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A guideline for planning and implementing an action-based and transnational course in higher engineering education:
A Case for Sustainable Value Creation

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ABSTRACT

This paper outlines a generic guideline for planning and implementing an action-based and transnational course in higher education for training the engineering competencies required in a future dynamic European workplace and economy. This guidance is intended for universities, research and teaching institutes, as well as for

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companies interested in establishing novel teaching concepts by closing the gap between know-how and experience. The guideline will provide suggestions and lessons learned for the realization of an efficient and effective implementation. Important development phases of the guideline are explained through a use case based on a master course, which has been jointly established in cooperation by four European universities. Learning objectives for this course aim at raising the awareness about sustainable value creation by focusing on the development of sustainable and technological innovations with entrepreneurial objectives.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Engineering Skills

Keywords: Guideline for Higher Education, Transnational Teaching and Learning, Sustainable Value Creation

INTRODUCTION

The future working environment of young engineers within the dynamic European society and economy will be coined by mobility, intercultural exchange, and virtual cross-border communication. Future engineers will be more and more required to work in international teams and be able to interact effectively and efficiently with colleagues, suppliers, and customers coming from different countries as well as cultural backgrounds. Moreover, modern digital engineering tools are driving this change in a very fast way. As a result, the training of mobility as well as of transnational and intercultural competencies has become a strong requirement for teaching and learning in higher education. To this aim, the paper outlines a guideline for planning and implementing an action-based and transnational course in higher education for training young engineers towards a future dynamic European workplace and economy. It aims to empower organizations to implement their own action-based and transnational activities by providing highly practical-oriented recommendations. This guidance is intended for universities, research and teaching institutes, as well as for companies interested in establishing novel teaching concepts in higher education. The action-based and transnational course addressed within this guideline consists of the following training and teaching phases involving a consortium of international learners and supervisors:

- A project working phase driven by a challenging engineering problem including:
  - International mobility phases for both students and teachers
  - Virtual cooperation and collaboration through digital tools
- E-learning lectures

The paper outlines the methodical background (1) and the state-of-the-art (2) for the action-based and transnational course. The guideline (3) addresses the activities: preparation, development, as well as implementation, evaluation, and follow-up. Important development phases of the guideline are explained on the basis of a use case patterned on the master course “European Engineering Team”. Learning objectives for this course aimed at raising the awareness about sustainable value creation by focusing on the development of sustainable and technological innovations with entrepreneurial objectives. The concept, first results, and outcomes of the course are described in [1] and at the project website (engineering-team.net/).

1 METHODICAL BACKGROUND

The framework for the action-based and transnational course in higher education follows the concept of Experiential Learning, based on the research results from David Kolb [2, 3]. Experiential Learning is based on a learning cycle of reflecting on the impacts of performed activities and subsequently deriving and implementing measures for improving these activities [3]. For combining the learning cycle with the search for solutions during the project work of the course, a specific logic was developed. This logic is an integration of the approaches presented in [3, 4, 5, 6, 7]; it supports the natural problem solving behaviour of humans and originally is inspired by the TOTE-Model [8]. *Fig. 1* shows the logic of the learning cycle applied during the project working phase. Moreover, specific elements have been developed for training different competencies of the learner. The structure of the relevant competencies is oriented on the competence profile for sustainable leadership [9] and consists of four main competencies: professional competence, methodical competence, social competence, and self-competence. *Table 1* points out the relevant course elements for training the four main competencies. For the improvement of the course, different evaluation activities with a subsequent development of improvement measures are carried out. The framework has been implemented and evaluated within the first and second cohort of the European Engineering Team.

