INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8 & 9 SEPTEMBER 2016, AALBORG UNIVERSITY, DENMARK

DEVELOPMENT OF METHODOLOGY FOR DISTRIBUTED COLLABORATIVE DESIGN ENVIRONMENT

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ABSTRACT
This paper describes the CODEVE (COllaborative DEsign in Virtual Environment) methodology developed in a joint educational project of four European universities called NARIP (Networked Activities for Realization of Innovative Products). The ultimate goal of the NARIP NPD course is to develop a concept and produce a physical product prototype within one academic semester. In order to expose students to real life situations the prototype is being produced in close collaboration with an industrial partner. Elements of the NARIP course comprise: (1) project definition – according to agreement with the industrial partner, (2) lectures composed and adapted to address the specific needs of the current project and which are equally distributed to partner universities, (3) project work monitored by academics, with three distinct phases and review points, and (4) the final workshop that includes prototype manufacturing, assembly and testing, final presentation and exhibition. The paper presents the structure and details of the developed methodology as well as an overview of the course development history. The core of the CODEVE methodology is a set of comprehensive guidelines for students and teachers that are specially adapted and focused to the issues and problems that arise in distributed collaborative multidisciplinary design projects. The methodology focuses on management of complex projects, emphasizing the importance of research phases, prompt clarification of any issues and balanced distribution of project tasks. The methodology also promotes the use of various virtual/on-line collaboration tools to foster discussion and exchange of 3D sketches and models.

Keywords: Project based learning, virtual collaboration, new product development, design process.

1 INTRODUCTION

In October 2014 four European universities launched a joint educational project called NARIP (Networked Activities for Realization of Innovative Products) supported by ERASMUS+ funding. The goal of the project is to develop, test and consolidate a methodology for collaborative new product development (NPD) in a dislocated, virtual environment. In the first semester 2015, the methodology was already developed to the extent where it could be tested on a first generation of students. This paper describes the CODEVE (COllaborative DEsign in Virtual Environment) methodology, giving a particular focus on its educational and industrial application. The NARIP project builds on long term experience gained through the European Global Product Realization course (EGPR) that was initiated by TU Delft, EPFL Lausanne, and University of Ljubljana in 2000. Several years later three more universities joined - University of Zagreb, City University of London, and University of Technology and Economics Budapest. The basic concept and purpose of the EGPR course is to immerse the students in a distributed collaborative, multidisciplinary, multinational and multicultural environment with the aim of simulating real industrial practice situations as much as possible. The project task in the EGPR course is to develop a concept and to produce a physical product prototype within one academic semester, starting from research into the market and innovation potential. In order to fully expose students to real life situations the whole design process during the semester is continuously supported by industrial partner company. Teachers and students collaborate closely with the company,

who provide the definition of project task and finally facilitate the production and testing of several variants of prototypes.
Elements of NARIP/EGPR course comprise: (1) project definition – according to agreement with the industrial partner, (2) lectures composed and adapted to address current year project specific needs which are equally distributed to partner universities, (3) project work monitored by academics and partner company, with three distinctive phases and review points, and (4) the final workshop that includes prototype manufacturing, assembly and testing, final presentation and exhibition. Such a concept is very demanding in terms of teaching, financial and timing resources. However, the partner universities managed to continuously develop and improve the course during past 13 years [1].
A wide variety of different projects have provided teachers with the opportunity to collect broad and valuable insights and long term experience because each year the industrial partner (and the host university) has been changed. Throughout the history of EGPR (table 1) partner universities managed project tasks in many different areas and disciplines, varying greatly in complexity and research focus. Broader description of project tasks from 2005 until 2010 can be found in [2] while other works thoroughly analyze the expected learning curve [1] and [3].

