Innovative Engineering Teaching Unit in International Context

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ABSTRACT: This communication is intended to disseminate the first learnings and outcomes of an Erasmus+ Strategic Partnership project (2018-1-DE1-KA203-00423) realized between Sept. 2018 and Aug. 2021 by 4 European applied science universities. The *InT#Tech (International Transfer of cooperative study programmes in Europe: Scientific expectations, challenges and potentials)* project's aim is the development of an international module for coop-students (apprentices), focusing on the digital transformation of engineering, i.e. the use of massive electronic data in design, manufacturing, mobility and facility management. After comparing the different models of coop-studies and identifying common requirements among the partners, after achieving a first level of cooperation during a Summer School, the most challenging task of the project was to imagine, develop, implement and analyse the execution of an innovative teaching unit, constituted of autonomous and supervised work, individual and team-based tasks in international context, theory and practice, distant and local lectures, academic and industrial inputs, so as to be able to grant ECTS credits to the participating coop-students. The paper includes recommendations to universities willing to implement a similar programme.

Keywords: Coop-education, International context, Digital transformation, Massive data.

1 INTRODUCTION

The digital transformation of society is now obvious to everybody, even the elderly. Online shopping, banking, service sourcing and even interaction with the public administration have become the standard. In engineering, virtual reality is used to optimize the performance of future products based on their digital mock-up, while augmented reality increases the information carried out by physical artefacts of the real world. The physical and the digital worlds interact with each other more and more, under the concept of the digital twin. Products, vehicles, machines and facilities are all affected. In industry, robots take over the tasks in smart factories, manufacturing execution systems control the planning and supervision of automated processes distributed onto flexible cells monitored by smart sensors. The industrial world is focused on digital transformation. In this context, universities try to train the engineers of tomorrow, so that they can meet the upcoming demands in industry: "Skills 4.0". Many countries, especially across Europe, opt for the concepts of coop-education in higher education. This special system, combining academic lectures and industrial experience has great future potential for all stakeholders: companies, students, universities, but also for the territories where this happens. For companies, coop-study programmes are a response to demographic change and skilled worker shortages. For students, coop-study programmes offer practice-oriented higher education combined with paid work in companies and valuable evidence of experience. For universities, it offers the opportunity to develop new study programmes and curricula tailored to the regional needs. Regions increase their attractiveness for young people, if a branch of a coop-university in close connection with local companies is available. The globalization of companies however results in a new challenge to internationalize coop-programmes. It may seem easy to develop joint international programmes among universities in this context, since coop-study programmes are generally not controlled by the central education policy, but rather by regional cooperation between universities and industry. However, the first tasks of the Erasmus+ *InT#Tech* project, revealed many challenges.

2 INTERNATIONALIZATION OF COOP-EDUCATION CHALLENGES

2.1 Coop-education in engineering

The steps to implement dual study programmes and the cooperation between companies and academia are different in different countries. In Europe, 3 models of dual study currently predominate. Dual programmes with a work experience component combine a course of study with extended practical phases with an employer. Students obtain a university degree, but not a recognised vocational qualification. A dual programme with employment component is primarily aimed at people who have already done vocational or professional training and/or already have a number of years of professional experience. It is designed to offer further professional development and combines a course of study with professional experience that is directly relevant to the academic contents. Students can enrol on this type of course without a general university entrance qualification. A dual programme with training component combines a course of study with training in a recognised occupation. In addition to the degree, students will obtain an official vocational qualification. In this model, the cooperation between academia and companies is increased. This is the model considered in the current communication, especially at the Bachelor 3 or Master 1 levels, when both

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the academic profile and the vocational skills have reached a sufficient level of maturity for considering internationalization.

