INTELLECTUAL OUTPUT 3 (IO3): STEM KIT – AN INCLUSIVE LEARNING ACTIVITY TO MAKE ENGINEERING EDUCATION MORE ATTRACTIVE

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Contents

Executive Summary

This Intellectual Output (IO3) document reports on the outcomes of Activity 3 as part of the A-STEP 2030 (Attracting diverSe Talent to the Engineering Professions of 2030) project. This project is an EU Erasmus + project funded under call number 2018-1-FR01-KA203-047854. The document begins by explaining the purpose and aims of the overall research project and more specifically, the tasks associated with Activity 3. Three tasks were completed in order to contribute to this report, the first being a mapping of pedagogical approaches in Europe (Nørgaard et al., 2021a), the second being the creation of future scenarios (Nørgaard et al., 2021b) and finally the pilot of a learning and teaching activity with 30 international students in August 2021 (Beagon et al., 2021). Reports associated with all activities are included on the project website https://www.astep2030.eu/en.

The report summarises the outcomes of the three tasks and presents a summary of the use of future thinking skills and scenario writing as an innovative way to prepare students with the skills necessary for a sustainable future. The feedback from the learning and teaching activity is also showcased to highlight its value in creating an attractive environment which can encourage diverse students to join the profession of engineering.

The STEM KIT also includes all resources used as part of the learning and teaching activity; presentations, reading material etc. and this can be accessed by other engineering educators for their own use from the project website.

1.0 Summary of Overall Research Project

The main objective of the A-STEP 2030 project is to develop new and innovative teaching approaches relevant to learners' values yet appropriate to teach a new set of skills and competencies needed for the future. Our goal is to create an attractive and fascinating learning environment thereby encouraging young people and adult learners with diverse backgrounds to engage in engineering studies and the profession as a whole. The project comprises the following three activities:

Activity 1: Determine future roles and skills requirements of engineers to enhance the sustainable development of society.

Activity 2: Investigate the values and motivations of young people, students and adult learners to determine how this influences their future career choices and use this knowledge to make a career in engineering more attractive to all young people.

Activity 3: Develop new and innovative teaching and learning practices to respond to these findings.

The project consortium has 7 members from six EU countries (France, Denmark, Finland, Ireland, Sweden and Belgium) and 10 associated partners. The team includes four different European HEIs all involved in Engineering Education Research. (ENSTA Bretagne, France, TU Dublin, Ireland, Aalborg University, Denmark and Metropolia University, Finland.) The team is also complemented by representatives from SEFI (European Society for Engineering Education) and Universum - experts in research relating to student motivations and career choices. Students are also represented through our project partner BEST (Board of European Students of Technology) which represents HEI students in STEM.

Figure 1 shows the main activities associated with the project. This report focuses on the result of Activity 3: New and innovative teaching and learning practices to attract students with diverse backgrounds.

