IMPACT: a strategic partnership for sustainable development in marine systems and robotics

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***Abstract*—The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. All sectors of the society need to be involved in order to achieve those goals. This paper represents an initiative among several universities to explicitly look at the UN SDGs from the higher education perspective, in the field of marine systems and robotics, fostering self-reflection, developing specific actions addressing several goals. Currently half-way in the project life, the preliminary results and the activities performed up to now are very promising, bringing academia closer to the implementation of the Agenda 2030.**

***Index Terms*—marine systems, marine robotics, sustainable development, AI4good, SDG**

I. Introduction

The oceans cover 71 percent of the Earth's surface and contain 97 percent of the Earth's water. Marine systems are pivotal to interact with this environment. They currently play a key role in the exploitation of marine resources (offshore), conservation of marine environments (environment assessment) and security applications (harbour protection). Autonomous marine systems like Autonomous Underwater Vehicles are increasingly able to perform more complex missions including survey and inspection tasks in complex environments. The European Commission has estimated that the economic impact of the blue economy (considering all activities linked to the sea) is worth more than 400 billions € annually, with more than 150 billions € in activities directly related to marine activities. Half of the oxygen available to us has been produced by phytoplankton – this means that every other breath comes from microscopic organisms in the ocean. The important and irrefutable role of the marine world for humanity has also been recognised by the UN with their Sustainable Development Goals (SDGs) initiative, where oceans are recognised in the SDG 14, in Figure1.

The presence of a specific SDG on Oceans was not however an easy target to achieve on the international level. From one side, the academic and research community prepared position papers. For example, Visbeck *et al.* argued that "the sustainable use and development of the ocean and the coasts concern all countries, whether they are coastal states or not, due to the

Fig. 1. SDG14 Oceans

The project IMPACT - Intelligent Marine systems a Pathway towards sustAinable eduCation, knowledge and empowermenT has received funding from the EU Erasmus+ program, Key Action 2, 2018-1-DE01-KA203-004259.

global nature and importance of the manifold functions and services delivered by the world's ocean and coasts, their relevance for the human society, and the interconnectedness with human activities" [1]. Statements from scientists were surely important for evidence-based policy, though the decisive factor was the active campaign from the Pacific Island Countries. As outlined by Quirk and Hanich [2] those countries used their experience with joint diplomatic efforts and regional oceans governance to successfully negotiate the inclusion of an *ad-hoc* SDG. As part of the so-called *Oceans Diplomacy*, the first UN Oceans Conference[1] happened in New York, USA, at the UN headquarters.

Looking at the conference participant distribution, the overwhelming majority of scientists was from natural sciences, in particular marine and ocean scientists. Whilst from one side this was to be expected, on the other hand the contribution of technology to achieve the SDG14 and, more in general, the Agenda 2030 needs to be highlighted. Sometimes the technical world is disconnected from societal issues, such as sustainable development, with few valuable exceptions.

Tjoa and Tjoa rightly advocate for a central role of Information and communications technology (ICT) to Achieve the UN Sustainable Development Goals [3]. They argue that ICT is definitely an enabler to more efficient resource usage, education and business operations which is critical success factor for achieving the SDGs. More broadly, Rahimifard and Trollman highight an engineering perspective, underlying the complex nature and the interconnections of the SDGs [4].

With the same philosophy in mind, one could ask about the role of robotics to achieve the SDGs. Bugmann *et al.* explore this aspect on he impact of robotics for sustainable development, though with no specific reference to the UN programs such as the Millenium Development Goals or the SDGs [5]. The interesting approach of this work is to contribute to analyse the impact of robotics without hiding possible criticisms, such as perceived promotion of over-production and under-employment. Robotics on the other hand can bring many advantages such as reduction of waste, reduction of transport thanks to telepresence, more efficient recycling systems thanks to various sensors and increased dexterity. Ilhan *et al.* focus on automation in the field of construction robotics, and how this can be pivotal for sustainability [6]. In particular they demonstrate the use of advanced building technology and construction robotics for smart energy solutions, which would have a positive impact with respect to standard energy approaches. Pan *et al.* also focus on sustainability in construction through robotics. A novel framework is presented as a robust and reliable assessment method that can be used in the industrial context to assess the sustainability of building construction projects [7].

In related fields emphasis on sustainable development was also shown with position papers. In the manufacturing area, Gaughran *et al.* encourage intelligent manufacturers to take into account the indicators of energy demands and supply in planning their chain supply, and processing strategies, highlighting opportunities but also responsibilities [8].