2 CODEVE (COLLABORATIVE DESIGN IN VIRTUAL ENVIRONMENT) METHODOLOGY

Research in design and engineering education has shown that the traditional engineering design practice is not sufficient anymore, as it cannot face and satisfy all the new design requirements within a reasonable design time frame. Collaborative design is emerging as a promising alternative to classical design approaches. Teams that are multi-disciplinary, multi-national and multi-cultural are being formed to enable an in-depth view of design problems. Various institutions are participating in the concept-to-market design process, making it even more complex. Furthermore, the nature of teams has changed significantly because of changes in organizations and the nature of the work they do. These new conditions of the business environment, being rooted in globalization, the explosion of new technologies, economy based on knowledge, and the information era have made working in virtual teams a common approach for many organizations today. Higher education is not necessarily aware of the respective emerging knowledge, skill, or competence requirements, and which may not currently be satisfied. In particular, the challenges of student projects being carried out in virtual teams in remote collaboration need to be addressed, because these projects are not parts of the traditional designer curricula. All these issues challenge the HEIs to be able to adapt to this paradigm change in design setting, and also to satisfy the emerging and changing knowledge, skill, and competence needs of the current situation [4].
The above mentioned theoretical issues as well as many other practical ones have been addressed in a series of international product development courses called EGPR. The EGPR course in 2002 has been brought to existence as an answer to the concept of borderless education as well as to the major trends in digitally-supported design such as (i) design across value chains (globalization of product development, realization and marketing), (ii) design across multiple domains (growing importance of integrated multi-disciplinary design), and (iii) designing across life cycle processes (from conceptualization, through production and utilization, to recycling). These are indicating the multiplicity of the aspects to be dealt with, the multi-faceted nature of the knowledge the students need to learn, and the complexity of the problem from an educational point of view. The professional content and didactic approach of the course were designed accordingly; the course applied two instructional streams, which are called professional navigation and industrial project, and followed a generic four-phase NPD model [5]. The series of lectures and presentations are provided for all participating students, and the industrial project is carried out in 5 or 6 international, multidisciplinary virtual teams, all working on an industrial assignment given by the selected industrial partner. From the project kick-off all parties communicate and collaborate by virtual means, yet the product realization (prototype fabrication and testing) and presentation is done at the site of the host university in the frame of a week-long workshop, where participants finally meet in person.
As it has been described previously, the know-how and methodology in this project based design course for collaborative new product development (NPD) in dislocated, virtual environment went through significant development and participating institutions and individuals gained a lot of knowledge and experience throughout the years. Therefore, CODEVE is definitely not without antecedents.

CODEVE methodology is indeed a refined and crystallized know-how to set up and successfully manage a NPD student project in industry-academia setting in a dislocated environment. The CODEVE methodology is the primary output of the first project year in the NARIP Erasmus+ Strategic partnership project.
The research and methodology development activity here was three-fold. Firstly, the recent and latest experiences both with NPD and virtual collaboration in the partners' practices (mainly related to the EGPR) had to be studied and processed. Secondly, the state-of-the-art methodological developments had to be discovered and the possibilities of effective implementation had to be identified. Upon the findings and conclusions, and also on the niches found, a streamlined approach and methodology applicable in virtual environment was formulated. Thirdly, the models were tested and continuously adapted to design education in virtual environment. For this purpose, an experimental industry-academia project was carried out (i.e. the NARIP EGPR student project), which was the subject of seeking and finding the most critical points for further development both in theory and in practice.

2.1 NPD Methodology

2.1.1 Design process model

The design process model applied in the project originates from the model of Pahl and Beitz [6] but in an extended, adapted version. The first phase, depending on the type of project may depart from Clarification of the task, and become more of a Fuzzy Front-End (FFE)-type of problem definition. Once the product is defined in terms of the demanded functions (and further requirements), teams could enter the concept generation phase. Another difference from the Pahl-Beitz model may be that there is no separate design phase for embodiment and detail design, with no intermediate review. The third major adjustment is that there is a prototype making phase at the end. Eventually, the design process resembles more closely the whole product development phase in the innovation model of Roozenburg and Eekels [6]. In the course methodology there are a number of guidelines and written aids available to ensure a common understanding in terms of the design process to follow. The goals, recommended tasks, and also expected outcomes and deliverables of each phase are prescribed in details. This, however, does not mean that the designers would be limited by obligatory methods and tools; in contrary, only the meeting points are defined to ensure the comparable outputs in time and depth, otherwise students are free to decide which way they choose.

2.1.2 Teams

In order to best simulate a real-life situation, the virtual enterprise of NARIP/EGPR acts like a flat-hierarchy virtual company, where the R&D and design departments are the student teams. The partner company is the customer, whereas academic staff takes only some higher level management roles, and otherwise facilitate interaction between company and student teams. The members of the teams are set before the project starts. Other than that, the team is an autonomous entity; it is responsible for setting up internal communication and working protocols, project and data management solutions, and definitely for the timely solution of the design assignment. Being a member of a dislocated international team, students might face challenges in language use or IT use, but most importantly, the greatest challenge is to actually perform as a team rather than eventually having the sum of individual efforts from remote locations. Within the team, not only the task distribution is important, but clear roles have to be set. This comes into focus, when the project assignment demands for a complex technical solution, where teams have to perform cross-team collaboration on top of internal team collaboration.