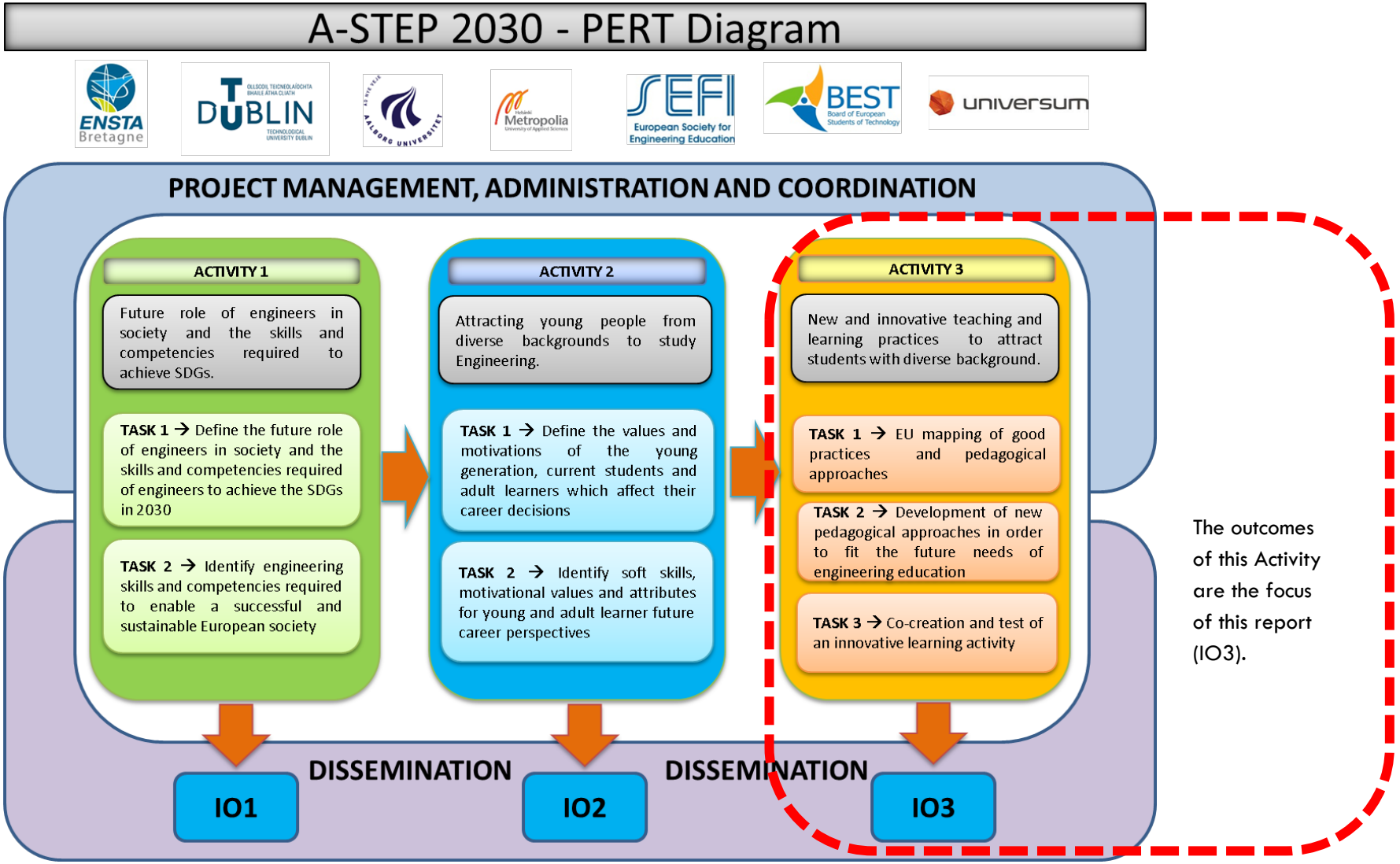

Figure 1: Overall Project details showing the aims of each activity.

2.0 Background

In Activity 1, we looked at the future skills that engineers would need in order to achieve the SDGs and in Activity 2 at the motivations and values of young and adult learners. We took two aspects of these findings together into the Activity 3 learning and teaching activity: Future Orientated Skills and Sustainable Development. The purpose of Activity 3 was to use these findings combined with a review of pedagogical approaches to pilot a learning and teaching activity which would be attractive to diverse students and appropriate to develop the skills engineers would need in the future. Therefore, in Activity 3 we firstly investigated the differing pedagogical practices employed in engineering education in Europe. From this exercise, the concepts of Digitisation, Technology, Co-creation, Group work emerged as innovative practices. All of these concepts were brought together in the design of the learning and teaching activity. Each task is now summarised, however full and detailed reports are available on the project website.

3.0 Task 1: Mapping of Pedagogical Approaches

The first task involved a review of local university pedagogical curriculum through interviews conducted by (ENSTA, TUD, MUAS, AAU) in 11 European STEM universities in six European countries. These included: AALTO University in Helsinki, Finland, Aalborg University in Aalborg, Denmark, Absalon University College in Kalundborg, Denmark, Budapest University of Technology and Economics in Budapest, Hungary, ENSTA, Bretagne, France, Institute of Technology Sligo, Ireland, KU Leuven, Belgium, Metropolia University of Applied Sciences in Helsinki, Finland, TU Dublin, Ireland, University of Limerick in Limerick, Ireland, University of Southern Denmark in Odense, Denmark.