Geoinformatics and sustainable development is addressed by Xiao *et al.* [9], in the specific field of conservation and promotion of cultural heritage in support of the UN Sustainable Development Goals. Three case studies are presented to demonstrate the contribution of geoinformatics technologies to the SDGs related to cultural heritage.

The consideration that no work has been done on marine systems and robotics with an attention to sustainable development was a big motivation to start this project, and to initiate a discussion on sustainability in the community.

A predominant focus on SDG14 however would have been extremely limited. In the framework of marine systems and robotics, universities deal with a much wider range of topics than the research focus. All organisations face horizontal challenges, like gender equality or the relation among teaching and research, or student employability when they finish their degree, but no one has come out with a clear solution or with a clear path to undertake in all of these areas. Moving to a higher level, all those areas are connected in a holistic approach to sustainability, currently in the Agenda 2030. There is a general lack of awareness about sustainability, about the SDGs, and how they are linked to everyday activities, including professional and educational activities. This project represents therefore a step towards a discussion about the links between university work and sustainability, and towards concrete actions to achieving the Goals, with innovative initiatives.

Regarding industry cooperation, there is a clear need to bridge the gap between academia and the private sector, in order to make these two worlds cooperating more closely for enhanced outputs [10]. There are no specific programmes in the field of marine systems, and therefore this was also chosen as an important point to address. Lee has examined the sustainability of university-industry collaboration by focusing on the actual "give-and-take" outcomes between university faculty members and industrial firms [11]. Based on various surveys he has identified clear benefits for both ends. In the marine system area there are examples of successful synergies, but the market is more fragmented into smaller start-up and large industrial companies - the latter focused mainly on defence or oil&gas business. Interestingly, there is also a gender aspect of the engagement between academia and industry which seems to be stronger in the technology field, as opposed to natural sciences [12].

An additional clear need that was identified is the pooling of knowledge and skills from a variety of European experts to deliver best quality courses to students. From the student perspective, there exists a clear interest to participate in intensive courses, which are not common in all organisations, mostly focused on regular semester classes. Intensive study programmes represent a unique opportunity for students to be fully immersed in a specific topic, with international colleagues - an approach that will additionally foster international cooperation and friendship.

[1] https://www.un.org/en/conf/ocean/about.shtml

II. The IMPACT Project

Based on the needs identified and the gap of a program focused on sustainability for the community, seven Higher Education Institutes (HEI) in Europe joined forces for a 28 month cooperation in the field of marine systems, called IMPACT: Intelligent Marine systems a Pathway towards sustAinable eduCation, knowledge and empowermenT (Figure 2). The main objectives of the project are:

- Create a sustainable, international, and cross-field network in the area, to foster cooperation, exchange of good practice and innovative approaches, providing a platform to discuss key topics in the area, linking them to the UN SDGs;
- Create novel study material in the field of marine systems
- Foster entrepreneurship mindset and creative thinking;
- Bridge the gap between academia and industry, making the two worlds working closer
- Create occasions for students to participate in international Intensive Study Programs, with renowned speakers.

A. Consortium make-up

Each organisation in the partnership has a diverse experience in intelligent marine systems, each of them has its own specialisation, but cooperation in the educational field is still limited to date. The project partners' research and entrepreneurship activities cover a vast array of applications of marine robots, such as sensors and technologies for biological and Earth sciences research [13] [14], automated survey and maintenance in the energy sector [15], underwater archaeology [16], harbour security and diver safety [17] [18], educational robotics, mine removal and autonomous shipping [19]. This work provides a number of technological contributions to the sustainable development can be inscribed into numerous trends which are expected to produce societal impact [citation needed] such as ocean-based clean energy generation and sustainable aquaculture. The advances in these field are made thanks to often transdisciplinary results in the domains of control, navigation, sensor design, material science, data processing and autonomous mission management.

Whilst there have been joint research projects among some of the partners (e.g. [20]–[24]), education still remained not fully covered. The composition of the partnership is made in a way that each organisation can bring something unique in their approach to intelligent marine systems, and therefore there is a clear benefit for all partners involved.

