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The SARENA Programme: Master's degree studies in nuclear engineering combining different educational and cultural environments

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A B S T R A C T

Within the SARENA programme, students from different parts of the world have the opportunity to obtain a Master's degree in nuclear engineering by participating in a two-year curriculum combining academic programs in France, Spain, Finland and Slovenia (depending on the selected study track). The concept and organization of the SARENA programme are described. The experience from the first four cohorts is presented and assessed both quantitatively and qualitatively. So far, the programme has mostly fulfilled expectations. As the students went through a very selective admission process, their mostly satisfactory academic performance was expected. An additional aspect was the cultural interaction between SARENA students and their new educational environments.

1. Introduction

Although the advent of globalisation seems to be felt mostly in the world economy, it affected also other fields of human activity. Specifically, in the field of engineering education, new ideas about the benefits, as well as the necessity of sudents moving between educational institutions in different countries have appeared and been discussed (Irandoust and Sjöberg, 2001; Borri et al., 2007; Diaz Lantada and De Juanes Marquez Sevillano, 2017). The relaxation of rules that in the past made students moving between different European countries very difficult (in administrative terms) and the harmonization of the systems of higher education (essentially universities) have finally created a favourable environment to develop opportunities for students to combine studies in different countries, with the possibility of moving each semester. The SARENA (Safe and Reliable Nuclear Applications) programme (2018–2024) was proposed and accepted within the European Commission's Erasmus Mundus programme with such a purpose. Namely, the following objectives are stated in the Erasmus+ Programme Guide devised in 2017 (European Commission, 2018; when the SARENA programme was conceived before being submitted and accepted) considering education:

- improve the level of key competences and skills… in particular through increased opportunities for learning mobility;
- foster quality improvements, innovation excellence and internationalisation at the level of education and training institutions, … in particular through enhanced transnational cooperation…;
- enhance the international dimension of education and training…

In addition, ensuring equal access and opportunities to participants from all backgrounds is stated as well among the principles of the Erasmus+ actions.

Within the SARENA programme, students from many parts of the world are offered the opportunity to complete a master programme in nuclear engineering in two different tracks, related respectively to radioactive waste management and nuclear reactor operation. Within the programme, students are awarded scholarships. However, the programme is also open to self-financing students as well.

During the two-year studies programme, students combine educational stays in the following higher education institutions (depending on the selected track): Institut Mines-Télécom Atlantique (IMT, Nantes, France, programme coordinator), Universidad Politécnica de Madrid (UPM, Spain), LUT University (Lappeenranta, Finland) and University of Ljubljana (UL, Slovenia). Thus, not only do the students pursue their

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studies at different institutions, but also in different European cultures (although, for students coming from outside Europe, the differences between the stated European cultures are much smaller than the difference between their original and any European culture).

The first cohort of students enrolled in the fall of 2019, whereas the last one (that is, within the current programme) enrolled in the fall of 2022. Thus, three cohorts have completed their two-year programme (and many of them also their master's theses defense), whereas the last cohort is currently in the middle of their studies.

The concept, content and organization of the SARENA studies are described first. Then, the quantitative outcomes of the first four generations are presented. Last, some general qualitative observations are offered and commented.

2. Curricula

Admission to the Joint Master Degree SARENA programme may be granted to persons holding academic degree of at least 180 ECTS (European Credit Transfer and Accumulation System) credits (bachelor's degree or equivalent) in engineering, physics, chemistry, environmental sciences, or sufficiently similar studies. The SARENA programme is fully taught in English and consists of three complementary semesters followed by one semester dedicated to the thesis project, to be completed in the industry or within a research laboratory.