The research team designed a loosely structured interview guide. The interviewers from the A-STEP 2030 partner universities applied this interview guide to structure interviews with respondents. The respondents were selected by the university partners who have the most knowledge of the university in question where the interview was to be conducted. The interviews lasted between 30 - 90 minutes and were conducted in the local language of the participants to facilitate exchange between interviewees and researchers. All interviews were transcribed and categorized according to the themes of the interview guide. NVivo was used for a more detailed and structured analysis of the interviews.

The mapping was presented using six themes:

- Teaching Method at European STEM Universities
- The Structure of Education
- Strategies for Pedagogy
- Pedagogical training for academic staff
- The Organisation of students
- Looking to the future of STEM education

What emerged was a diverse selection of different teaching pedagogies, structures, training requirements and opportunities and finally how students are organised in learning activities depending on the university and the type of teaching approaches used. For the majority of Universities, there were no formal strategies for the teaching approaches used. Looking to the future, there was a focus on digitisation and online teaching, with an acknowledgement that the pandemic has created a situation where academics have moved very quickly to online teaching and that it is here to stay.

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4.0 Tasks 2 and 3: Development of new pedagogical approaches in order to fit the future needs of education and Co-creation and Test of an innovative learning activity.

Our learning from the mapping of pedagogical approaches and our discussions within the team about innovative teaching led us to focus on the concept of scenario writing in order to develop future orientated thinking skills. We also took note of the focus on digitisation and online teaching and finally of student centred learning and co-creation of curriculum. We determined that rather than use the small research team to design scenarios that would be presented to students, that one of our innovative approaches should be to co-create the scenarios with the students during the learning and teaching activity. Hence rather than undertake Task 2 and 3 separately, we decided to do both during the learning and teaching activity. We then followed this up with more detailed discussions within the project team about the scenarios which were co-created. Due to the pandemic situation, we were unable to host the learning and teaching activity in person, and so we turned this to our advantage and ran the learning and teaching activity online to provide an opportunity for students and academics to develop their digital skills. Thirty international students were hosted online in the learning and teaching activity which took place in August 2021 as the "A STEP 2030 Summer School".

Students were invited to attend the free Summer School through advertisement in student networks, universities, SEFI, Universum networks and on social media. As we wanted to enhance multi-cultural skills by creating diverse teams, the application form requested general demographic details, but also selection of preferred team roles in line with the Belbin Team Roles Framework (Belbin, 2011). Students were selected from 266 applicants to attend the Summer School. The Summer School took place over 3 days, using 6 sessions of 2 hours. Students were also expected to work together off line. The Agenda for the Summer School is included in Table 1. Each partner in the project hosted a different session in order to provide diverse teaching approaches and views from the project team.

The team set up a Collaborative Workspace before the event so that each team member could upload pre-reading material and resources. Worksheets and documentation that was required for each activity was also provided within separate folders. This allowed students to access, work on and upload progress in each session and was available to all hosts and students within that group to work on and review. We also provided a Code of Conduct for student's participation online and a certificate of participation for students who completed the Summer School.

Another innovative pedagogical approach introduced students to the concept of Futures Literacy and Scenario Thinking and sessions were held on developing skills on Backcasting, Roadmapping and Designing a Monster. The Summer School event concluded with a Show and Tell session which allowed students to present their scenarios to the research team. The co-creative exercise enabled the research team to trial this innovative exercise whilst helping students develop their skills in future orientated thinking.