B. Innovation Aspects

This project represents a first partnership in the field where education is the main focus, and is dealt with considering many different aspects. Current cooperation is mainly research-based, and thus it represents a unique opportunity to complement the existing cooperation. Interaction between academia and industry is still limited, whilst potential for cooperation in this field is great. Intensifying contacts with industry has the potential of creating a real impact, fostering professional development and lifelong learning. Some of the partners run entrepreneurship courses, but they are usually short and sparse in time (e.g. a couple of hours each week), in addition of being very general, to cover the needs for students coming from a variety of backgrounds. The study courses developed in this project will be both intensive and with a clear reference to the marine systems world and its peculiarities. The link to the United Nations Sustainable Development Goals is unfortunately not very common in this field. Four different SDGs are analysed in the transnational project meetings, linking the various activities from the partners to a holistic approach in sustainability, as outlined by the UN. The current situation in the marine system world sees a few large companies dominating the market, whilst the potential for small and medium enterprises is high. This project aims to lay the basis for the creation of a fertile ecosystem which would foster and support such initiatives, which are still very sparse in the field. The general architecture of the project can be seen in Figure 3. The transnational meetings allow a discussion of the topic of marine systems with respect to a specific SDG. Four intellectual outputs are envisaged during the project, two of them directly linked to intensive training programs for students, one on marine systems and one on entrepreneurship. The other intellectual outputs envisaged are the preparation of study module for industry, and an overall report on the partnership activities, with a reflection on how this had an impact on the various participanting organisations. Overall, the SDG14 Oceans is the overarching theme of the project, and all actions are channelled to concrete action points.

Fig. 2. The IMPACT project logo

III. Transnational Meetings

A. December 2018: Kick-off meeting in Bremen, Germany

During the first meeting we chose to focus on the big picture, both looking at the overall project and at the overall Agenda2030 of the United Nations. Some videos from the UN Oceans Conference were used as an initial point to start a discussion.

B. May 2019: transnational project meeting in Tallinn, Estonia

The project focus was on Quality Education (SDG4). Teaching & Research have been discussed and analysed to identify strengths and weaknesses. Presentations from the partners allowed to identify synergies and best practices, as well as ways