2.2 Internationalization of coop-studies

Independent of the study model, there are several difficulties in developing and implementing coop-courses of study at the international level. On the one hand, the period that students spend abroad has to be discussed not only within universities, but also with participating companies. This results in several constellations between universities and companies in different European countries. A suitable cooperation model must be found in each case and be regulated in a compatible manner by a cooperation agreement. In addition, students must consider the requirements and expectations of their company in their homeland when choosing their stay abroad. Not all companies show an interest and understanding for stays abroad of their dual students. They may fear uncontrolled outflow of professionals and intellectual property. The duration of the stay abroad in the dual study programmes is usually limited to a few weeks. As a result, the students are overwhelmed with the theory phase, but above all, with the very intensive practical phase. Another problem is the financial aspect of the students' mobility. There is currently no special scholarship programme across Europe tailored to the needs of coop-students. Another relevant point is the recognition of academic achievements from abroad. Again, there is no standardized procedure at the EU level, except the ECTS (European Credit Transfer System). Furthermore, there are significant differences between universities in terms of rhythm of alternation and teaching agenda. International cooperation requires synchronization.

2.3 Comparison of 4 European partners' models

Before trying to implement a teaching unit in collaboration, it was necessary for the partners to understand the others' models of coop-education so as to identify obstacles and opportunities. Two project tasks were dedicated to this purpose. The first one was focused on identifying the coop-study models themselves, the second one was focused on the comparison of the cooperation models between companies, universities and students.

2.3.1 Coop-study models

The coop-study models among the partners of the project highly depend on the maturity of coop-study models in the country or in the region where it is observed, as well as the experience of each partner in implementing it. While dual education is a strong tradition in Germany [1], especially in the Baden-Württemberg Land (34,000 coop-students per year at DHBW), while also it is well established in Engineering Higher Institutes in France [2], following the "Decomps report" in 1989 and the initiative, in 1990, of the ITII network (Institut des techniques d'Ingénieurs de l'Industrie: 2500 graduates per year), it is only emerging at Heriot-Watt University (Scotland) [3] and in Metropolia (Finland) [4]. So as to perform a precise analytic comparison of the 4 partners, several topics were listed in the lines of a large spreadsheet and filled like a questionnaire by each partner. The topics headlines include: identity, legal framework, economic model, financial support, relationship with the government and with the region, impact on the economic development of the region, available data and surveys, insertion of the former students on the labour market, specificity of coop-training models, alternation rhythm, quality and checks, staff, international mobility… This comparative analysis was extremely useful for the partners, as a kick-off survey, mainly to confirm the variety of approaches, but none of the topics was susceptible to be adjusted by any partner to improve the ability to cooperate with each other, since the constraints generally have an external origin.

2.3.2 Cooperation-with-industry models

So as to encompass all the aspects of a coop-student's programme, the student *journey* according to a Life-Cycle Assessment approach was used: each life phase was analysed separately, so as to iteratively collect all the relevant specifications. Here, for each phase of the coop-student journey, each partner was asked to describe the role of its university, the role of the coop-student and the role of the company, in the execution of the whole process, from being recruited to becoming a practitioner and possibly a mentor.
The life phases of a coop-student include: (1) being recruited: application by candidate coop-students and selection process, (2) being trained: learn theory / learn practice / learn internationalization, supervision method / communication method among the 3 stakeholders, (3) progression and graduation: assessment of teaching units, ~practice, ~sessions, ~semesters, ~graduation, (4) joining the labour market: exerting the engineering job and, optionally, becoming a mentor in turn.

fig 1 : Life phases of a coop-student

After collection and synthesis of copious data from the 4 partners, the 4 models were evaluated in 2 ways: (I) and (II).
(I) the models were compared two by two to highlight similarities and differences that may impact the ability for the partners to collaborate, in the scope of internationalization of programmes. An example is showed hereafter, according to the life-cycle phase "being trained", sub-item "teaching theory".

Partner	Student's role	Company's role	University's role
DHBW	Attend class 24 W/Y	Teach 60 % of courses	Teach 40 % of courses
INSA HdF	Attend class ½ W	Teach 20 % of courses	Teach 80 % of courses
HWU	Attend class 1 day/W		Teach 100 %
Metropolia	Attend class 28 W/Y	Teach 20%	Teach 80%

fig 2 : Synthesis model of "teaching theory"

Estim. similarity	DHBW	INSA HdF	HWU	Metropolia
DHBW		4	2	2.5
INSA HdF	4		2	1.5
HWU	2	2		1
Metropolia	2.5	1.5	1	

fig 3 : Model comparison of "teaching theory"

In fig 3, the values indicated correspond to the average value of a cross evaluation: Estimated similarity = ½*(similarity estimation of A considering B + similarity estimation of B considering A). 0 means "completely converse" and "5" means "identical".