Table 1: Overall Schedule for Summer School

Wednesday 18th August 2021 (09.00 -11.00 GMT+1)	**Wednesday 18th August 2021 (13.00-15.00 GMT+1)**
Session 1: Futures Literacy **Session Hosts: AALBORG and ENSTA** Purpose of Session: Introductions to the project and to the participants Schedule: 09.00-09.10 Welcomes, Code of Conduct 09.10-10.00 Introductions [Interactive Session] 10.00-11.00 Future Literacy Interactive Session	**Session 2: What is scenario thinking?** **Session Hosts: METROPOLIA** Purpose of Session: Introduction to Strategic Thinking, Driver Mapping & Creation of four futures Schedule: 13.00-13.05 Joining the room 13.05-13.15 Introduction to Strategic thinking 13.15-13.30 Introduction to Driver Mapping 13.30-14.55 Students work in groups 14.55-15.00 Wrap Up
Thursday 19th August 2021 (09.00-11.00 GMT+1)	**Wednesday 18th August 2021 (13.00-15.00 GMT+1)**
Session 3: Backcasting **Session Hosts: TU Dublin** Purpose of Session: Introduction to the technique of backcasting and deepening the four futures they have identified in Session 2. Schedule: 09.00- 09.05 Joining the room 09.05- 09.15 Intro to Backcasting techniques 09.15- 10.55 Students work in groups 10.55- 11.00 Wrap Up	**Session 4: Roadmapping** **Session Hosts: ENSTA** Purpose of Session : Deepening of scenario building – Creating a strategic plan Schedule: 13.00-13.05 Joining the room 13.05-13.15 Introduction to Roadmapping 13.15-13.30 Discussion with whole group on realism 13.30-14.55 Students work in groups 14.55-15.00 Wrap Up
Friday 20th August 2021 (09.00-11.00 GMT+1)	**Friday 20th August 2021 (13.00- 15.00 GMT+1)**
Session 5: Designing a Monster **Session Hosts: AALBORG** Purpose of Session : Introduction to the technique of Monstering with a view to creating a plan or model for a future classroom and how it will function. Schedule: 09.00- 09.05 Joining the room 09.05- 09.15 Introduction to Monstering 09.15- 10.55 Students work in groups to create their Monster 10.55- 11.00 Wrap Up	**Session 6: "Show and Tell"** **Session Hosts: TU Dublin** Purpose of Session: To see the outputs of the scenarios created by each group Schedule: 13.00-13.05 Joining the room 13.05-14.00 Two parallel sessions of "Show and Tell" 14.00-14.15 Feedback 14.15-14.25 BEST Presentation 14.25-14.30 Wrap up, thank you and goodbye

The research team considered the findings of Task 1 in order to design the Summer School and in particular the students wish to have self-directed learning. To this end, each session host began with a short presentation to the topic which was covered. This generally lasted about 15 minutes. Students then joined individual group rooms to work on a task which was provided by the instructor. The researchers visited each team to assist with any queries and to listen to the ideas the students were discussing, but the work was very much student centred.

As the final aspect of the Summer School, we asked students to "Create a Monster". We specifically left this exercise open to interpretation, to initiate creativity in the final artefact. Students created videos to describe their "monster" which ranged from scenario orientated radio interviews to a scenario where students were describing a dream and also included an advertisement for some new edible products which would help people better understand engineering topics. Overall, there was much novelty, creativity and lots of fun had by all. Full details of the topics covered in the Summer School and the scenarios created are included in Report 6 and videos of each monster are available on the project website. The eight scenarios are described briefly in Table 2.

Table 2: Summary of scenarios created in summer School "The Future of Engineering Education".

Scenario Title	Key points
Back to the Future	• Technology used to translate languages • Food delivered by drones • No lecture theatres • Online delivery • Knowledge transferred directly to brain
EPS Podcast and Vision Water	• An individualised software system "Engineering Positions System" • Guides engineering students through their educational journey • Helps student decide on their majors • Engineering Education becomes part of everyday life • Vision Water is a drink which helps creativity, innovation, technical knowledge, critical thinking skills and problem solving
Interview with STEM Agent and College Graduate	• Hybrid learning • Worldwide collaboration between universities • Industrial experience standard within educational journey • Career Based Exchange Programme • More women engineers
The future of Education	• Free Education for all • Personalised Education • Virtual Reality as a learning tool • Robots as Educators • Accessibility to people with disabilities • Holograms as a communication tool

