cerebral palsy and spina bifida. The primary objective of this study led by the team from Poznan University of Technology was to transform a mechanical orthosis into a mechatronic device. This transformation involved enhancing the orthosis with sensors and utilizing the data from these sensors for therapeutic purposes, such as improving diagnostics and controlling a rehabilitation game, possibly with VR technology. Originally conceived as part of the AutoMedPrint project, the orthosis's development began with the creation of a personalized design based on 3D scans. These scans were performed using the AutoMedPrint automatic workstation, with extra backup scans taken using the EINSCAN-PRO scanner (Figure 52). The focus was on achieving a perfect fit for the patient, ensuring comfort and reliability.

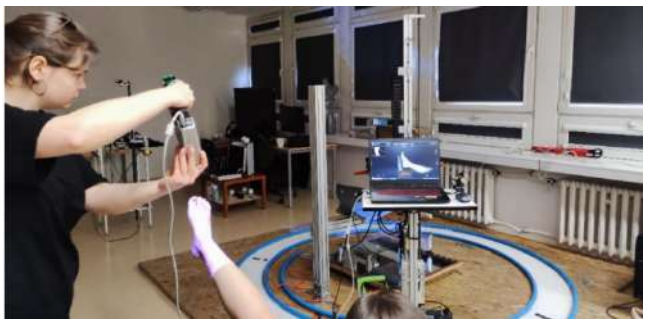

Figure 52. Lower limb scanning process realized at PUT

The project progressed to adapting the 3D CAD model of the orthosis. This involved a hybrid modelling approach, starting from a wireframe to a surface and finally a 3D solid model, all based on points extracted from the scans. This model served as the basis for incorporating the electronics, including the battery and PCB board (Figure 53), which were strategically placed outside of the knee

Figure 53. CAD designing step of the orthosis

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Manufacturing of the orthosis involved 3D printing using Fused Deposition Modelling. After testing various materials, the team selected a composite material of PETG with embedded Carbon Fiber, utilizing large FDM printers like the Zortrax M300 and delta kinematic machines like the FLSun Super Racer for the printing process (see Figure 54).

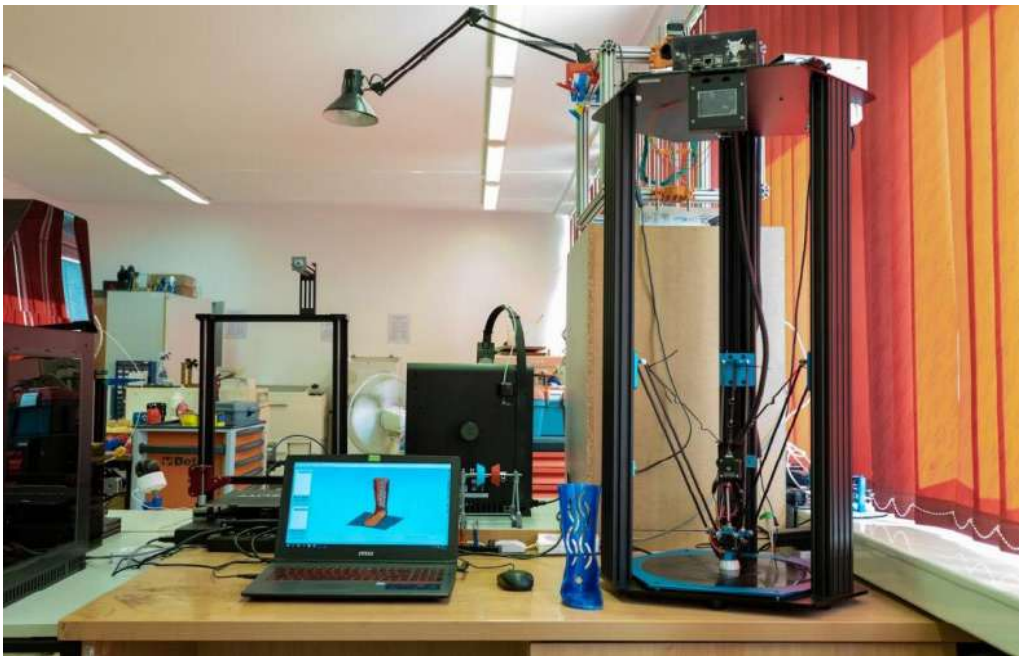

Figure 54. 3D printing process of the realized orthosis

The electronic system of the orthosis (Figure 55) was built around three individual ESP32 microcontrollers, one for each orthosis and one connected to the PC. Communication between these components was established via wifi. The microcontrollers were equipped with IMU LSM6DSO module, strain gauges, an HX711 amplifier for the strain gauge beam, and user interface electronics like diodes and buzzers.

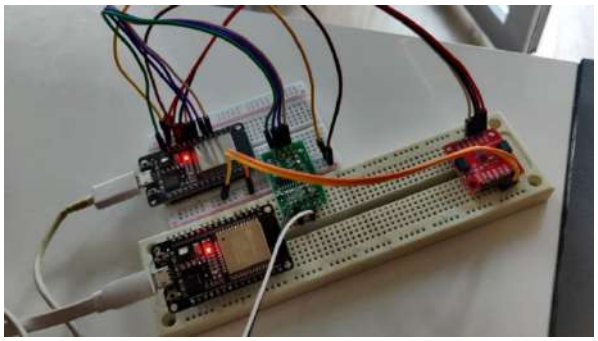

Figure 55. Client and server prototypes

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This innovative approach in Case Study #4 demonstrates a significant advancement in the field of biomechatronics. By combining personalized 3D modeling, advanced electronic systems, and therapeutic applications, the project offers a promising solution for enhancing the quality of life for patients requiring lower limb orthoses. The success of this case study paves the way for further exploration and development in the bio-mechatronic and medical devices domains.

Concerning the realized case studies, it is to be mentioned that prof. Filip Górski and his team from Poznan University of Technology (PUT) Poland has end up with one highly important invention - modular 3D printed prosthesis for children – which have been awarded as best Polish invention 2023 in "Eureka DGP" contest (see Figure 56). Details about the prize and the realized invention can be found on the next following links: https://edgp.gazetaprawna.pl/e-wydanie/59003,30-czerwca-2023/76346,Dziennik-Gazeta-Prawna.html/863954,Wynalazcy-odebrali-nagrody.html & https://www.facebook.com/permalink.php?story_fbid=pfbid0a3FAdqZ9DpiXZqDkbRV5eu92qhAJdMcx4gMGpSURHJQCfDy9P6yNK3QcW1qqGkcWl&id=100057177441812.


Wydanie z dnia: piątek, 30. czerwiec 2023 » Dziennik Gazeta Prawna

Wynalazcy odebrali nagrody

KONKURS DZIENNIKA GAZETY PRAWNEJ

Figure 56. Best Polish invention 2023 in "Eureka DGP" contest won by Prof. Filp Gorski and his team

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Based on this highly important achievement, prof. Filip Górski (PUT) has been invited to take part to a round table about intellectual property in technology transfer, having the chance to talk about medical technology inventions, at congress organized by Polish Patent Office in 2023. Details about participating to this event of prof. Filip Gorksi can be seen in Figure 57 and can be seen also on the next following links:
https://www.facebook.com/permalink.php?story_fbid=pfbid095ZCBGngkdBW1WB5rz7PpT9XJ2Xt2kD1Pxt7Yx8F2ZsUN7wuvozMeyvtVpSY8e3Kl&id=100057177441812 and
https://uprp.gov.pl/pl/aktualnosci/wydarzenia/miedzynarodowy-kongres-wlasnosci-intelektualnej-ochrona-wlasnosci-intelektualnej-przyszlosc-wyzwania-trendy-z-okazji-105-lat-urzedu-patentowego-rp-w-dniach-21-22-wrzesnia-2023

Figure 57. Round table about intellectual property in technology transfer organized by Polish Patent Office in 2023

Also it is important to be mentioned at the end of this chapter that based on these dissemination activities realized by Poznan University of Technology (prof. Filip Gorski) and based on his experience with his team related to patents, one joint patent has been realized by the EMERALD consortium under coordination of PUT, based on one case study that has been realized in the frame of the EMERALD project (O4), this patent being submitted at the end of November 2023 at the Polish Patent Office –registered number P 446940 /30.11.2023 (see Figure 58).