(II) based on a list of criteria that universities, students and companies wish to satisfy at most, the performance of each model was evaluated by the other 3 partners (and by self, for comparison purposes), so as to foster the emergence of recommendations to universities willing to implement international coop-programmes. The following short list of criteria was selected: (for universities) increase the number and quality of students, increase the number of collaborations with companies; (for companies) increase the appeal for new talents, increase the quality of staff and corporate knowhow; (for coop-students) increase their own qualification and employability (experience), increase their monetary benefit (higher salary, reduced fees). The average evaluations of how each model item impacts on the 6 criteria was reported on radar graphs. An example (extract) is shown hereafter, comparing the impact of the "teaching process" of DHBW and INSA-HdF upon the 6 satisfaction criteria. The industrial opinions were collected from practitioners involved in the teaching activity within our 4 universities.

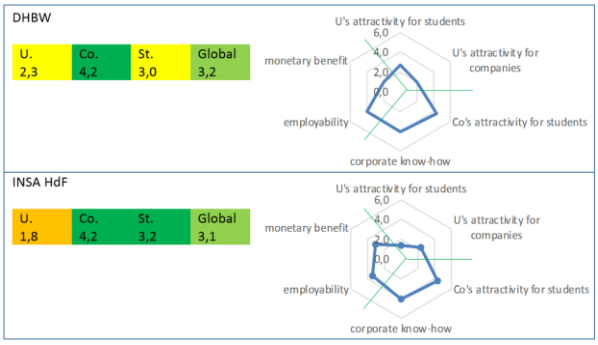

fig 4: Compared impacts of teaching processes

The scores on the radar graphs in fig 4 are to be interpreted like this: 5 means that the model has a strong positive impact on the criterion. The number 0 means that the model has no impact at all on the criterion. The scores do not at all correspond to a value judgement about the partners. Nor do they intend to suggest any ranking. If university A gets a score near to 5 on a criterion, while university B gets a score near to 0, it does not mean that university A is performing better than university B. The context, the regulation, the constraints existing or not in the region or in the country, the financial model, the experience of coop-education are determining what can and cannot be done. The criteria which the authors used to compare their programmes can also be extended or changed. Regarding other evaluation models, the results would look different. A very positive score for an item, however, suggests that the model item can be recommended as good practice for establishing a cooperative study programme, because it provides satisfaction to all the concerned actors (student, company, university). It also means that the cooperation is close. In some cases, close cooperation can cause challenges as well. After comparing all the items and their respective impacts on the satisfaction of the success criteria for universities, companies and coop-students, the consortium was able to synthesize a list of objective recommendations.

2.4 Recommendations

The process of recruitment of coop-students can provide equally high satisfaction to all the parties because every actor has influence on it and can make a decision. The university should decide which student it would like to recruit and with which companies it would like to cooperate. The company should decide which student it would like to train and in which university this student should learn theory. The coop-student should decide which university programme to attend and in which company to be trained on-the-job.

The rhythm of alternation, which is very different in each university, does not influence the satisfaction levels of the theory teaching process. This process mainly influences the university satisfaction. The implication of practitioners in the theory teaching process, which is generalized in every university, seems to be a good practice. The practice teaching process mainly influences the company's satisfaction, since practice is executed inside the company. The best practice seems to have students carrying out projects with increasing difficulty in the company, under close control by a company mentor and the approval of the practice learning programme by the partner university.

The determinant for the satisfaction of all the actors regarding internationalization is the fact that a stay abroad is recommended (or even imposed) by the training programme, with a dedicated period. The student gains a cultural (generally also linguistic) experience, the company improves its corporate expertise in terms of international openness, the university gains attractiveness. The ideal situation is when the placement abroad is consistent with the company's activity and the programmes' major topics.