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How to become an Engineer in the Future	• Personal AI Mentor for every student • AI mentors will learn the learning styles, strengths and weaknesses of the student • Standardised and globalised STEM education programme • Specialisms learned on the job with companies • Free education for all
Robotic Assisted Teaching	• Robotic assisted teaching will yield better results, in a world which is less stressful and more productive. • Personalised lessons for students allows for specialisation and the robots also ensure that the student's progress is tracked. • Virtual simulation of laboratories has become the norm
Artificial Intelligence in Future Engineering Education	• AI provides an adaptive, personalised experience • Human robot Interaction • AI Based streaming of courses online • Multilingual teaching through AI • Used for classroom design, monitor behaviour, bridge gaps in student's knowledge
The LEGO Educational Model	• Like LEGO, at the beginning, each one has the same shape and the same size, but with imagination, different outputs are created from the same input • HAT Day uses an AI system to assess the mental and physical abilities of children and to decide what their career in STEM will be

5.0 Feedback on Learning and Teaching Activity

The final part of Activity 3 was to assess how effective the learning and teaching activity was in achieving the aims of the project. More specifically:

- The attractiveness of this type of learning and teaching activity
- The effectiveness of the learning and teaching activity in developing skills such as;
    - critical thinking,
    - future orientated thinking,
    - teamwork,
    - communication
    - multicultural skills
    - scenario writing.

The team undertook an online survey of participants after completion of the course to assess these research questions and received 26 responses. The findings show that overall students very much enjoyed their participation in the summer school, with an average score of 9.4/10 for the question: "How likely would you recommend taking part in the A-STEP 2030 Summer School to a fellow student?".

Detailed results of the feedback from students is included in Report R7 on the project website, however, some aspects are summarised here.

Students were asked how effective the Summer School was in developing specific skills and allowing for opportunities such as building a network with international students. Average responses (between a score of 0-5) are indicated in Figure 2. The standard deviation of response scores ranged (0.45-1.06).

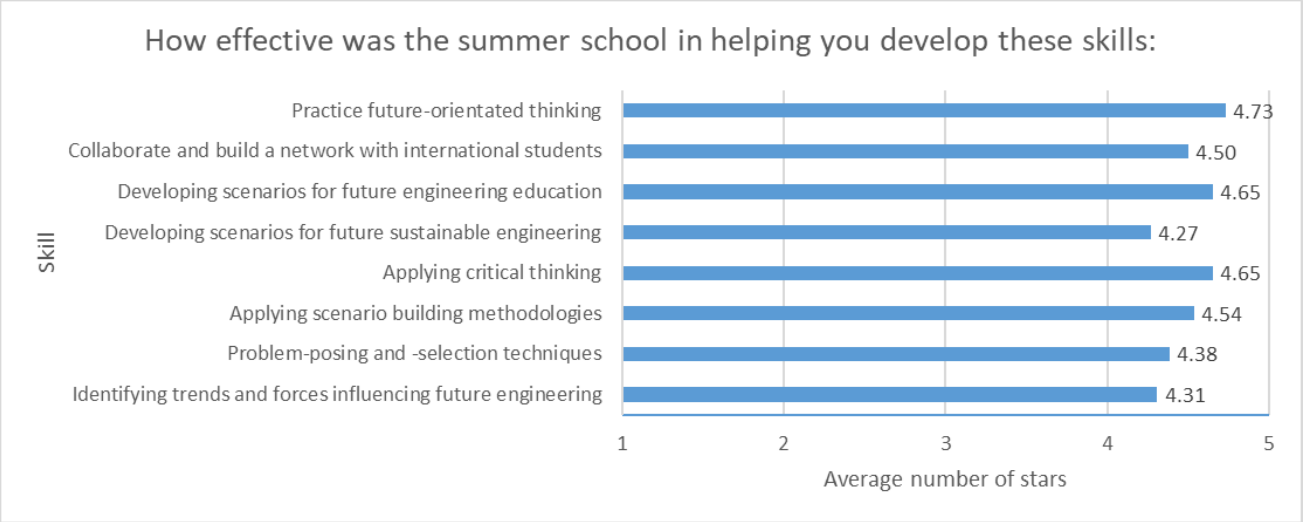

Figure 2: Average student response score for effectiveness of Summer School in reaching goals.