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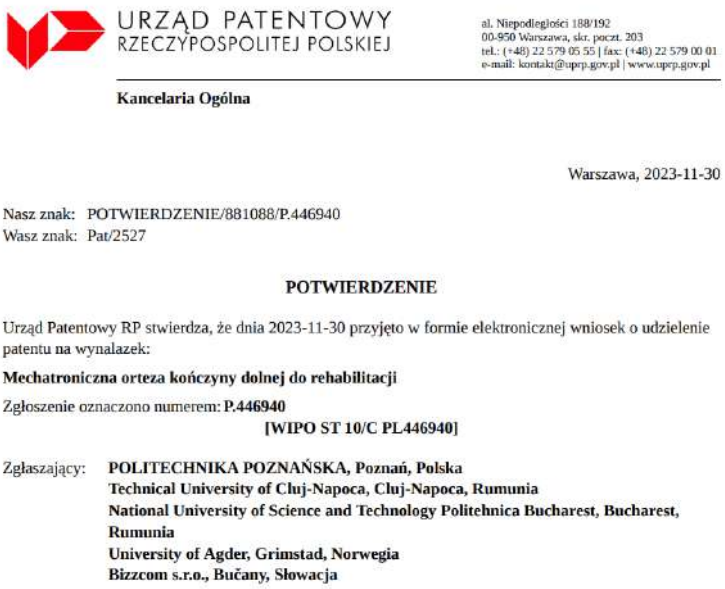

URZĄD PATENTOWY RZECZYPOSPOLITEJ POLSKIEJ

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Kancelaria Ogólna

Warszawa, 2023-11-30

Nasz znak: POTWIERDZENIE/881088/P.446940
Wasz znak: Pat/2527

POTWIERDZENIE

Urząd Patentowy RP stwierdza, że dnia 2023-11-30 przyjęto w formie elektronicznej wniosek o udzielenie patentu na wynalazek:

Mechatroniczna orteza kończyny dolnej do rehabilitacji

Zgłoszenie oznaczono numerem: **P.446940**

[WIPO ST 10/C PL446940]

Zgłaszający: **POLITECHNIKA POZNAŃSKA, Poznań, Polska**
Technical University of Cluj-Napoca, Cluj-Napoca, Rumunia
National University of Science and Technology Politehnica Bucharest, Bucharest, Rumunia
University of Agder, Grimstad, Norwegia
Bizzcom s.r.o., Bučany, Słowacja

Figure 58.Joined patent submission realized by the EMERALD consortium under PUT coordinating in the frame of the EMERALD project (O4)

7.2. EMERALD diploma theses

As a results of the EMERALD project it is worth mentioning that more than 10 theses have been realized in the field of conceiving & producing of bio-mechatronic systems for people with amputated arms (with support of industrial companies with whom the EMERALD consortium has signed partnership agreements), which were developed & produced in the frame of the EMERALD project, highlighting its impact with regards to students & professors that have been working on real case studies in the frame of the EMERALD project, as following:

1. Filip, Gorski, Olga Komorowska, Filippo Sanfilippo, Automation of design of modular upper limb prosthesis, August 2022.
2. Filip, Gorski, Aleksandra Grohs, Jan Madejek, Filippo Sanfilippo, Personalized hand orthosis used as VR game controller, September 2023.
3. Filip Gorski, Agnieszka Marciniak, Filippo Sanfilippo, Mechatronic personalized upper limb prostheses, August 2023.
4. Filip Gorski, Piotr Dorna, Filippo Sanfilippo, Personalized mechatronic lower limb orthosis, September 2023.

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5. Filip Gorski, Justyna Rybarczyk, Răzvan Păcurar, Experimental and analytical studies on 3D printed composite leg orthoses, PhD thesis, September 2023.
6. Ionescu Roxana, Gheorghe Militaru, Răzvan Păcurar, Research on business potential related to customized hand orthoses, June 2023.
7. Răzvan Păcurar, Diana Horincar, Filip Gorski, Research on customized medical parts with lattice structures realized by 3D printing technologies, PhD thesis, September 2023.
8. Răzvan Păcurar, Tudor Cazacu, Filip Gorski, Research on the design and manufacturing of hand wrist orthosis realized by 3D printing technologies, September 2023.
9. Răzvan Păcurar, Diana Ioana Maria Negrea, Filip Gorski, Research on the mechanical behaviour of medical implants with lattice structures made of PEEK material by 3D printing technologies, September 2023.
10. Răzvan Păcurar, Iuliana Aanitei, Filip Gorski, Research on the Constructive and Technological Design of Coronary Stents Made from CoCr by Selective Laser Melting (SLM), September 2023.

7.3. Publishing of articles and books

7.3.1. Scientific jointly articles published / submitted to ISI journals in the period of project implementation (indicators)

1. Górski F, Łabudzki R, Żukowska M, Sanfilippo F, Ottestad M, Zelenay M, Băilă D-I, Pacurar R. Experimental Evaluation of Extended Reality Technologies in the Development of Individualized Three- Dimensionally Printed Upper Limb Prostheses. Applied Sciences. 2023; 13(14):8035. https://doi.org/10.3390/app13148035 ; Impact factor: 2.7 (Q2) – joint article published.
2. Górski, F., Rybarczyk, D., Wichniarek, R., Wierzbicka, N., Kuczko, W., Żukowska, M., Regulski, R., Păcurar, R., Comsa, D.S., Băilă, D.I., Zelenay, M., Sanfilippo, F., Development and testing of individualized sensorized 3D printed upper limb bicycle prosthesis for adult patient Applied Sciences; 13(23), 12918; 2023, https://doi.org/10.3390/app132312918 , Impact factor: 2.7 (Q2) – joint article published.

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3. Górski, F., Grohs, A., Kuczko, W., Żukowska, M., Wichniarek, R., Siwiec, S., Băilă, D.I., Zelenay, M., Păcurar, R., Sanfilippo, F., Development and studies of VR-assisted hand therapy using a customized bio-mechatronic 3D printed orthosis. Electronics, 2024; 13(1):79, https://doi.org/10.3390/electronics13010079 Impact factor: 2.9 (Q2) – joint article published.
4. Păcurar R.I., Sanfilippo F., Økter M.B., Băilă D-I, Zaharia C., Nicoară A.I., Radu I.C., Savu T., Górski F., Kuczko W., Wichniarek R., Comşa D.S., Zelenay M. and Woźniak P. (2024), Use of high-performance polymeric materials in customized low-cost robotic grippers for biomechatronic applications: experimental and analytical research. Frontiers in Materials. 11: 1304339. https://doi.org/10.3389/fmats.2024.1304339 . Impact factor: 3.2 (Q2) – joint article published.