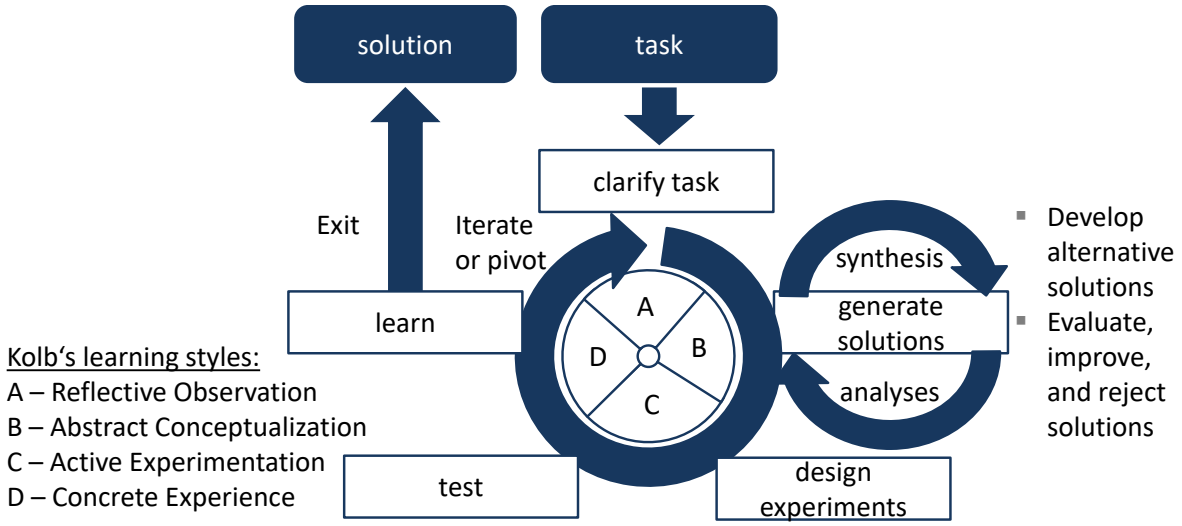

Fig. 1. Learning cycle for the project working phase (in accordance with [10])

Table 1. Course elements for training the competencies

Competencies		Course Elements
Professional and methodical competencies	▪ Depending on the involved engineering disciplines	▪ Project topic ▪ E-learning lectures ▪ Application of specific engineering methods and tools depending on the project topic ▪ Application of digital tools for communication
Social competencies	▪ Intercultural competencies ▪ Capacity for team work ▪ Communication capability ▪ Willingness to resolve conflicts ▪ Persuasive strength	▪ Intercultural team composition ▪ Project work in small teams and with work packages ▪ Periodic presentations of the work progress
Self-competencies	▪ Self-confidence and leadership ▪ Mobility and flexibility ▪ Engagement and reliability ▪ Target orientation and commitment	▪ Mobility phases ▪ Intercultural teamwork

2 STATE-OF-THE-ART

The state-of-the-art derives from approaches for action-based and transnational curricula in engineering education, considering both virtual and physical elements. The virtual-oriented approaches put an emphasis on online cooperation between the transnational partner organizations.

- Moore and May describe an interactive online course for engineering students based on a web-platform between the University of Virginia and the Dortmund University [11].
- Petrea and Velescu present an example of a mostly virtual-oriented approach with only one initial meeting for inter-university teaching of science students in a foreign language (French) [12].
- TRIP was a project aimed at using web services for distribution of large software engineering projects [13].
- Teaching students global software engineering skills using distributed Scrum in inter-university Canadian-Finnish teams was described in [14].

The physical-oriented approaches are essentially characterized by short-term, collaborative working phases, which take place with a co-located team and specific tasks and objectives.

- The BASE Transnational Training Course established by Fundação da Faculdade de Ciências da Universidade de Lisboa (FFCUL) and by the Ecologic Institute in Berlin provides a curriculum for the implementation of climate change adaptation projects using hands-on experiments and case studies for 16 learners [15].
- “Global Engineering Teams” managed by Global Education Team UG is an international and interdisciplinary project-oriented study course specifically for engineers [16].
- Jane presented a transnational course prepared by four European universities in the area of construction engineering and management [17]. All the activities were performed during physical meeting. The entire course lasts 28 academic weeks and students reside 9-10 full weeks at three different campuses, respectively.
- Mukerji presents further examples in [18].

The approach presented in this paper integrates both sets of practices and puts the focus on sustainability in entrepreneurial engineering.