Overall participants felt the participation in the Summer School helped develop many skills and when asked specifically, which skill was developed in particular, there was significant mention of Critical Thinking, Future Orientated Thinking, Teamworking and Scenario building. These are all skills which were identified earlier in the project as being important for the future and hence shows the effectiveness of this learning and teaching activity. However, one student also recognised the importance of being involved in such initiative in order to help improve confidence overall.

> "I learnt how to get out of my shell and interact with teachers and students around the world. It helped a lot in increasing my confidence". [P8]

Participants were also invited to comment on the innovative nature of the activity, whether they were exposed to this type of teaching before and particularly what they found innovative. The average score for innovation was 4.2/5 indicating that most participants had not experienced this type of activity before.

Some examples of innovation in the learning and teaching activity included the emphasis on questioning things and on reflecting, learning by doing and working with a diverse team of people. For some it was their first time undertaking this type of group work and for one participant, they felt it was innovative because the contribution of the instructors was minimum allowing them to think for themselves.

Some quotations are provided here as background.

> "I really enjoyed the questions about defining what the future is and when the future is, questioning what makes something realistic, I found myself thinking and looking at these topics from different angles, some questions I never really thought of before." [P14]

> "I found it really effective to brainstorm with diverse people and hear new opinions, more engaging than normal teaching methods" [P17]

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> "I really enjoyed the group work and collaboration which I found innovative. I much preferred this to just listening to lectures. I also found the monster challenge really innovative. I really enjoyed it and I loved having the opportunity to work on a team to create some original ideas." [P10]
>
> "The break out groups were very good, it helped to understand the teaching more when a fellow student explains" [P2]
>
> "The questions asked and lessons learned were very thought-provoking and engaging" [P3].
>
> "It is really innovative, and leave a lot of spaces for students to develop their own ideas/thinkings"[P5].
>
> "Very different from the basic form of learning in school, was able to communicate with new people and find new perspectives." [P24]

Some students had experienced breakout rooms and group work before, but not to the extent of the Summer School and others have had very little exposure to this method of teaching and the emphasis on student directed learning. One participant noted that they had undertaken group work before, but within a student organisation, not in "official" learning environments [P19] whilst another recognised the focus on student centred learning "Not really, previously was more teacher-centered or equal between students and teachers, but this type of teaching has its focus on students own interactions" [P5].

Students were also asked specifically how the learning and teaching activity compared with more traditional teaching methods, in terms of Engagement, Effectiveness and Enjoyability, the results of which are indicated in Figure 3. In the main, the participants found the teaching methodologies employed in the Summer School to be either a little bit more or a lot more engaging, effective and enjoyable.