7.3.2. Additional scientific articles published / submitted to ISI journals by the EMERALD consortium

1. Băilă D-I, Păcurar R, Savu T, Zaharia C, Truşcă R, Nemeş O, Górski F, Păcurar A, Pleşa A, Sabău E. Mechanical and Wetting Properties of Ta2O5 and ZnO Coatings on Alloy Substrate of Cardiovascular Stents Manufactured by Casting and DMLS. Materials. 2022; 15(16):5580. Impact factor: 3.748 (Q1), https://doi.org/10.3390/ma15165580
2. Stojković JR, Turudija R, Vitković N, Górski F, Păcurar A, Pleşa A, Ianoşi-Andreeva-Dimitrova A, Păcurar R. An Experimental Study on the Impact of Layer Height and Annealing Parameters on the Tensile Strength and Dimensional Accuracy of FDM 3D Printed Parts. Materials. 2023; 16(13):4574. ; Impact factor: 3.4. (Q2) https://doi.org/10.3390/ma16134574
3. Vitković N, Stojković JR, Korunović N, Teuţan E, Pleşa A, Ianoşi-Andreeva-Dimitrova A, Górski F, Păcurar R. Extra-Articular Distal Humerus Plate 3D Model Creation by Using the Method of Anatomical Features. Materials. 2023; 16(15):5409. Impact factor: 3.4 (Q2) https://doi.org/10.3390/ma16155409
4. Păcurar, R., Comşa, D.S., Sabău, E., Teuţan, E., Zelenay, M., Băilă, D.I., Kuckzo, W., Filip Górski, F., Research On The Design And Manufacturing Of An Upper-Limb Prosthesis By Fused Deposition Modelling, Acta Technica Napocensis, 2023; 16 (4), pp.493-498, impact factor: 0.3 (Q4) https://atna-mam.utcluj.ro/index.php/Acta/article/view/2259/1746

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5. Păcurar, R., Comșa, D.S., Sabău, E., Guțiu, E., Ianoși-Andreeva-Dimitrova, A., Pleșa, A., Zelenay, M., Băilă, D.I., Żukowska, M., Górski, F., Research On The Design And Manufacturing Of a Wrist- Hand Orthosis By Fused Deposition Modelling, Acta Technica Napocensis, 2023; 16 (4), pp.499-504, impact factor: 0.3 (Q4) https://atna-mam.utcluj.ro/index.php/Acta/article/view/2260/1747
6. Băilă D.I., Sanfilippo F., Savu T. Zaharia C., Górski, F., Radu, I.C., Pârâu, C.A., Zelenay, M., Păcurar. R. 3D printing of personalised stents using new advanced photopolymerizable resins and Ti-6Al-4V alloy, Rapid Prototyping journal, Vol. 30 No. 4, pp. 696-710, Impact factor: 3.9 (Q2) https://doi.org/10.1108/RPJ-10-2023-0360

7.3.3. Scientific articles published in proceedings of scientific international conferences (SCOPUS, PROQUEST)

1. Băilă, D.I., Păcurar, R., Păcurar, A.,Mechanical properties and microstructural analyzes of epoxy resins reinforced with satin tissue, International Conference SGEM Bulgaria 2022 , ISSN 1314-2704, International Multidisciplinary Scientific GeoConference SGEM, ISBN 978-619-7603-48-4, vol 22, iss.6.1., 2022, https://doi.org/10.5593/sgem2022/6.1/s24.03
2. Băilă, D.I., Păcurar, R., Păcurar, A., Mechanical behaviors of polyester resins reinforced with unifilo fiberglass, International Conference SGEM Bulgaria, ISSN 1314-2704, ISBN 978-619-7603-48-4, Vol. 22, Iss. 6.1, 2022, https://doi.org/10.5593/sgem2022/6.1/s24.05
3. Băilă, D.I., Păcurar, R., Păcurar, A., Moisture absorption behavior of CP5 composite materials used in industry, International Conference ICBASET Turcia 2022, EPSTEM 2022 The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), ISSN: 2602-3199, vol.18, pg. 55-63, https://doi.org/10.55549/epstem.1192332
4. Băilă, D.I., Păcurar, R., Păcurar, A., Thin-Film Protective Coatings on Samples Manufactured by Direct Metal Laser Sintering Technology Used in Dentistry, Lecture Notes in Mechanical Engineering, Manufacturing 2022, pp. 59–68; https://link.springer.com/chapter/10.1007/978-3-030-99769-4_5
5. Băilă, D.I., Păcurar, R., Păcurar, A.,, Sintered Compacts of Co-Cr Powders Doped with HAp and ZrO2 Used in Implantology, Lecture Notes in Mechanical Engineering, Springer, 2022, pp. 69–78; https://link.springer.com/chapter/10.1007/978-3-030-99769-4_6
6. Vitković, N, Trajanović, M., Aranđelović, J., Păcurar, R., Borzan, C., Contact Surface Model Parameterization of the Extra-Articular Distal Humerus Plate, Lecture Notes in Mechanical Engineering, Manufacturing 2022, pp. 79–92; https://link.springer.com/chapter/10.1007/978-3-030-99769-4_7

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7. Răzvan Păcurar, Diana Ioana Maria Negrea, Emilia Sabău, Dan Sorin Comşa, Cristina Borzan, Nikola Vitkovic, Justyna Rybarczyk and Ancuţa Păcurar, Research on the Mechanical Characteristics of 3D-Printed PEEK Material-Based Lattice Structures Used for Vertebral Implants, Lecture Notes in Mechanical Engineering, Manufacturing 2024, pp. 95–107; https://link.springer.com/chapter/10.1007/978-3-031-56456-7_8
8. Răzvan Păcurar, Consuella Gania, Emilia Sabău, Dan Sorin Comşa, Nikola Vitkovic, Sven Maricic, Stanislaw Legutko and Ancuţa Păcurar, Research on Design and Manufacturing of PEKK-Based Mandibular Implants Made by Fused Deposition Modeling, Lecture Notes in Mechanical Engineering, Manufacturing 2024, pp. 108–120; https://link.springer.com/chapter/10.1007/978-3-031-56456-7_9
9. Răzvan Păcurar, Gabriela Friciu, Emilia Sabău, Cristian Vilău, Eugen Guţiu, Ovidiu Nemeş, Nikola Vitkovic, Remigiusz Łabudzki and Ancuţa Păcurar, Research on Design and Manufacturing of Pelvic Bone Structure by Fused Deposition Modeling Method, Lecture Notes in Mechanical Engineering, Manufacturing 2024, pp. 130–145; https://link.springer.com/chapter/10.1007/978-3-031-56456-7_11

7.3.4. Published books

1. Răzvan PACURAR, Filip GÓRSKI, Filippo SANFILIPPO, Diana BĂILĂ, Branislav Rabara, Martin Bjaadal ØKTER, Dan-Sorin COMȘA, Emilia SABĂU, Magdalena ŻUKOWSKA, Dominik RYBARCZYK, Natalia WIERZBICKA, Radosław WICHNIAREK, Wiesław KUCZKO, Roman REGULSKI, *EMERALD e-toolkit for teaching purposes, basic knowledge about realizing biomimetic mechatronic systems*, Risoprint publishing house, 2023, ISBN 978-973-53-3158-0.
2. Răzvan PĂCURAR, Filip GÓRSKI, Filippo SANFILIPPO, Diana BĂILĂ, Martin ZELENAY, Dan-Sorin COMȘA, Emilia SABĂU, Remigiusz ŁABUDZKI, Michal GALLIA, Tom SAVU, Nicolae IONESCU, Mihaela ULMEANU, Bogdan JUGRAVU, Vlad ENACHE, Cătălin ZAHARIA, Ionuț-Cristian RADU, Magdalena ŻUKOWSKA, Justyna RYBARCZYK, Dominik RYBARCZYK, Roman REGULSKI, Natalia WIERZBICKA, Radosław WICHNIAREK, Wiesław KUCZKO, *EMERALD e-book for developing of biomimetic mechatronic systems*, Risoprint publishing house, 2023, ISBN 978-973-53-3157-3.