Good practice in supervision is when the university is involved in the control of the student's activity in the company, by means of regular visits, and when the company is also involved in the control of the student's academic progress in the university and regularly invited to

visit the university, for informative meetings or attendance at student's oral presentations.
Despite different implementations of the communication between actors and different levels of constraints, in the consortium, the coop-student is the key element (student progress is the subject of the exchanges; students generally organize the meetings between the company and the university). The use of an electronic data repository, to ensure the tractability of the exchanges, can be suggested as a good practice.
The maximum satisfaction of all the parties, regarding the practice assessment process is when the practical work is assessed by both the company assessing the work and a written and/or an oral presentation of this work, and the university, based on a report and/or an oral presentation of the work. Self-evaluation by the coop-student may also be recommended, in addition, as a good practice.
Most of the time, the students have no role in the semester validation and graduation process and it is difficult to satisfy their criteria, except by offering them a second chance to pass. The university is the main actor for these processes, which can be sometimes considered as automatic, when based on grades with a pass/fail threshold. The company can gain satisfaction if it is granted a role in the graduation process, for example by participating to the jury.
The impact of the job finding process is not observable at HWU and Metropolia due to the very recent implementation of coop-programmes. In the two other universities, the satisfaction is high for all the parties. Proposing coop-programmes probably benefits the universities in terms of attractiveness. Graduated from coop-programmes is an excellent factor for employability with monetary benefit for students, while companies benefit from experienced new practitioners, on the condition that they can retain them.
Keeping in mind these recommendations, the consortium started to prepare a first level of cooperation regarding the collaborative implementation of an international short educational programme, with teamwork, which was called the "InT#Tech Summer School".

3 FIRST LEVEL: SUMMER SCHOOL

The Summer School was organized at Heriot-Watt University in Edinburgh during the last week of May 2019, just after the local finish week of the semester, so that a lot of constraints could be relaxed regarding the availability of classrooms and accommodation on the campus. This week was also the most convenient for the 3 other partners. The session was open to 5 Bachelor3-level coop-students from every university. 2 professors from each university would participate to give lectures and to provide guidance for the teamwork. The focus of the week was on digital contents in the context of "Skills 4.0". These skills include: work independently in international teams on unknown issues, integrate knowledge into new tasks, work on multidisciplinary issues, use and share their scientific and technical knowledge, use and share their practical experience, improve their presentation skills, reflect on international project management and international cooperation, reflect on the input of digitalisation in technical departments, reflect on their own project. The added value for the participating students is of course to gain new expertise and knowledge, but also to work on innovation and project management and to gain international experience. The agenda of the week comprised lectures, visits (local or in the Region), and teamwork for small groups of mixed students regarding their origin and their skills (industrial engg, automotive engg, electrical engg, facility management and energetics). The working language was of course English.

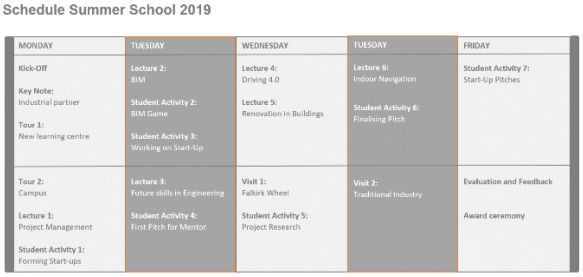

Fig 5: Schedule of the Summer School '19

The lectures were given either in front of the audience or by means of videoconference, highlighting some challenges in modelling, engineering and manufacturing, mobility or energy saving. The visits highlighted local technical expertise and local culture (including the remarkable labs of HWU, a unique boat-lift and a Scotch whisky distillery). The student activities were focused on unsatisfied societal needs requiring technical knowledge and creative thinking. The final half-day was dedicated to the oral presentation of the propositions from the students. The jury, composed of the partner's professors, voted for the most convincing project. The winner team proposed a prototype of real-time car park sharing app for smartphones. This student's project is currently being continued in the scope of a start-up company.
This experience was, obviously, strongly appreciated by all the participants (coop-students and teaching staff), all of them looking forward to continuing the experiment suggested by the InT#Tech project. The topics addressed by the lectures, the mixt of physical presence and online knowledge transmission, the challenge-based teamwork on innovative engineering, the international context with a touch of local culture contributed to this success.
It had nevertheless significant drawbacks: the students could get no official recognition of their new knowledge; the Scottish students and staff were not really experiencing an international event, since the summer school took place in their own university. Moreover, this experiment was financially supported by the project budget complemented with the academic partners themselves. So, the participation (travel, lectures,