There are two tracks (therefore, two different mobility paths across different countries):

- Track A: RWMD (Reactor Waste Management & Decommissioning) provides the following nuclear knowledge:
  - scientific and technical knowledge for managing nuclear waste projects and competencies for dismantlement and decommissioning of nuclear installations;
  - competencies to master operational techniques and strategies for whole project lifetime.
- Track B: NROS (Nuclear Reactor Operation & Safety) provides the following nuclear knowledge:
  - basic knowledge necessary for understanding nuclear energy production (power reactors) and industrial applications;
  - competencies in reactor operation, maintenance and safety issues, including radioprotection;
  - competencies in nuclear modelling necessary for demonstrating the behaviour of nuclear systems in normal and abnormal situations;
  - competencies in nuclear radiations applications: instrumentation, non destructive control, security, …

The first semester is common to both tracks, and takes place at IMT Atlantique. The curriculum consists mostly of physics and engineering, needed in all aspects of nuclear engineering. The second and third semester are more oriented towards the respective track specifics. For track A, the second semester takes place at UPM Madrid, and the third semester again at IMT Atlantique. For track B, the second semester takes place at LUT Lappeenranta and the third semester at UL Ljubljana. Upon successful completion of the programme, the student completing the RWMD track is awarded a dual-degree from IMT Atlantique and UPM Madrid, while the student completing the NROS track is awarded a dual-degree from LUT Lappeenranta and UL Ljubljana. This concept of "double diploma", not only from different educational institutions but also from different countries, has already been adopted in another engineering field (Smieja et al., 2007) and probably also in others. In this, it follows the trend of providing graduates with more universal and visible recognitions of their achievements, of which, in the field of nuclear education, the European Master of Science in Nuclear Engineering (EMSNE), delivered by the European Nuclear Education Network (ENEN) Association, is also an example (Safieh et al., 2011; Cizelj et al., 2018).

3. Financing

The SARENA project has been granted 3.35 M€ in total to finance four consecutive intakes of students (66 scholarships in total), as well as the running costs. The agreed distribution of the 66 scholarships over different countries should be the following:

- Twelve (12) scholarships for candidates from so-called "programme countries": the 27 EU countries, North Macedonia, Iceland, Liechtenstein, Norway, Serbia, Turkey and the UK.
- Forty-eight (48) scholarships for candidates from so-called "partner countries" (all countries except programme countries).
- Six (6) "special scholarships" for candidates from so-called "targeted countries": Armenia, Algeria, Azerbaijan, Belarus, DPR Korea, Egypt, Georgia, Indonesia, Israel, Jordan, Lebanon, Libya, Malaysia, Maldives, Moldova, Mongolia, Morocco, Palestine, Pakistan, Philippines, Sri Lanka, Syria, Thailand, Tunisia, Ukraine and Vietnam.

In addition, in each cohort, no more than 3 (three) students could be selected from the same country.

Students who did not wish to apply for the Erasmus Mundus scholarship or who have not been selected to receive it could apply for the SARENA programme as self-funded (with their own funds or with some other scholarship).

4. Analysis of programme outcomes

Contrary to the assessment of successfulness of usual courses, where a high number of students coming mostly from similar educational and cultural backgrounds are enrolled in studies within a single educational institution, the assessment of the SARENA programme has the following peculiarities:

- students come from very different educational and cultural backgrounds;
- students attend educational institutions in different European countries (with cultural differences of their own, although, being all European, much smaller than the differences from students' original cultures);

In analysing the outcomes of the SARENA programme, two additional facts should also be taken into account. The first fact is the relatively small number of the sample (63 students were accepted altogether for the four intakes). This prevents making a detailed analysis that would take into account the combinations of selected study tracks, origins of students, genders…, but allows consideration of only a single parameter at a time.

The second fact is that the programme is still going on. That is, students from the 2021 intake have completed their regular studies in June 2023. Thus, many of them have not yet graduated (i.e., completed their master's theses) although they are studying regularly. Also, the 2022 intake has just started their second year. As this prevents a comprehensive analysis of the success of the programme, the presented analysis should not be taken as definitive.

4.1. General analysis of acceptance and success

The initial intention was to accept approximately the same number of students in both tracks, and this was achieved (Fig. 1). However, it appears that there was much more interest in the NROS track than in the RWMD track. This may be attributed to the educational background of the candidates, as the curriculum of track NROS is much more in line with the customary curricula of engineering and physics studies.