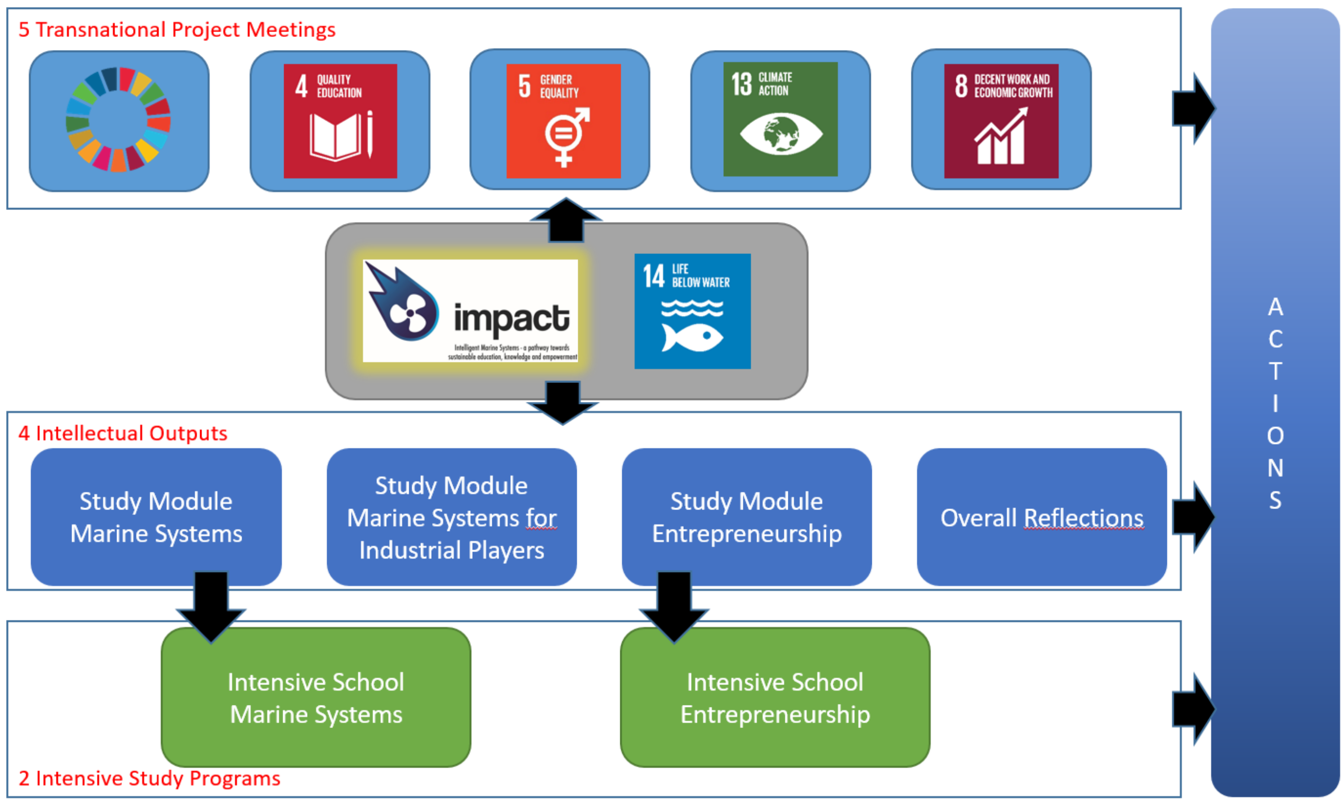

Fig. 3. The IMPACT project architecture: five transnational meetings allow a discussion of the topic of marine systems with respect to a specific SDG. Four intellectual outputs are envisaged during the project, two of them directly linked to intensive training programs for students. Overall, the SDG14 Oceans is the overarching theme of the project, and all actions are channelled to concrete action points.

to integrate the teaching and the research aspects in order to foster a virtuous system of reciprocal reinforcing. As pointed out by Vladimirovaa & Blanc, education is directly connected to all other SDGs. Without quality education, no sustainable progress in possible in any field [25]. Paradoxally, the link between SDG4 Quality Education and SDG14 Oceans is ignored to a large extent, in the various UN flagship reports [26]. Combining hard science education in light of sustainable development is unfortunately a not easy challenge, as also outlined by Dias *et al.* [27]: "Designing higher educational initiatives enabling technological innovation for sustainable development is a new and largely uncharted region." They present three higher education initiatives focused on robotics involved in humanitarian actions and some specific programs. Although those are very valuable initiatives, they are mildly rooted in the curriculum of the students, hence avoiding the much more challenging option to embed sustainability in the normal study programs. Whilst most universities launch and promote ad-hoc activities and initiatives, a notable exception in this area is represented by the work of Grau *et al.*, with the explicit intent of integratinig sustainability in technological degrees, with the case study of Robotics at the Technical University of Catalonia (UPC) [28].

The lack of analysis and discussion about sustainability in education in programs related to marine systems and robotics was a key motivation to address this topic, keeping in mind that for robotic technology to be used as a model to support education for sustainable development, specific curriculum, adaptable to local contexts, needs to be readily available, as argued by Gerretson *et al.* [29]. A survey to collect data about education in marine systems and robotics across the world has been launched, and the data are currently analysed, in order to tailor suggested actions to the specific domain.

C. October 2019: transnational project meeting in Zagreb, Croatia

The project focus was on Gender Equality (SDG5), very important and currently very much debated in our society, though not always properly analysed, especially in male-dominated fields, such as robotics and engineering. Initiatives in this area are very sparse, even considering the broader robotics theme. A key challenge that was discussed is the timeline of education and interest building. It is often too late to work at university level in order to foster gender equality, but societal transformation activities need to be initiated at much lower level, i.e. at much younger age. For example, Screpanti *et al.* have presented a project whose aim was to raise interest in STEM education in K12 students and, in particular, to address the lack of participation of female students in STEM careers [30]. The University of Girona has made a survey of around 200 female graduate students, which show what are the current issues affecting them during their study and research. It was decided to perform a reverse survey: ask male students on their perception of female students' situation. This work is on-going and will be compared with the original survey. Societal perception was also discussed: women studying engineering topics are facing constant comments from peers expressing surprise. On an anecdotal evidence, during a technical talk at the University of Central Punjab in Lahore, Pakistan, many more female students attended than in similar talks in a western European university. Fairly often female students and researchers are given secretarial tasks, rather than scientifically relevant. Expectations about family and children also discourage women from a career in STEM. Focusing on the Marine Systems and Robotics aspects, several practical issues arise especially during field activities. Female needs are too often ignored - most likely unintentionally, as women are not thought to participate in field activities. Some examples include missing toilets on small operation boats, lack of same-gender cabins on bigger boats. A striking example is represented by technical fairs, where women are still hired as *decoration*. This leads to the fact that female engineers - even when in a leading position - are not taken seriously by potential clients and customers. An initial sketch of actions was designed, including female colleagues in the process, in order to produce some recommendations (for example in the form of a checklist) for field operations, in order to increase inclusiveness.

Further reflection include non-binary people, which of course suffer from various degrees of discrimination.

D. tentative May 2020: transnational project meeting

The project focus will be on Environment and sustainability, with a specific focus on SDG13 - climate change. The first part of the meeting will be formed by a guided discussion and brainstorming on how to include sustainability aspects in marine systems curricula and in operations. The second part will then focus on the role that marine systems can play for an environmentally sustainable planet, considering autonomous monitoring, inspection, but also - where appropriate - autonomous intervention.