3 GUIDELINE

The guideline is one of the final deliverables from an ERASMUS+ strategic partnership project. It captures lessons learned from our experiences as well as practical recommendations for any educational or training consortium interesting in replicating our engineering program. The guideline will be structured in the main activities: preparation (3.1) development (3.2), as well as implementation, evaluation, and follow-up (3.3). These activities are briefly outlined in this paper and are undergoing continuous improvements as we proceed with the ERASMUS+ project. Each activity covers different development phases (A-I) for the action-based and transnational course in higher engineering education. These phases address the development of different course elements.

3.1 Preparation

The definition of the course curriculum is the first relevant phase (A) for initiating the future action-based and transnational teaching and learning activity. This phase follows a fairly typical planning model including the development of the course elements A.1-A.5 It covers the definition of a vision and mission for the course (A.1),

as well as an outline of the leaning outcomes (A.2) and learning contents (A.3). This includes a definition of specific competencies for the course as well as a generic description of the applied procedures, principles, methods, and tools. The learning outcomes and learning contents define specific teaching and learning activities against which a duration and workload needs to be subsequently determined (A.4). Lastly, the target group and pre-requisite knowledge of the participants (A.5) are elaborated. For the development of the course elements, it should be ensured that they can be realized by applying the learning cycle in *Fig. 1*.

Within the second phase (B), the necessary stakeholders have to be identified, selected, and first contacts have to be established (B.1). The main relevant stakeholders are the transnational teaching partners from different countries. The partners should be selected according to the different competencies required to realize the learning outcomes as well as the learning contents. Besides, it should be ensured that the curriculum can be adjusted to the individual academic calendars of the partners. Other relevant stakeholders are e.g. external experts or organizations who/which are required for supporting the course with know-how or materials. For establishing the cooperation with the stakeholders, it seems to be more promising to select stakeholders with already existing good contacts on all organizational levels, e.g. from chair, to department, and up to administrative level. All project partners should be involved as early as possible in the development of the course elements. This process was applied by the European Engineering Team, with an early assessment of the feasibility of the course concept and detailed schedule for each university's curriculum and academic calendar. Concurrent to the selection of the stakeholders, a funding for the mobility phases (B.2) and the required materials for the project working phase (B.3) need to be specified.

The alignment of the course schedule to the academic calendars of the partners as well as the establishment of a funding for the course has been experienced as especially critical for the development of the European Engineering Team.

3.2 Development of the course model

After the preparation, the detailed course model has to be elaborated. This covers as a first development phase, the definition of the educational contents (C). The concrete topic for the project working phase (C.1) has to be determined. Moreover, the duration, sequence and objectives of the mobility phases (C.2) have to be specified. Additionally, a set of topics for the supporting e-learning lectures (C.3) must be selected, addressing professional and methodological as well as transversal competencies for the students.

In a second phase (D), the roles and expectations on both teachers (D.1) and supervisors (D.2) have to be detailed. This includes to define "who teaches what and when" as well as the learning outcomes and outputs for the students.

A third phase addresses the development of a concept for the quality assurance of the curriculum (E). In this context, an evaluation plan (E.1) and specific evaluation criteria (E.2) must be defined.

Lastly, the communication between the different stakeholders has to be set (F). For this purpose, the communication infrastructure and required tools are selected, e.g. for web-conferences. A first schedule for the communication between the different stakeholders is specified, especially taking into account the virtual cooperation and collaboration phases (F.1-F.3). *Table 2* shows a detailed use case for the course elements of the development phases C-F based on the European Engineering Team (EET).