The figure also shows that it took time for the programme to become sufficiently known - the number of the applications in the first year was

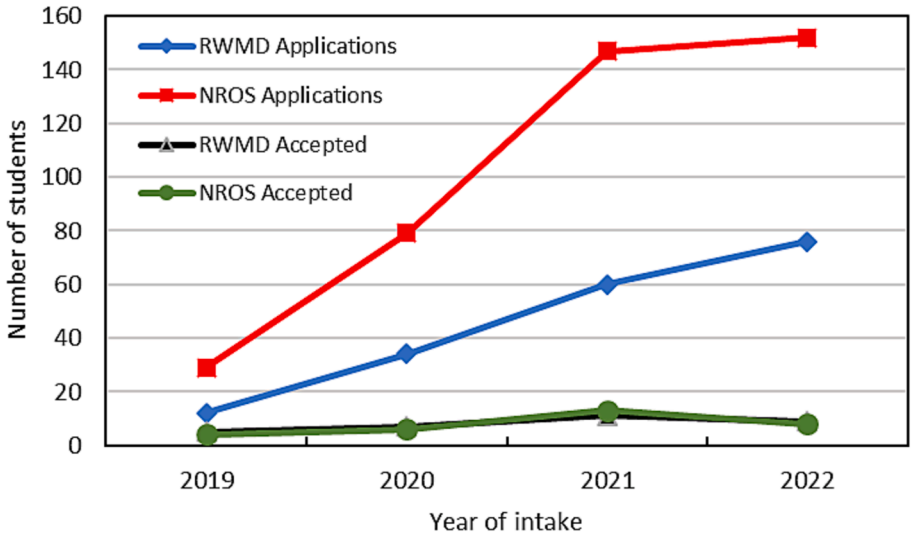

Fig. 1. Applications and acceptance by tracks (4 intakes: 2019—2022).

indeed very low. However, it seems that in the last two intakes (2021 and 2022), some kind of "plateau" was reached, probably as the programme gained reputation, when the number of applications is sufficient to accept, through a process of rigorous selection, only capable students who will be able to complete the studies programme without major problems.

The general impression from considered applications was that students are mostly highly-graded and ambitious, and are committed to pursuing further studies. Most students are from engineering (mechanical, electrical and chemical) and physics backgrounds.

As already stated, it is difficult to judge the success of the programme, as it is still going on. In Fig. 2, students who have graduated within one year after the completion of their two-year studies are taken into account (these figures are of course somewhat inconsistent, since many students from the 2021 intake will also fall into this category later). As it was expected, for the first two intakes (2019 and 2020), the number of students who have graduated follows closely the number of accepted students for both tracks; the difference is at most two students, almost always because it took some students more than one year after the completion of their two-year studies to finish their master's thesis. As to the intake of the year 2021, the reasons for the difference is that many students (especially in the NROS track) are currently still working on their theses. Nevertheless, these numbers show that the SARENA programme is mostly going on as expected.

4.2. Analysis by world regions

To divide the world into regions, which will be meaningful not only geographically but also culturally, is difficult, as there will always be some significant differences within the same region. However, an attempt was still made, to see whether any particularities might appear.

The following regions were defined, based on some common classifications in other topics:

- EU, other programme countries (see above), Western Balkans, Neighbourhood-East, Russian Federation: "European continent" (EC);
- Middle-East & North Africa (MENA);
- Asia, including Central Asia (ASIA);
- Sub-Saharan Africa (SSA);
- Latin America and Caribbean (LAC);
- US, Canada and Pacific (USCP).

One should also be reminded of the limiting conditions, described earlier for the origins of students, so that the results of acceptance were not based solely on the applications but were also constrained by the described rules. However, there was no restrictions on the number of applications. Fig. 3 clearly shows that most applications were submitted by students from Asia (which is, among the considered regions, probably the most diverse culturally). After Asia, the second region is sub-Saharan Africa. Compared to these two regions, the numbers of applications from all other regions are much lower (especially from US, Canada and

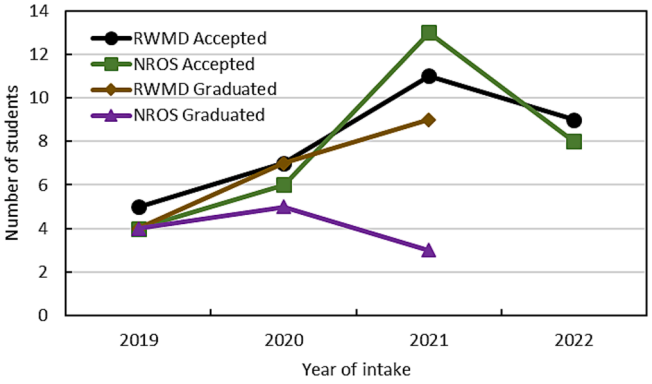

Fig. 2. Accepted students and students who have graduated within one year after completing their two-year studies (3 intakes: 2019–2021).