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3. Filip Gorski, Michal Rychlik, Răzvan Păcurar, „Advances in Manufacturing III, vol. 5 – Biomedical Engineering: Research and Technology Innovations, Industry 4.0", Lectures Notes in Mechanical Engineering, Springer, 2022, ISBN 978-3-030-99768-7; https://link.springer.com/book/10.1007/978-3-030-99769-4
4. Păcurar, R., Gorski, F., Special Issue "Smart Materials, Intelligent Structures and Innovative Applications of 3D Printing and Bio-Printing Methods", MDPI Materials journal, ISSN 1996-1944, https://www.mdpi.com/journal/materials/special_issues/XA56C5IU0T
5. Filip Gorski, Răzvan Păcurar, Joaquín F. Roca González, Michal Rychlik, „Advances in Manufacturing IV, vol. 5 – Biomedical Engineering: Digitalization, Sustainability and Industry Applications", Lectures Notes in Mechanical Engineering, Springer, 2024, ISBN 978-3-031-56456-7; https://link.springer.com/book/10.1007/978-3-031-56456-7

7.4. Dissemination realized by the EMERALD partners through presentations realized at different organized events (conferences, workshops, etc.)

Regarding dissemination that was been made during the international **conferences,** it is worth mentioning the MANUFACTURING 2022 conference that was organized by Poznan University of Technology - PUT (Poland) in the period 16-19.05.2022 in Poznan, Poland (see: https://manufacturing.put.poznan.pl/) , conference in which professor Filip Gorski (PUT-Poland) and Răzvan Păcurar (Technical University of Cluj-Napoca, Romania) have been involved in chairing sections, wo rking together as co-editors of a book that has been published by Springerlink Publishing house, etc. (see Figure 59)

Figure 59. Disseminating activities realized by the EMERALD consortium at Manufacturing 2022 conference organized in Poznan (Poland)

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At this point is important to mention also the disseminating of case study #4 of EMERALD project (see Figures 52-55) which has been presented at Polish Conference of Biomedical Engineering by Piotr Dorna (Poznan University of Technology). Details about the realized presentation, as well as video recording of made presentation can be seen in Figure 60 and can be accessed on the following links:

https://www.youtube.com/live/kxsPJdli8YU?si=zCDHY_ROCYRbQa59&t=16083

https://sin.put.poznan.pl/publications/details/i55818

https://sin.put.poznan.pl/files/download/53222

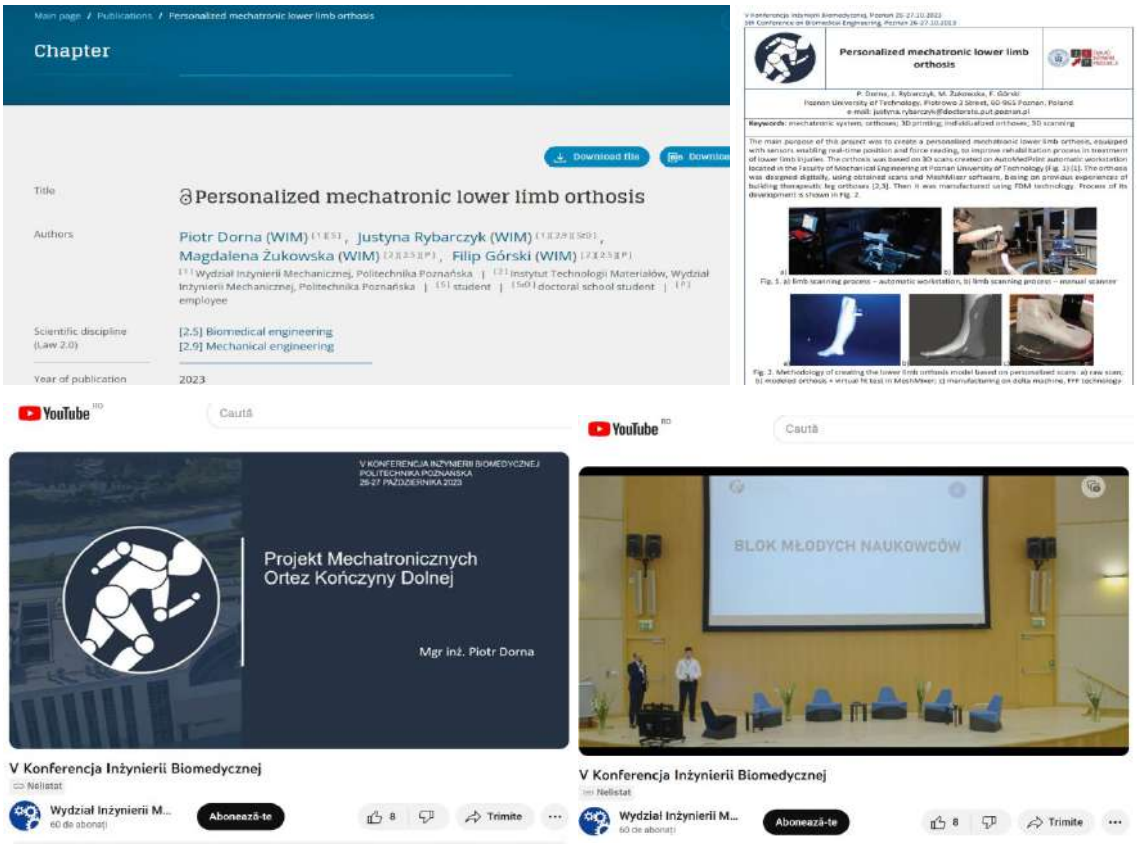

Figure 60. Presentation of the case study # 4 realized in the frame of the EMERALD project at Polish Conference of Biomedical Engineering

Also concerning dissemination of the EMERALD project results through scientific conferences events it is important to be mentioned that prof. Filip Górski (PUT) took part in round table "3D printing in orthopedics" held at Polish Conference of Biomedical Engineering in 2023. Details about the round table organized at this conference where prof. Filip Gorski (PUT) attended can be seen on Figure 61 and can be accessed on the next following links:

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https://www.facebook.com/bioengineeringput/posts/pfbid0e8ENkryBd2cCURN3BpQNqP6dFU4VqWkmo8CnMPibRPE8MryNnT3q7HChH6woX8Nml and https://www.youtube.com/live/kxsPJdli8YU?si=vS0stcPOMOVtdJOg&t=4499