Table 2. Use case for the course elements for the development phases C-F

C Educational contents
C.1 Project working phase: The project topic for the EET is to find a solution for breaking the chain of infection by developing an autonomous disinfection vehicle for application in hospitals based on the Sustainable Development Goals of the United Nations. This covers the development of a prototype as well as the development of a suitable business model. A sub-group of 4-8 students will be working on one topic supervised by four teachers from the partner universities.
C.2 Mobility phases: Four mobility phases at each of the partner universities are planned, one at each partner university with a duration of five days: week 14, Milan – introductions, define and analyze the problem to be solved; week 19, Trondheim – refine the problem definition and candidate solutions; week 41, Berlin – active prototyping; week 2, Warsaw – final meeting and introduction of the solution to investors.
C.3 E-learning lectures: For assisting the project work of the students the following e-learning lectures have been defined: Sustainable Value Creation, Systems Thinking & Systems Engineering, Technology Management, Circular Economy, Development of sustainability-oriented Startups, Sustainable Supply Chain Management, Virtual and Augmented Reality, and Digital Factory. The partner universities are recording the screen-casts and are prepare an exercise for each topic.
D. Roles of and expectations on teachers and learners
D.1 Roles of and expectations on teachers: For the EET, two different roles are required to be taken by the teachers: lecturer for the e-learning contents and supervisor for the project work of the students. The teachers are expected to be PhD students, post docs, or professors. Moreover, the teachers must attend all mobility phases and must closely supervise a small sub group of up to five students according to their individual competencies.
D.2 Roles of and expectations on learners: The students (learners) are expected to take different roles according to the project, such as project managers, product developers, or business model developers. In terms of the learning outcomes, the following expectations have been determined: ability to critically assess the goodness of a solution and its ability to meet a real customer's need; ability to work together and at the same time work in smaller groups that are capable of effectively sharing information between themselves; demonstrate (virtual) communications techniques learned during the project; ability to structure plans that address interdependencies and pre-requisites between the groups; ability to use abstract methods such as digital simulation or drawing to support decision making and design; ability to critically assess the contributions of a proposed solution to sustainable development. As output during the course, the students need to produce different reports including a reflection on the progress of the project work as well as a description of the produced results. Furthermore, the students have to create presentations for each mobility phase.
E Concept for quality assurance
E.1 Evaluation plan: It is necessary to monitor the learning and teaching progress and outcomes. During the course, three course evaluations are carried out with the participating students based on an anonymous online questionnaire. At the end of the EET an evaluation and improvement workshop is carried out by the teachers. As part of the workshop, feedback and possible improvement measures will be discussed with the students during their last mobility phase.
E.2 Evaluation criteria: For monitoring qualitative evaluation criteria, the change in the intercultural, mobility, methodical, professional, and self- competence of each student are evaluated during the anonymous online questionnaires. Therefore, the students rate their competencies in terms of speaking/understanding/writing English, sustainability, dealing with valued rules/norms, and expectations of people from other cultures, startup development, etc.
F Communication between the stakeholders
F.1 Communication of teachers and leaners: The infrastructure for communication between teachers and learners is designed as an open-source web-based platform. Moreover, the teachers and students meet physically at the mobility phases and virtually during the project work on the basis of web-based conference calls.
F.2 Communication between students for the virtual cooperation and collaboration phases: The communication between the students is organized in a decentralized manner. The students themselves chose within their group, the relevant digital tools for organizing their work.
F.3 Communication between teachers: The communication between the teachers takes place during the mobility phases, as well as by using web-based conference calls.

3.3 Implementation, Evaluation, and Follow-Up

This final section of the guideline includes recommendations for project management, for implementing the educational contents, and for continuous evaluation. The implementation of the course model entails an effective transnational project management (G) of the curriculum. This requires the adherence to responsibilities and scheduled meetings as well as the usage of the digital, communication tools. Secondly, the educational contents have to be implemented (H). This activity comprises the acquisition of students (H.1) as well as the operational planning and execution of the mobility phases (H.2), the virtual cooperation and collaboration phases (H.3), and the e-learning lectures (H.4). After the course is implemented and performed, evaluation and follow-up actions (I) ensure the educational quality of the curriculum and identify possible criticalities and subsequent improvements.

4 SUMMARY AND ACKNOWLEDGMENTS

The paper addressed the definition of a guideline for planning and implementing an action-based and transnational course in higher education for training the engineering competencies required in a future dynamic European workplace and economy. The main activities highlighted were: preparation, development of the course model, as well as implementation, evaluation, and follow-up. Important development phases for the main activities were explained on the basis of a real implementation of a master course focusing on the development of sustainable and technological innovations with entrepreneurial objectives.

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