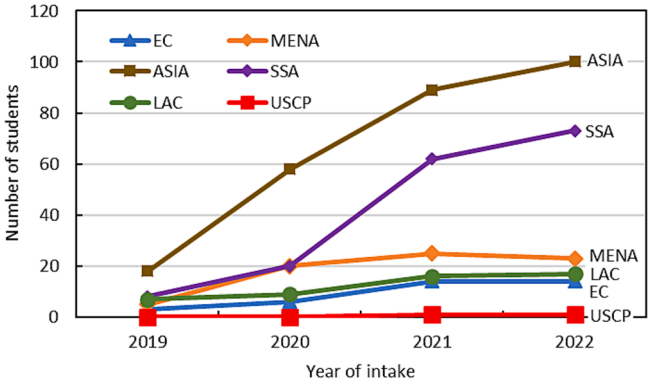

Fig. 3. Applications of students by world region.

Pacific, where students are apparently not interested in studying nuclear engineering in Europe or have already better opportunities). These figures probably reflect the general differences in ratios of ambitious (though not necessarily capable) young people and opportunities available to them. One should also notice the relatively small interest from the European continent. Within the considered regions, a predominance of applications from students from countries with developing or planned nuclear programs was observed.

Whereas applications were open to all, the acceptance was based on the evaluation of students' capabilities as assessed from the submitted documents and, as already stated, on some constraints. As a result, the number of accepted students from Asia for the four intakes is not so dominating anymore, although relatively still higher than the number of accepted students from sub-Saharan Africa. Latin America and Caribbean had the highest acceptance ratio (0.31), whereas sub-Saharan Africa had the lowest one (0.06). The acceptance ratio for the European continent is 0.22, and Asia and Middle East & North Africa have very similar ones (0.09 and 0.08, respectively), which is an interesting feature (in the cultural sense). The numbers for US, Canada and Pacific are much too low for such analyses.

As already stated, the evaluation of the success of the students is difficult, as the SARENA program is still going on. As in Fig. 2, the number of students from the first three intakes who have graduated within one year after the completion of their two-year studies is shown in Fig. 5 by regions (again, the numbers are somewhat inconsistent, since many students from the 2021 intake will also fall into this category later). Contrary to Fig. 4, the numbers here are much lower, so that the calculated success ratios are not as indicative. Nevertheless, one may notice that, for now, Middle East & North Africa has the highest success ratio. The other ratios are more or less comparable (again, due to the low numbers). As before, the numbers for US, Canada and Pacific are much too low for such analyses.

4.3. Analysis by gender

In the selection process, there was no intention or policy of gender balance. However, as nuclear has a reputation (whether deserved or not) of being a "male" field, the analysis of gender may offer interesting insights. Fig. 6 shows the number of applicants and students by gender. The number of male applicants consistently dominates the number of female ones (this is also the reason why, in this section, males are considered before females). However, when it comes to the number of accepted students, there are no significant differences, except for the first intake. In that intake, the total number of applicants was low, and that should also be the reason for no female students. As to later intakes, the sample is too small to analyse the small differences between the number of male and female students. Nevertheless, these numbers suggest that, in the future, nuclear will not be so "male-dominated" field as it is now.

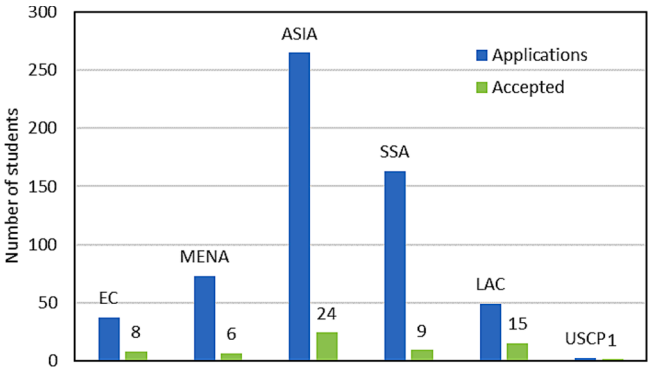

Fig. 4. Applications and acceptance of students by region - all four intakes (2019—2022).