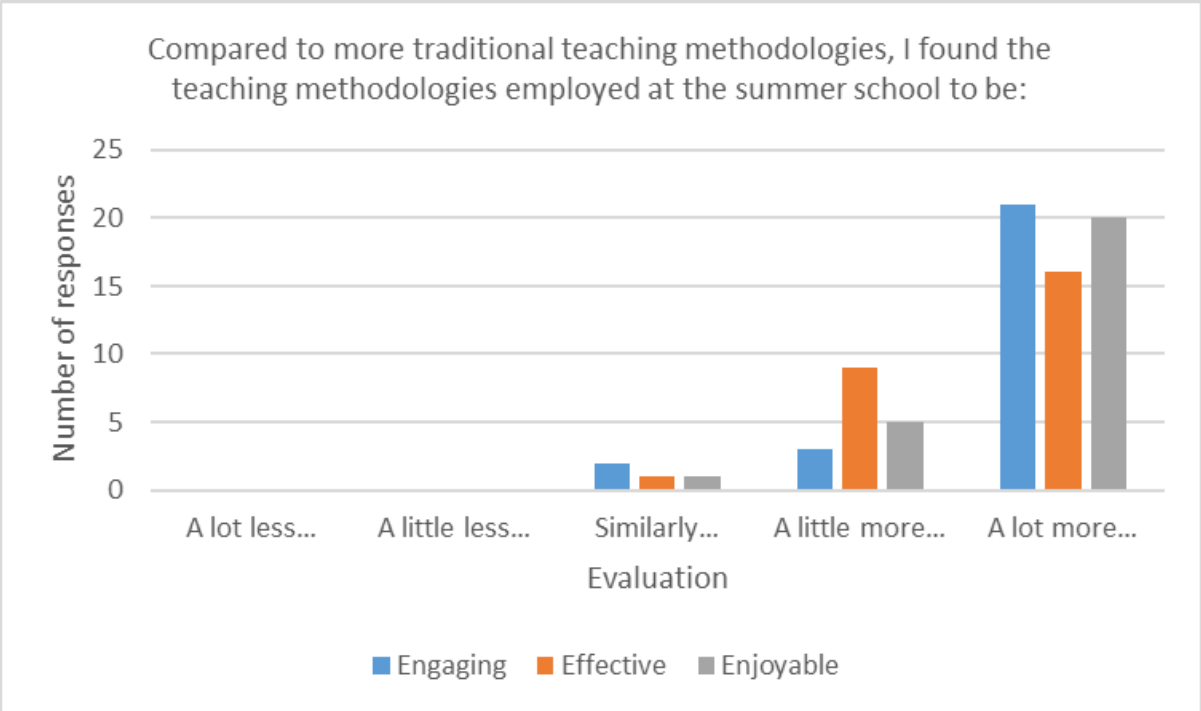

Figure 3: Student responses to question comparing the Summer School with more traditional teaching methodologies

The research team also asked students about their most important takeaway and responses ranged from specific skills they have learned (scenario thinking, future thinking) the diversity of peoples' opinions and

perhaps most encouragingly the acknowledgement that the future is what we make it, that they now feel they have control over it.

> "That working with other people can open your eyes to things you would have never thought about on your own" [P6]
>
> "That people has different points of view in different matters pending on where they are from" [P18]
>
> "The importance of other people's input on ideas and how everyone's point of view is unique and special". [P22]
>
> "Learning with other students will encourage you to come up with ideas that you would otherwise never come up with on your own" [P26]
>
> "That the future can be as near or as far as we want it to be and it is really important to plan for the benefit for future generations." [P8]
>
> "It has helped me think about the future in a more positive way, I now have the mindset that the future is what I make of it." [P3]
>
> "How important it is to think about the future now and to take action now with scenario planning and putting road maps in place to achieve sustainable engineering in the future." [P10]
>
> "There is so much to look forward in the future but also so much to be done also. If we want education to get better we have to start today and the tools we used and learn; the topics we mentioned are a perfect way to start." [P19].

We also asked participants how likely they would be to recommend the A-STEP Summer School to other students. The average score was 9.4/10, but the distribution of scores is also interesting as indicated in Figure 4.