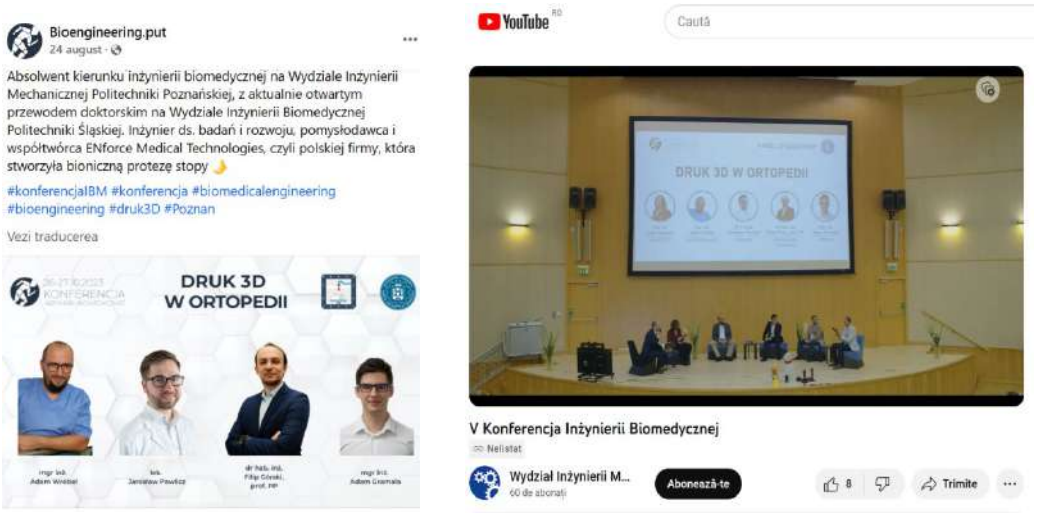

Figure 61. Round table "3D printing in orthopedics" held at Polish Conference of Biomedical Engineering in 2023

In terms of disseminating the results of the EMERALD project one important opportunity for the promoter of the project (Technical University of Cluj-Napoca) constituted by the existing cooperation that exists with other Higher Educational institutions of Europe in the frame of European University of Technology - EuT+ project (see: https://univ-tech.eu/). EuT+ is relying on radically human-centered model of technology, as Figure 62 is suggesting.

Figure 62. Dissemination realized through European University of Technology - EuT+ project alliance

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One plenary presentation was realized by Razvan Pacurar (TUCN) at Polytechnic University of Cartagena (Spain) on the date of 7th of October 2022 at Santa Lucia Hospital of Cartagena (see: https://www.upct.es/sait/es/Noticias/jornada-presentacion-laboratorio-liditeb/) with more than 100 attendees (medical doctors) who have participated and were eager to find which opportunities there are for the medical hospitals given by the 3D printing technologies, many of the solutions achieved in the EMERALD project being disseminated in this way on this event (see Figure 63) .

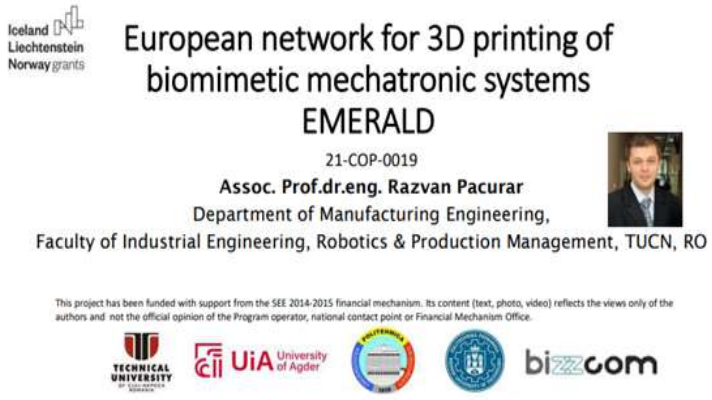

Figure 63. Dissemination event realized at Santa Lucia Hospital of Cartagena in 2022

The event has also being transmitted online (see Figure 64) and one recording of video presentation that was made at LIDITEB 2022 event is available and can be visualized for free on the next following link: https://www.youtube.com/watch?v=W4ocdudm_IA

Figure 64. Dissemination realized at Liditeb event organized by Polytechnic University of Cartagena (Spain) in October 2022

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One group of professors from Polytechnic University of Cartagena (Spain) have been visiting Technical University of Cluj-Napoca (TUCN) in return in February 2023, attending with highly valuable presentations during the Multiplier Event organized by TUCN (see Figure 65).

Figure 65. Group of professors from Polytehnic University of Cartagena visiting and attending to the Multiplier Event organized by TUCN in February 2023

As a result of this wonderful cooperation between Technical University of Cluj-Napoca (Romania), Poznan University of Technology (Poland) and Polytechnic University of Cartagena (Spain) it is to be mentioned the fact that at the Manufacturing 2024 International Scientific Conference organized by Poznan University of Technology in May, prof. Filip Gorski (PUT), prof. Răzvan Păcurar (TUCN) and prof. Joaqun Francisco Roca Gonzalez (Polytechnica Cartagena) will have the chance to jointly lead one special session on "Innovations in design and manufacturing of customized medical products in the wake of digital healthcare revolution) as one may notice in Figure 66, on this event, both prof. Filip Gorski (PUT), prof. Răzvan Păcurar (TUCN) having the chance to disseminate in continuing the results reached in the frame of EMERALD project and opportunities offered by the EEA grants.

Figure 66. Jointly organized session at Manufacturing Scientific International Conference organized by PUT in 2024

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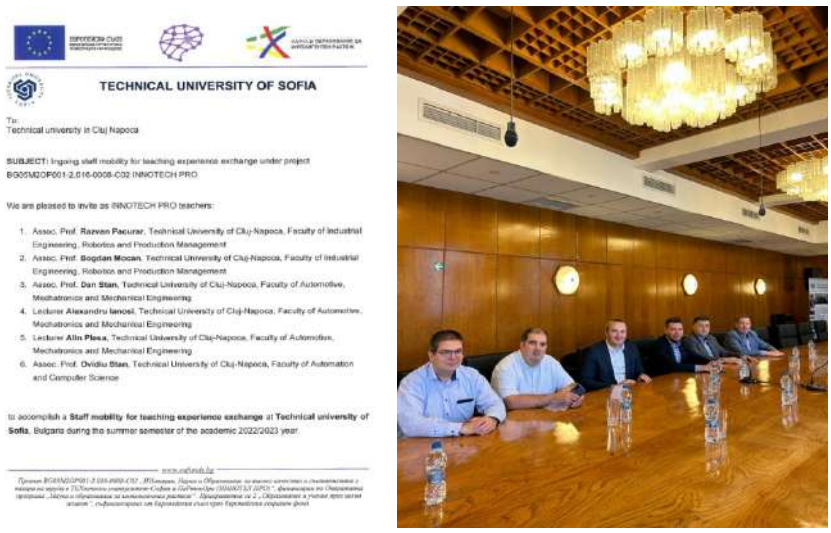
In terms of disseminating the results that were reached in the frame of the EMERALD project another important occasion for was during the **staff mobility for teaching experience exchange** that was realized within the European project Innotech-Pro led by the Technical University of Sofia (Bulgaria) in June 2023 on which staff from Technical University of Cluj-Napoca attended. Important sharing experience related to the results reached in the frame of the EMERALD project (especially on VR domain) were disseminated during this staff mobility visit (see Figure 67).


TECHNICAL UNIVERSITY OF SOFIA

To:
Technical university in Cluj Napoca

SUBJECT: Ingoing staff mobility for teaching experience exchange under project BG05M2OP001-2.016-0008-C02 INNOTECH PRO

We are pleased to invite as INNOTECH PRO teachers:

1. Assoc. Prof. **Razvan Pacurar**, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management
2. Assoc. Prof. **Bogdan Mocan**, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management
3. Assoc. Prof. **Dan Stan**, Technical University of Cluj-Napoca, Faculty of Automotive, Mechatronics and Mechanical Engineering
4. Lecturer **Alexandru Ianosi**, Technical University of Cluj-Napoca, Faculty of Automotive, Mechatronics and Mechanical Engineering
5. Lecturer **Alin Plesa**, Technical University of Cluj-Napoca, Faculty of Automotive, Mechatronics and Mechanical Engineering
6. Assoc. Prof. **Ovidiu Stan**, Technical University of Cluj-Napoca, Faculty of Automation and Computer Science

to accomplish a **Staff mobility for teaching experience exchange** at **Technical university of Sofia**, Bulgaria during the summer semester of the academic 2022/2023 year.