E. tentative November 2020: transnational project meeting

The project focus will be on entrepreneurship, with a specific focus on SDG 8 - decent work and economic growth. Entrepreneurship represents a possible outcome after the studies and it is therefore very important to give to our students the tools to succeed. Whilst several institutions run entreprenuership activities, the focus will be on marine-related tech-entrepreneurship, analysing success cases to bring to the various institutions.

IV. Intellectual Outputs

A. Marine Systems

This is a 8-day study course, aimed at university students, from BSc to PhD level, focused on marine systems. Its main innovative aspects are: - Link to sustainability and UN SDGs, and not only to pure science - Holistic approach, with the contribution of different expertise at the project partners - Teaching method which is more prone to learning by doing, and allows student-centric, independent discovery activities in the field, with some guidance. The availability of such module will be useful for the marine systems community. Its structure and content will make it easy to be implemented in various settings, and to be personalised according to the specific local constraints. This course can be effectively used from many institutions that are interested in marine systems and have access to at least basic facilities for the hands-on parts of the module. The topics have been chosen for their importance in the marine system community across Europe, with an effort of providing cutting-edge education.

B. Entrepreneurship

Some of the partners run entrepreneurship-related courses, but they usually are either full semester courses, or as a kind of additional activity, like a two-hour session every week, for 4-6 weeks. We have found the need to have an intensive 5-day program, where the students could really be in an immersive environment, where they can learn, but also practice team-work, cooperation, problem solving, strategic planning. Following the feedback from students about the benefits of an intensive one-week course, we believe that the potential impact of this study course will be very beneficial to empower young people giving them an opportunity to build their ideas. The transferability potential is very high, as the material will be ready-to-use and there are no special requirements, like an equipped lab, for example. Some inputs from the MIT Sloan School of Management (in particular Martin Trust Center for Entrepreneurship) will be taken into account for the development of this study course, thanks to the frequent interactions with the Center.

C. Industry

This short 3-day study course explicitly targets industry participants, which usually cannot afford the time for longer courses. Currently industry players in the marine systems field are mainly large companies, which are not very much in contact with the latest R&D development at university research level, but which could be really beneficial in their domain of operation. In a view of lifelong learning and to stimulate a productive transfer from academia to industry, the development of this course represents an innovative initiative which is currently missing in the field. The impact can be potentially very high, with novel research findings being applied to real-world problems, which can mean a reduction in cost of operation, an increased safety, the achievability of otherwise unreachable goals. The transferability potential is also very high, as the material will be self-contained, and no particular equipment would be needed to run this course in other places by other institutions.

D. Lessons Learned an Final Reflections

At the end of the project in 2021 we will summarise the overall partnership experience, its outcome and its results in the various institutions. This represents a first international initiative that links marine systems to the UN SDGs, with a specific focus on the role of education. It is important therefore that a concrete output is developed, overarching the various topics of the transnational meetings, reporting also on the results of any change in methodology which the project will bring in the partners' activities.

V. Intensive Study Programs

The Intensive Study Programmes fit very well with the main partnership activities and are support the achievement of the project objectives. They are occasions to reinforce the collaboration among the partners, and give a very valuable international experience to students. Most importantly they serve as testbed to try the study courses developed in the project. The feedback received from the participants will be very important to fine-tune the intellectual outputs.

A. Marine Systems

This is a 8-day ISP, based on Intellectual Output 1. It is aimed at university students, from BSc to PhD level, focused on marine systems. This program did run in October 2019, in the framework of the Breaking the Surface program, in Croatia. Feedback from participants was extremely encouraging, as the program was built with a mix of lectures, team activities and field trials.

B. Entrepreneurship

This is a 5-day ISP, based on Intellectual Output 2. It is aimed at university students, from BSc to PhD level, focused on entrepreneurship, with a flavour for marine systems and robotics. It will be consituted by a mix of lectures and team / practical activities. It is currently scheduled to happen later in 2019.

VI. Conclusions

This paper has presented an on-going partnership project among various universities to embed sustainable development and in particular the SDGs in the current activities of higher education institutions, with a focus on marine systems and robotics. The project is currently at around half of its lifetime and the preliminary results are encouraging. Among the challenges in running this kind of projects, there is a lack of incentives for academics to be engaged into something which is - on a superficial view - unrelated with the hard algorithm development. However, we are confident that those topics will be considered more and more important for research and teaching, and can create a real impact, starting from own institutions. Some of the discussions have touched uncomfortable topics, but those sometimes awkward moments were just a sign on how much needed these discussions were. Overall, we are looking forward to the next phase of the project, with enthusiasm and commitment.

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