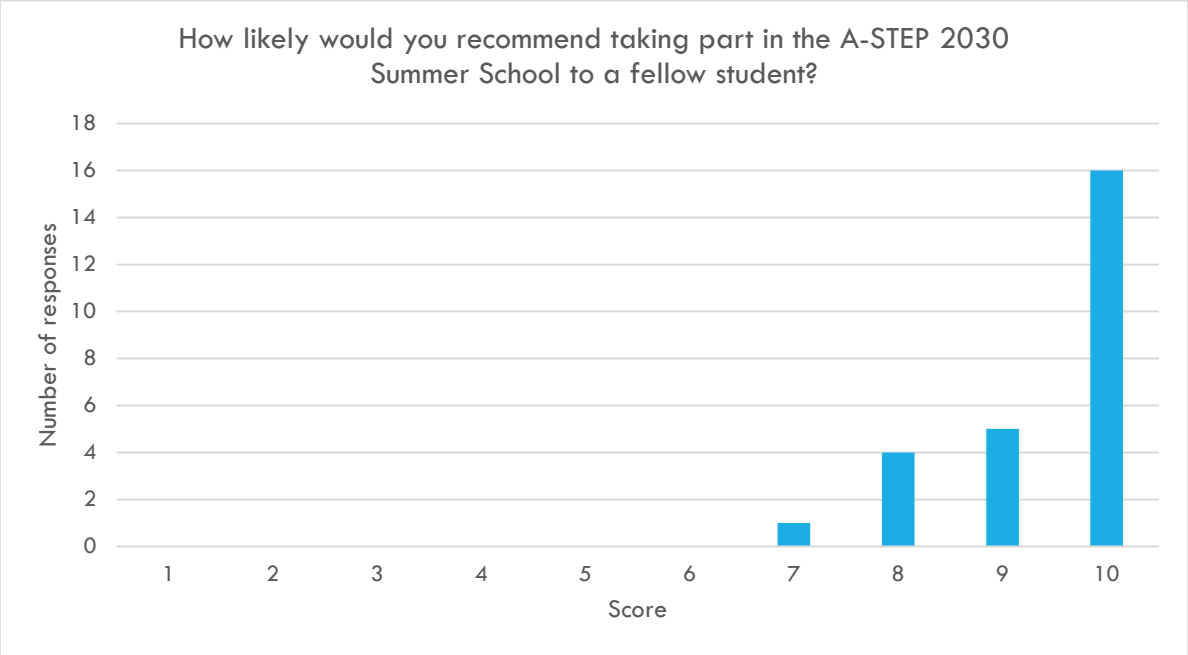

Figure 4: Responses to question "How likely would you recommend taking part in the A-STEP 2030 Summer School to a fellow student?" (Score 1-10)

Explanatory Note:

The Net Promoter Score ® (NPS) is calculated based on responses to a single question: How likely is it that you would recommend our company/product/service to a friend or colleague? The scoring for this answer is based on a 0 to 10 scale. Those who respond with a score of 9 to 10 are called Promoters, and those people are most likely to sincerely enjoy and promote the service. Those who respond with a score of 0 to 6 are labelled Detractors, and they are most likely to have a negative experience with the service and disapprove the service if asked about it. The ones which score 7 or 8 are neutral and by norm should not promote nor discourage the usage of the service.

As seen in the graph above, 16 participants responded 10 and 5 participants responded 9. Therefore, there are 21 Promoters. No participants attributed a score below 7, therefore, there are no Detractors. Dividing the difference of the Promoters (21) and Detractors (0) by the total number of respondents (26) yields the Net Promoter Score: 81%. Bain & Co. (2021), the source of the NPS ® system, suggests that above 80% is world class.[1]

The final section of the feedback questionnaire was to engage participants in feedback which could assist in designing the next iteration of the Summer School. Overwhelmingly, participants highlighted the request to meet in person in order to form stronger bonds with other students. Some participants noted the importance of having cameras turned on to help engagement in the groups. Each group remained intact during the Summer School, and it was recommended that groups be mixed up to enable students to get to know more participants. Others suggested that the Summer School be extended to 5-6 days with a 3 hour session each day so that groups had more time to work on their activities between sessions. Finally, participants noted that there were different levels of English ability throughout and thus the published presentations along with written notes explaining what was required were helpful to those students who have differing English competence. Overall, there was a clear wish from participants to network and meet other students, they very much enjoyed this opportunity which would have been enhanced with a physical Summer School activity. Their responses to the questionnaire (both qualitative and quantitative) indicate that they felt there was value in this experience in the learning and teaching pedagogies used and that they came away with a sense of action about the future and a positive mindset about the Summer School.

> "The entire summer school was perfectly thought out and used so many strategies to help us develop, and I can't think of a single thing to change. It was an absolutely wonderful experience." [P22]

6.0 Conclusion

One of our aims was to educate future engineers with new and better teaching approaches to support the development of a more sustainable future society. An overall goal for the IO3 was to discover and analyse existing experiences and identify best practice in engineering education, which matches future skills and competences needs as well as meeting the students' mind-set and expectations. This learning and teaching activity has shown success in not only using future thinking and scenario writing as an innovative teaching approach, but also one that is appreciated by students as preparing them to create a sustainable future in their career as engineers.

[1] *"Net Promoter®, NPS®, NPS Prism®, and the NPS-related emoticons are registered trademarks of Bain & Company, Inc., Satmetrix Systems, Inc., and Fred Reichheld. Net Promoter Score℠ and Net Promoter System℠ are service marks of Bain & Company, Inc., Satmetrix Systems, Inc., and Fred Reichheld." https://www.netpromotersystem.com/*

7.0 Acknowledgements

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