Figure 67. Staff mobility for teaching experience exchange at Technical University of Sofia (Bulgaria)

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Disseminating of EMERALD project activities and reached results has been realized also through different **workshops and seminars** that have been organized with attendees coming from outside the EMERALD project consortium. One such occasion was in April 2022, through which the coordinator of the EMERALD project, associate prof. dr. eng. Razvan Pacurar has been invited to deliver an online presentation to colleagues coming from the Technical University of Cluj-Napoca, through which he was invited not just to share the main ideas related to the EMERALD project, but also general ideas regarding the characteristics and the approach ways related to the Norwegian grants in concordance with the particularities of these types of grants (rules, financial mechanisms, etc.). The event was held online using the Ms Teams online platform with more than 60 attendees that were interested about the topic (see Figure 68) and details provided on the next following link: https://ces-utcn.webis.ro/wp-content/uploads/2023/05/Invitatie_atelier-online_13-aprilie-2022.pdf .

Figure 68. Dissemination realized during the online seminar organized by TUCN in April 2022

In similar way prof. Filip Gorski (PUT) has been invited Filip Górski invited to podcast a series of talking about science, 3D printing of prostheses and VR, grants and team building on an event called Polipodkast, through which he had the chance to disseminate the results and share with all attendees about the experience that he has gained on the EEA grants and collaborating with Norwegian partner coming from the University of Agder in Grimstad, but also the other partners of the EMERALD consortium (project) as well. Details about the organized event can be seen presented in Figure 69 and on the next following links:

https://www.facebook.com/politechnika.innowacje/posts/pfbid0jocFrscMkLK17wDmU5YRufhVZpWCUnUDLndjiGnCvkSEfEMfwmhi9RjDfnH5orEyl and

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https://www.youtube.com/watch?v=mBErJVfJJgM&fbclid=IwAR1ZTAdLi8lvBBEcKhEHKZbevH8pX3pfhY25nRFsjuUco7QP7pPXI1SeQas&ab_channel=POLIPODKAST

Figure 69. Dissemination of the EMERALD project realized at PoliPodKast event

Since EMERALD project has been highly practical in terms of achieved results, there were few workshops that have been organized in collaboration with EMERALD professors, being addressed to the ERASMUS students who have been visiting Technical University of Cluj-Napoca. One workshop was organized in June 2023 and one in September 2023 with more than 100 attendees (ERASMUS students coming from institutions outside the EMERALD consortium) in total (see Figure 70 and the next following link: https://www.utcluj.ro/media/notices/2023/workshop.pdf) .

Figure 70. Workshops organized at TUCN in June 2023 and September 2023 with ERASMUS students

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Similar activities (workshops) have been organized with ERASMUS students during the Blended Intensive Program that was held at Polytechnic University of Cartagena (Spain) in November 2023.

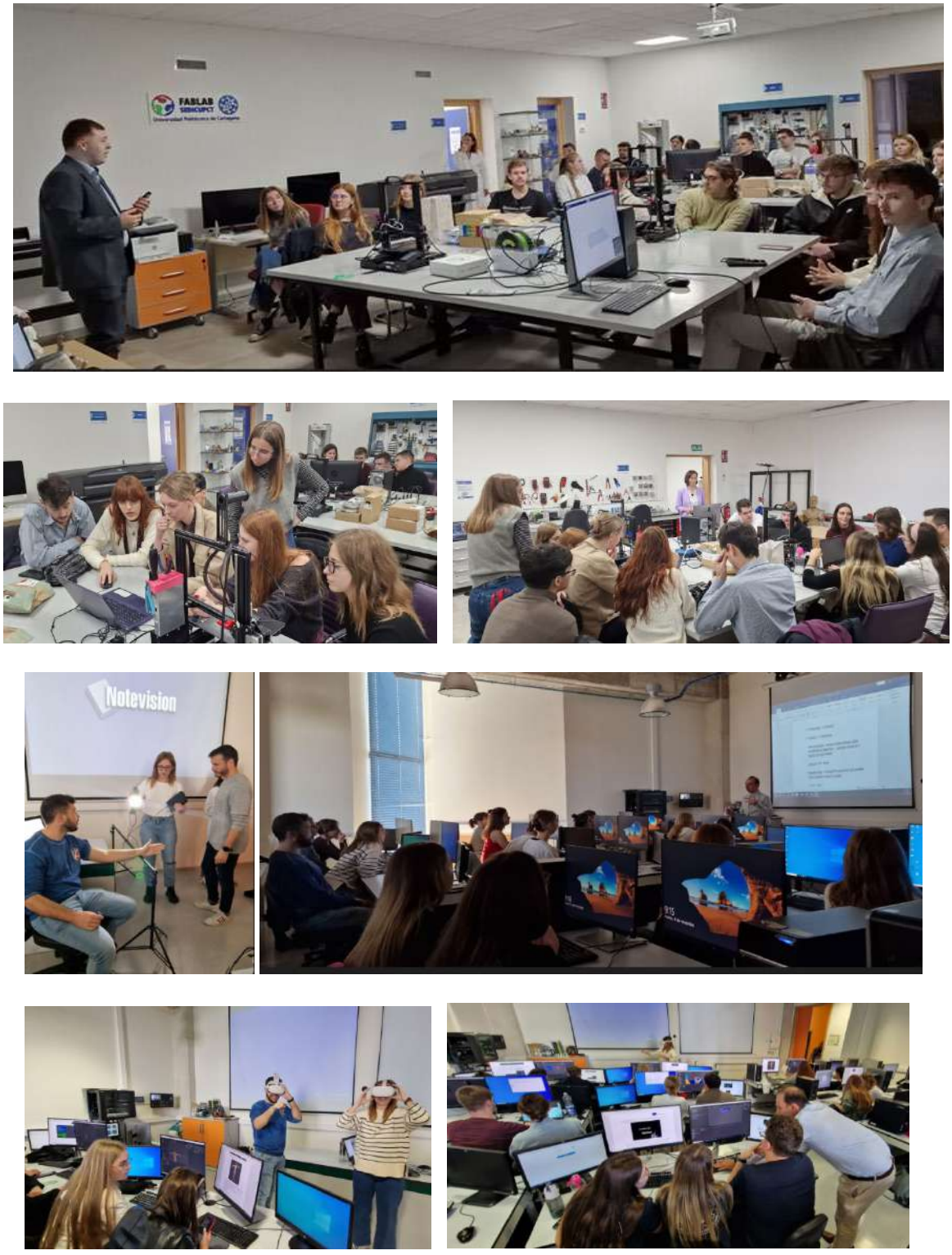

Figure 71. Dissemination workshop organized at Polytechnic University of Cartagena - 2023