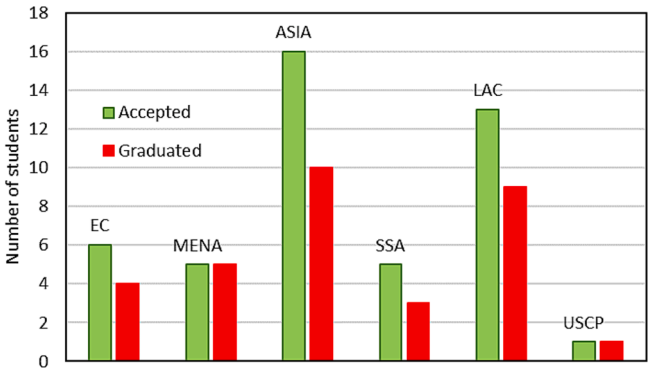

Fig. 5. Acceptance and success of students by region - first three intakes (2019–2021).

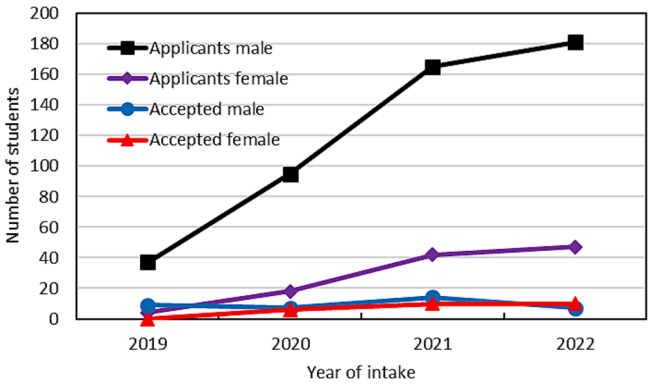

Fig. 6. Applications and acceptance of students by gender.

As to the success, if we group together the 2nd (2020) and 3rd (2021) intake, and exclude the 1st one (2019), which is not gender-representative, and taking the same criteria as before, 13 out of 21 male students, and 11 out of 16 female students have graduated (Fig. 7), meaning that the graduation ratio of female students (0.69) is slightly higher than the ratio of male students (0.62), as much as these ratios can be compared due to the small sample.

5. General comments about students and studies

5.1. Selection of accepted students

In the past, preparing and submitting the complete documentation for some selection process was a tedious task, so this functioned as a kind of first filter. However, since the advent of modern computer hardware

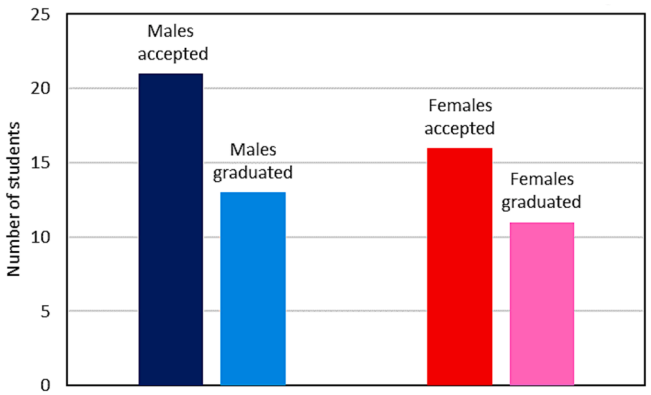

Fig. 7. Acceptance and success by gender (2020 and 2021 intakes only).

and software, as well as on-line submissions, this process has become much simpler. Also, once candidates have prepared scans of their documents and other required documents, they can use them repeatedly. As a consequence, candidates (apparently) submit applications to many different programmes. In SARENA, some of the candidates who were selected for this (supposedly) coveted programme declined to join it, probably because they were also accepted in some other programme that was more attractive to them. After this occurred in the beginning of the programme, this was remediated by first making a long-list of accepted candidates that was later finalised after candidates confirmed that they will join the programme.