visits, accommodation) was free for all the coop-students, but expensive anyway, which is not sustainable in the long term.

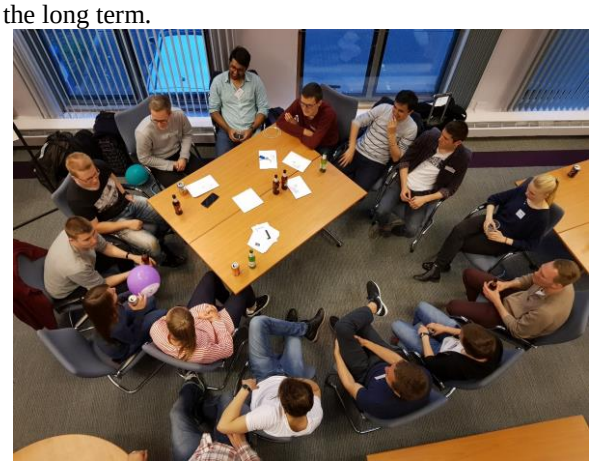

fig 6: Teamwork during the Summer School

Combining the positive features of the Summer School and granting the participants a valuable recognition of the work executed was the challenge of the second level of cooperation: implementing a collaborative teaching unit in international context, with an official recognition.

4 SECOND LEVEL: TEACHING UNIT IN INTERNATIONAL CONTEXT

The requirements were: 5 ECTS for participants who pass the tests, the smallest acceptable reward for a teaching unit within the consortium, a balanced workload between theory and practice, a coherent series of keynote lectures related to the general theme "digital transformation", practical work on outstanding equipment, immersion in the world of work in geographical and technical multiculturalism, assimilation of new knowledge, autonomous work and teamwork, involvement of the 4 institutes, a repeatable scenario and of course a tenable budget. The emergence of the 2020 health crisis brought new constraints and obliged us to think of the whole course as distance learning, which considerably reduced the budget to be allocated to the experimentation. Erasmus+ agreed to consider the period April'20 / April'21 as a "blank year" for the project. The remainder of this paper focuses on the engineering of the module, taking the distance mode as an explicit constraint, which was not the case initially.

4.1 Engineering of the specification for the teaching unit

The experiment was sized to correspond to a typical class of 24 apprentices assembled in 6 international quadrinomials. To justify the award of 5 ECTS, a minimum workload equivalent to 6 to 8 weeks of training was required. But neither the teachers nor the trainees could make themselves available synchronously during weeks in any institute. The very few common intersections of availability in the consortium are in the spring and do not last more than a week (apart from holidays, public holidays and examinations). Therefore, it was decided to mobilise only one week for synchronous teaching, but to spread the duration of the module over two months, so that the workload would be both tenable in an already busy apprentice's schedule, while remaining compatible with the 5 ECTS credits. As the week consists of 5 days for 4 partners, it was decided that each institute should organise one day. A teaching day should combine a lecture and a practical lab involving a remarkable experimental device, generating digital data. A standard duration of 3 hours, for a lecture as well as for a practical lab, was retained, including a median break. The lectures were placed in the morning (9:00 am to 12:00 pm) for a better receptivity of the trainees, and the practical exercises in the afternoon (1:00 pm to 7:00 pm, in two batches of 12 trainees). The fifth day is devoted to giving the floor to representatives of European politics and industrialists close to the consortium's institutes. The first month is dedicated to acquiring the knowledge required to follow the course. The start of the first month and therefore of the course consists of a virtual meeting of a few hours, so that the participants can introduce themselves and the teams can be formed.
The week of the course (fig. 7) is placed in the middle of the experiment.