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Through this event (workshop entitled “"Applied digital design and manufacturing techniques for biomedical applications" held in the period 18-25 November 2023), there have been 30 students coming from Polytechnic University of Cartagena (Spain), Technical University of Riga (Latvia), Poznan University of Technology (Poznan) and Technical University of Cluj-Napoca who took benefit and have used the resources that were realized by the EMERALD consortium (especially the ones reached in the frame of O3 about the e-learning virtual platform) that they have been using for conceiving, developing and testing of bio-mechatronic systems for people with amputated arms (see Figure 71). but also experiencing the VR / AR / Mixed Reality using resources realized in the frame of O3 (e-learning virtual laboratory platform) as they have been shared by the Technical University of Cluj-Napoca and Poznan University of Technology partners who have brought contribution in sharing the resources related to the EMERALD project during this organized event (see Figure 72 and the next following links: - https://www.upct.es/noticias/2023-11-20-estudiantes-de-rumania-letonia-y-polonia-se-forman-en-diseno-e-impresion-3d-de-protesis-en-la-upct); https://www.facebook.com/permalink.php?story_fbid=pfbid02ox6DwLUXd2wBrAcNSq4LacF2PYEqkm4YadupNu7bE1kDNgzGc4QcE2HhN7bSbY2Hl&id=100057177441812 ; https://www.facebook.com/utcluj.ro/posts/pfbid026ci9B8tpDRB1HJpy7fPR53P7t58ip7zPjvi4xuCi2DBHTawh6TD6njPBsySnP1dHl ; https://www.utcluj.ro/media/documents/2023/BIP_Erasmus__Cartagena.pdf?fbclid=IwAR2VkqQbUteBe3RMZwFpiX-7G64D6bGrQftlP2ewn2PXMmvjQSFZDFVLcaI

Regarding the disseminating of the achievements reached in the frame of the EMERALD project on behalf of the industrial partner of the EMERALD consortium - BIZZCOM, it's worth noting the presentation given by Branislav Rabara, the Director of BIZZCOM company that he was realizing on March 28, 2022, in Bratislava, Slovakia, in front of an international delegation from Taiwan. The delegation included Pei-Zen Chang, the Executive Vice President of the Industrial Technology Research Institute, Alex Hao-Chih Liao, the Director General of the Department of International Cooperation of the Ministry of Foreign Affairs of Taiwan, and Karol Galek, the State Secretary of the Ministry of Economy of the Slovak Republic (see Figure 72). The subject of the meeting was to try to settle new possibilities of strategic cooperation between Europe and Taiwan, investment possibilities, partnerships in the field of research and development and business activity. In addition, Taiwan declared its interest in supporting European designers through several training programs concerning bio-mechatronic systems that can be realized by 3D printing technologies to support people with amputated arms.

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Figure 72. Dissemination of the EMERALD project results realized by BIZZCOM in March 2023

8. EMERALD strategic partnerships and new projects

As mentioned in the previous chapter, BIZZCOM company has played a pivotal role in the EMERALD project, particularly in driving dissemination activities among industrial partners and significantly contributing to the formation of the European Network for 3D printing of Biomimetic Mechatronic Systems (EMERALD network) in the end (see Figure 73). Their efforts have been highly important in enhancing the visibility and impact of the EMERALD project results among the industrial companies, ensuring a wider reach and deeper engagement with the industrial sector in this way.

Figure 73. List of companies with whom there have been signed Partnership agreements for the EMERALD Network

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It is important to mention in this context that BIZZCOM company involvement during the EMERALD project implementation has been relied on an Important Project of Common European Interest (IPCEI) – (see: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3087 and Figure 74), where they have extended an invitation to EMERALD consortium members to participate in a project that aligns closely with the objectives of the EMERALD project. This collaboration presents an invaluable opportunity for the EMERALD consortium partners to share their expertise and achievements from the EMERALD project and benefit from this significant European initiative, furthering research and development in microelectronics and communication technologies in this direction in the future.

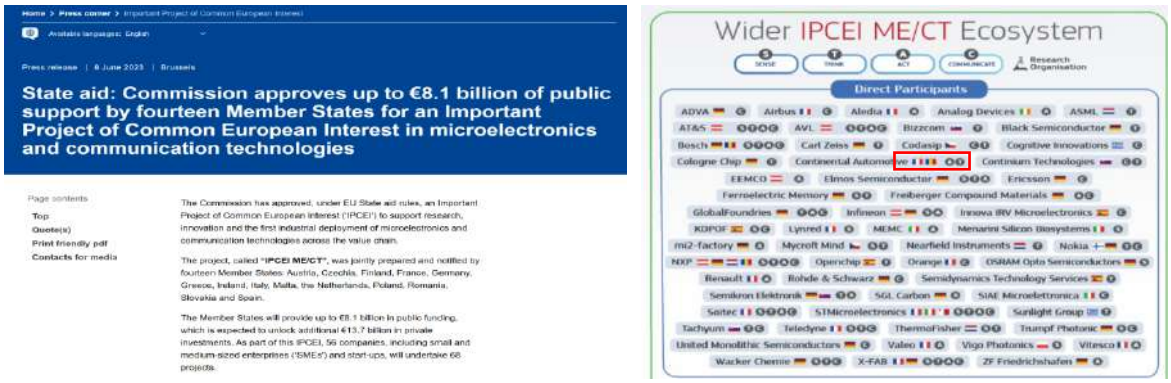

Figure 74. IPCEI project initiative in which BIZZCOM partner is part of and addressed invitations to the EMERALD partners to join

Alongside their collective efforts in the EMERALD project and IPCEI project, the EMERALD consortium partners have achieved remarkable success by winning two innovative ERASMUS KA 220 projects. The first, led by the University of Agder (UiA), is titled “Beyond the Classroom: VR, AR & Haptics for Enhanced Surgical Training & Education” - https://www.uia.no/en/centres-and-networks/ciem-centre-for-integrated-emergency-management/projects-by-ciem). This Erasmus+ Cooperation Partnerships in Higher Education KA220-HED project explores cutting-edge virtual and augmented reality technologies to revolutionize surgical training and education, extending learning beyond traditional classroom boundaries. The second project, led by the UPB partner, is the “European Network for Additive Manufacturing in Industrial Design for Ukrainian Context” - https://upb.ro/unstpb-anunta-lansarea-proiectului-international-erasmus-european-network-for-additive-manufacturing-in-industrial-design-for-ukrainian-context-amaze/.

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This project aligns closely with the methods and approaches used in the EMERALD project, focusing on the application of VR/AR in teaching within an industrial design context (see Figure 75).