Also, we sometimes had the impression that a few students were not really interested in the nuclear field, but only looked for an opportunity to study in Europe. So, the issue was how to discern the "right ones"? So far, this issue has been addressed by putting very much attention to the motivation letter and its coherence with the past activities presented in the submitted academic transcripts. For the last intake, the examination of the submitted documents was complemented by on-line interviews with long-listed candidates.

5.2. Ability to follow curricula

In general, students have successfully integrated into university curricula. Specifically, students mostly have a sufficient level of knowledge (and of English) to pursue their studies. They did not lag behind their "home" colleagues and, in some cases, even proved to be more conscientious. Students have also successfully switched between different universities and different European cultures. All of this was in fact expected, as the selection was quite rigorous due to the high number of applications and the limited number of available places. On the other hand, a tendency to have less experience in scientific work on computers was observed for students from less developed countries. This will undoubtedly influence the future expectations of teachers from these students (although it should not lead to lowering standards). However, for these students, the gaining of such (additional) experience is also one of the side benefits of enrolling in the SARENA programme.

5.3. Cultural interaction

Culture of the original environment definitely influences human behaviour (Hall, 1977; Rapaille, 2007). As most of the students come from Africa, Asia and Latin America, they had to adapt to European cultures with which they were not familiar. And then, even when changing educational institutions within Europe, students still faced different cultures, which necessitated further adaptation. Thus, the candidates needed also a different set of skills, a matter that has already been discussed in the literature (Fernandez-Sanz et al., 2017). The (alleged) possession of such skills was also favoured in the admission process, as significant grades could be assigned for prior inter-cultural experience as well as for active participation in extra-curricular activities. So far, no acute problems have been noticed and many students have reached excellent results. On the opposite side, the SARENA programme offered their teachers and European fellow students the opportunity to engage with students from very different educational and cultural backgrounds. Thus, teachers learned to be aware of different cultural backgrounds to sometimes understand some unexpected reactions. Although all students exhibited their own specific features, with some being indeed excellent, a few (less than 5 %) had lower performance and did not care much about the quality of their work.

5.4. Influence of covid-19 pandemic

A significant influence was of course the covid-19 pandemic. In spring 2020 (1st intake, 2nd semester), autumn 2020 (1st intake, 3rd semester and 2nd intake, 1st semester) and spring 2021 (1st intake, internship and 2nd intake, 2nd semester), most lectures and consultations took place on-line. In addition to limiting contact with the teaching staff, this also limited one of the purposes of Erasmus Mundus, that is the interaction between different cultures. On the positive side, not much impact on the level of students' acquired knowledge has been noticed. Also, this situation enforced the implementation of novel tools needed for online teaching, e.g. development of student labs on virtual machines to be piloted by Web interface, which proved beneficial even after the end of the pandemic.

6. Conclusions

The Erasmus Mundus Joint Master Degree SARENA programme has so far shown to be a successful international and intercultural studies programme. Students from all over the world (from Asia, Africa, Latin America, Europe) have enrolled, with currently the third cohort nearing completion of their studies and the fourth being in the middle. On the opposite side, universities taking part in the programme have also been fulfilling their part, essentially successfully coordinating their educational activities. A comprehensive analysis will be performed at the end of the project, where the benefits as well as the drawbacks of this innovative educational concept will be assessed. This analysis, as well as the overall experience of running this innovative programme, shall be used to improve the implementation of the programme for its second iteration (2023–2030), which follows the recent evaluation and approval of the programme by the European Education and Culture Executive Agency.

CRediT authorship contribution statement

Ivo Kljenak: Writing – original draft, Formal analysis, Conceptualization. **Abdesselam Abdelouas:** Writing – review & editing. **Manon Desmytter:** Data curation. **Francisco J. Elorza:** Writing – review & editing. **Eduardo Gallego:** Writing – review & editing. **Andreas Hartnack:** Writing – review & editing, Data curation. **Christoph Hartnack:** Writing – review & editing. **Juhani Hyvärinen:** Writing – review & editing. **Juhani Vihavainen:** Writing – review & editing. **Iztok Tiselj:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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