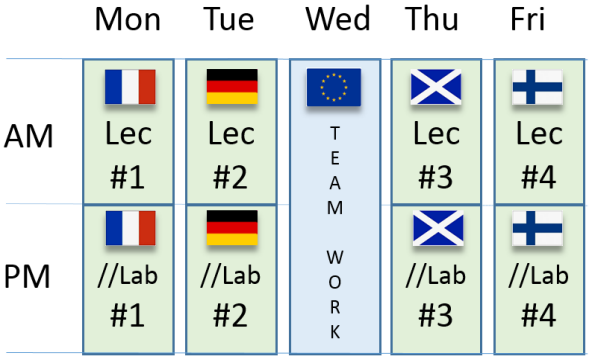

fig 7 : Week of course

The second month is dedicated to the production of deliverables, in the form of posters and written reports. The end of the second month and therefore of the teaching unit consists of a finisher workshop. It was planned to occur in Brussels, but had to be replaced by a distant meeting. Once this framework has been established, the next step was to identify the contents of the course week (themes, resources, organisation and evaluation methods).

4.2 Identification of the teaching unit contents

The search for local teachers who could contribute to the module was different for the course and for the practical labs. For the course, a detailed call for tenders was launched and the offer most consistent with the general theme was selected. For the practical labs, a survey of the most remarkable equipments of the institute was carried out, and the teachers in charge of each equipment were invited to contribute. Thus, a group of potential contributors was quickly identified. Bearing in mind that

one ECTS represents about 16 hours of teaching but that the international week only involves 30 hours of face-to-face teaching, an additional 50 hours of work was therefore required (i.e. 6.25 hours for each of the 8 contributors during the week), either before the week (preparatory work, suggested readings, mainly for the conference), or after the week (reports, mainly for the practical sessions). These requests were passed on to the group of teachers, particularly with regard to the workload constraint, the organisation of the practical sessions (individual tasks or team work or competition between groups), and the method of evaluation, in order to obtain a precise definition of each contribution. For the question of workload, preparatory readings have been chosen for the course. The lecture will start with an assessed quiz on the reading and understanding of the preparatory material. A second assessed quiz will be given after the lecture to check its assimilation. For the practical exercises, the evaluation depends on the teacher. It can be based on a classical presentation or on a written report.
As far as INSA-HdF is concerned, the conference will focus on the impact of Big Data and machine learning in various situations related to production planning and control. As far as the practical lab is concerned, the remarkable devices of INSA-HdF that can be used for a distant practical lab are (1) the sustainable development platform is used for the determination, by means of remote measurements, of a cooling strategy for a building instrumented with more than 1000 sensors, (2) a remote diagnosis device implementing the supervision of controllable breakdowns of a strip unwinding and punching machine. The second one was finally retained because it is more available. The autonomous car and virtual reality equipment, although remarkable, were not selected because they are too difficult to use remotely.

fig 8 : Supporting equipment for labs

From an administrative point of view, a new teaching unit has been created and referenced in the pedagogical information system, so that apprentices can be officially enrolled in this unit and the lecturers and rooms can be officially identified as pedagogical resources. The status of the participating apprentices will be "Erasmus+ incoming students" in short-term virtual mobility. This teaching unit is about to start on 19th April 2021.

5 CONCLUSION

InT#Tech is an exciting European project, giving 4 European institutes the opportunity to develop a replicable and low cost teaching unit on innovative engineering in an international context. The first implementation focusses on the digital transformation of skills needed to meet the current needs of Industry 4.0. The partners compared their respective work-study models and models of cooperation with companies. Despite a variety of situations, leading to many obstacles to the implementation of a mutualised teaching unit, a first level of collaboration was reached with a Summer School, which suggested the characteristics that needed to be maintained. One year later (2 because of COVID-19), the actual implementation of the Teaching Unit is imminent. This experience is largely reproducible, both in face-to-face and distance learning. It can easily integrate new international partners and seems to be fully transposable to other consortia and other themes.

ACKNOWLEDGEMENT

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