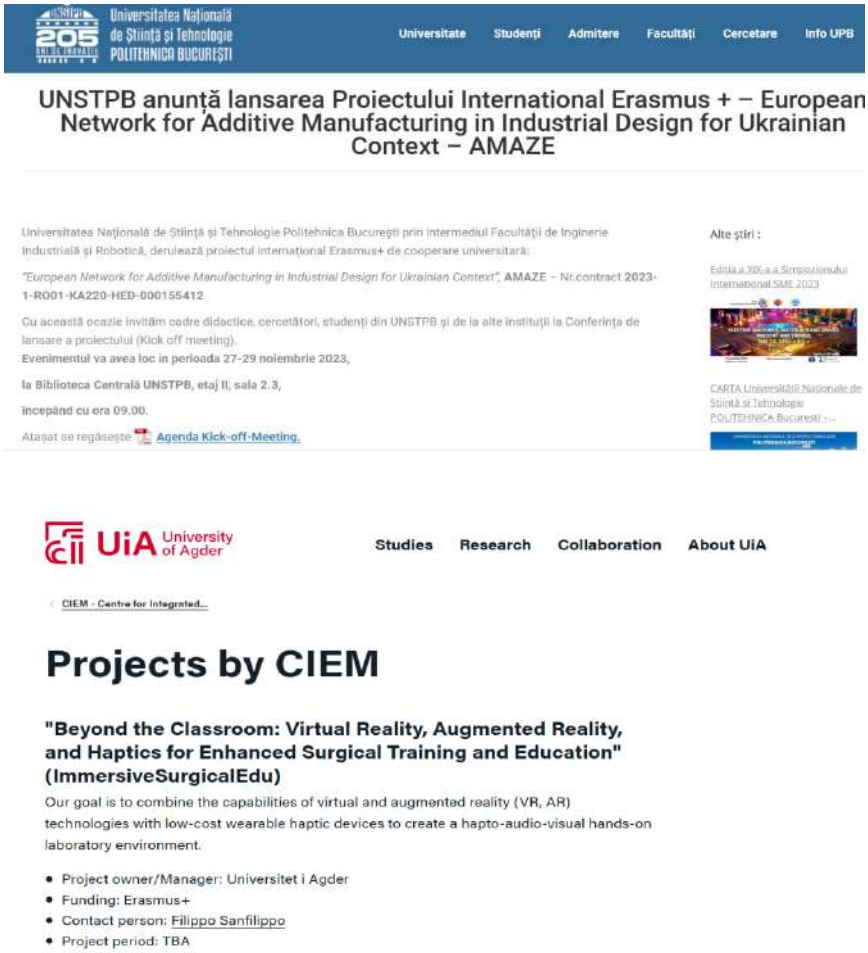

Figure 75. New ERASMUS KA 220 projects won by UiA and UPB partners in 2023

In continuing it is worth mentioning the ERASMUS agreement that has been signed between the University of Agder (UiA) and the Technical University of Cluj-Napoca (TUCN) representing the proper context to continue international educational collaboration in the next period (until 2024) (see Figure 76). The partnership agreements that has been signed between UiA and TUCN EMERALD institutions has strengthen the successful international cooperation that has been reached in between these institutions in the frame of the EMERALD project, highlighting the impact and success that has been reached through the sustained academic exchange that took place in the implementing period of the EMERALD project, involving professors and students coming from these two institutions in the period 2022-2023.

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EUROPEAN UNION

Erasmus+

2021-2027

Erasmus+ Programme

Bilateral Inter-Institutional Agreement

Key Action 1
Learning Mobility for Higher Education Students and Staff

among EU Member States and third countries associated to the Programme

The institutions agree to cooperate for the exchange of students and/or staff in the context of the Erasmus+ programme. They commit to respect the quality requirements of the Erasmus Charter for Higher Education in all aspects related to the organisation and management of the mobility, including automatic recognition of the credits awarded to students by the partner institution as agreed in the Learning Agreement and confirmed in the Transcript of Records, or according to the learning outcomes of the modules completed abroad, as described in the Course Catalogue, in line with the European Credit Transfer and Accumulation System. The institutions agree on exchanging their mobility related data in line with the technical standards of the European Student Card Initiative.

Grading systems of the institutions

Receiving higher education institutions need to provide a link to the statistical distribution of grades or make the information available through EGRACONS according to the descriptions in the ECTS users' guide. The information will facilitate the interpretation of each grade awarded to students and will facilitate the credit transfer by the sending institution.

Validity period of the agreement

Timeframe	Academic Year*
Start of validity	[2022/2023]
End of validity	[2023/2024]

A. Information about the higher education institutions

Name of the institution (and department, where relevant)	Erasmus code	Contact details² (email, phone)	Websites (General/Faculties/ Course catalogue)
Technical University of Cluj Napoca Romania	RO CLUJNAP05	Office for European Programs Andreea Papa-Erasmus Program Officer Memorandumului Street 28, 400114 Cluj-Napoca, Romania Tel: + 40 264 202261 / Fax: +40 264 591690 E-mail: Int.Rel.Office@staff.utcluj.ro Manufacturing Engineering Department (ERASMUS agreement responsible): Associate Prof.dr.eng. Răzvan Păcurar Department of Manufacturing Engineering Technical University of Cluj-Napoca B-dul Muncii 103-105, 400641, Cluj-Napoca, RO Tel. +40-264 401784 razvan.pacurar@tcm.utcluj.ro	Relatii internationale (utcluj.ro)
University of Agder Faculty of Engineering and Science	N KRISTIA01	Institutional Coordinator: Terje Eugen Thorsdalen Erasmus coordinator +4737233232/+47 99602052 terje.thorsdalen@uia.no Departmental coordinator: Pål Grandal Tel: +47 91873571 Email: pal.grandal@uia.no Academic coordinator: Assoc.Prof.Filippo Sanfilippo filippo.sanfilippo@uia.no +47 37 23 30 76 +47 942 58 929	https://www.uia.no/en

Figure 76. ERASMUS agreement signed between TUCN and UiA

Based on the EMERALD project and on the existing agreement signed in between UiA and TUCN institutions, a new project entitled "Mobility for Sustainability" - ID 22-MOB-0032, which is in the period of implementation until April 2024, has been won by TUCN and was financed through the SEE mechanism in 2022 (see Figure 67). This project states as the base framework for sharing knowledge and experiences in between Romanian and Norwegian higher education institutions in the field of bio-mechatronics in continuing in education and research areas in the future.

Iceland Liechtenstein Norway grants

Education, Scholarships, Apprenticeships and Youth Entrepreneurship Programme in Romania

– Mobility for learners and staff –
Higher Education Student and Staff Mobility

Inter-institutional[1] agreement 2022-2025[2]
between Romania and Donor States

[Minimum requirements][3]

The institutions named below agree to cooperate for the exchange of students and/or staff in the context of the **Education, Scholarships, Apprenticeships and Youth Entrepreneurship Programme in Romania** programme. They commit to respect the quality requirements of the Erasmus Charter for Higher Education in all aspects related to the organisation and management of the mobility, in particular the recognition of the credits awarded to students by the partner institution.

A. Information about higher education institutions

Name of the institution (and department, where relevant)	Erasmus code	Contact details[4] (email, phone)	Website (eg. of the course catalogue)
Technical University of Cluj Napoca Romania	RO CLUJNAP05	Manufacturing Engineering Department (ERASMUS agreement responsible): Associate Prof.dr.eng. Răzvan Păcurar Department of Manufacturing Engineering Technical University of Cluj-Napoca B-dul Muncii 103-105, 400641, Cluj-Napoca, RO Tel. +40-264 401784 razvan.pacurar@tcm.utcluj.ro	Relatii internationale (utcluj.ro)
University of Agder Faculty of Engineering and Science	N KRISTIA01	Institutional Coordinator: Terje Eugen Thorsdalen Erasmus coordinator +4737233232/+47 99602052 terje.thorsdalen@uia.no Departmental coordinator: Pål Grandal Tel: +47 91873571 Email: pal.grandal@uia.no Academic coordinator: Assoc.Prof.Filippo Sanfilippo filippo.sanfilippo@uia.no +47 37 23 30 76 +47 942 58 929	https://www.uia.no/en

Figure 77. New project "Mobility for Sustainability" financed through the SEE mechanism in 2022

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9. Conclusions

In conclusion, the EMERALD project consortium has managed to achieve its objectives in producing valuable teaching resources that can be practically used and applied in the field of bio-mechatronics systems for people with amputated arms. All these resources have been consistently disseminated by all partners of the EMERALD consortium in the end. These resources have been shared not only within the academic community, including professors and students both within and outside the EMERALD consortium, but also with various stakeholders (industrial partners) that were interested about this topic. The outcomes, achievements and results of the EMERALD project were consistent in terms of educational materials like course modules, e-toolkit manual, the e-learning virtual laboratory platform, but also in terms of scientific papers, books and diploma thesis projects that have been jointly produced by the EMERALD partners in the consortium. Dissemination has been realized through various channels like media, social media, postings on blogs and official institutions of the EMERALD consortium, as well as through different organized events like conferences, workshops, seminars, etc, which finally led to the constituting of the EMERALD network with several industrial companies with whom there were signed collaborating partnerships. All These collaborations have provided invaluable support in implementing the EMERALD project objectives, ensuring the success in reaching all the results and KPIs of the EMERALD project as they have been stated in the proposal in the end.

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