2.2 Project Preparation

2.2.1 Partners

For a successful project there has to be a sufficient number of partner universities involved, plus one industrial partner has to be selected. As the partner company changes each year, they need to understand the philosophy and scheme of the project, for which there exist several written documents. In the early preparatory phases, the form and amount of contribution (material and immaterial) from company side has to be settled, while on the other hand the company expectations and possible benefits will also have to be clearly stated. IP rights are an issue which are addressed in advance as an agreement between industrial partner and organizing university on behalf of the whole project

consortium. Further external, supporting and guesting partners could join the virtual enterprise, in the consensual agreement with the others. However, the most important contribution of the industrial partner is a document called Project Proposal. It is prepared by the company in collaboration with the host university, and in consensus with the other partners. This document gives an overview of the aims and background of the project, briefly introduces partners, and most importantly the design challenge. The document specifies the project goals and expectations, recommends tasks to be performed by student teams, lists the deliverables with respective specifications, and also specifies phases, defining milestones with deadlines.

2.2.2 IT communication and collaborative environment

The main means of communication and collaboration in a distributed environment are the Computer Supported Co-operative Work (CSCW) and Groupware solutions. Surprisingly, the most widely used social platform is also quite often used to manage the teamwork. In terms of asynchronous collaboration in the course a few e-mailing lists are used, there is a shared workspace available for data exchange and backup. A whiteboard application is also available. The activities of joint problem solving (e.g. group ideation, common sketching, explaining and discussing the concepts, the discussion of needs for modification, common CAD modelling, etc.) are all still considered challenging, as even though the tools are available students may not be familiar with them. There has been a thorough document developed titled the "IT Guide", describing the official and optional IT solutions in details, furthermore there are chapters dedicated to proprieties and good practice in virtual environment.

2.3 Project Support

2.3.1 Academic lectures and professional presentations

Although the student project is an integrating type of design project (building on the already acquired knowledge), additional domain-specific lectures and topic-specific presentations are inevitable from the perspective of knowledge development. Academic lectures are delivered by renowned university staff, while professional presentations are held by external experts, professionals, and importantly, the representatives of the partner company. In terms of topics there are a variety of areas covered, e.g. project methodology and background, design methodology, relevant fields of engineering, management of virtual teams, CSCW solutions, creativity and innovation, presentation techniques, etc. In advance of the course start, the series of lectures and presentations are carefully planned in line with the logic and need of the current project and all are indicated in the Course schedule.

2.3.2 Coaching and project management

No project management can be successful without strict time management. The NARIP/EGPR timeline is specified with all details in a document called Course Calendar prior the start of any student project activities. In this document the course/project activities are broken down on a weekly basis. The weekly two classes via videoconferencing are assigned with titles, types of session, responsible location and a session moderator. Academic and professional lectures, student design review presentations, preparatory and consolidation meetings may use up the available timeslots.

Strict project and time management are also crucial to synchronize the performance of the otherwise independent teams. Therefore, each virtual student team has a coach assigned (sometimes a co-coach as well), who is ideally an academic staff member with long coaching experience in student projects. The coach is essentially a point of reference; in the first place they enhance a common understanding in terms of tasks, duties, inputs, processes and the contents and form of delivery. The other major role of the coach is to monitor team activity and to point out underperforming or risks of failure well in advance. On the other hand, coaches and company representative in consensus with board of professors operationally manage the project. Coaches and company representative have regular weekly meetings (if necessary more frequently), to check the progress, evaluate the status against the work plan, and to analyze the possible risks on the level of the whole project. If necessary, these meetings can allow decisions to be made to initiate additional review points, prepare additional guidelines or protocols or apply shortcuts. This kind of continuous monitoring, quality control, and flexibility aims to realize the maximum effectiveness of all contributors and ensures that project goals are met successfully. In the project repository there are a number of documents and templates that can be used

in different situations, however the management and quality assurance protocols are continuously evaluated and updated.

2.4 Project Closing

2.4.1 Closing workshop

The project is generally 16-20 weeks long in total, and is divided into four phases according to the development process applied, each lasting 4-5 weeks. The last phase, the Prototyping phase begins while teams are still operating in the distributed environment, but there is a great change for the last project week (called the "Workshop week"), when all participants come together in the host country. The purpose of this co-located week is to assemble and test the prototype or prototypes, and also to present the project results to the academic staff, the company (generally located in the host country), and to a wider audience in a form of a large scale public presentation and exhibition. This is the first time participants meet in person, which is reportedly very motivating and a great experience for the rest of the week. The peak point in the project is definitely the closing presentation and exhibition. This is a large scale event held at the host university campus. In practice, the closing day comprises of a series of presentation events. As EGPR is a university course, a formal academic-type presentation is required for final assessment and marking. A slightly different presentation is expected from student teams for company management with the emphasis adjusted to the interests of the audience. As the part of one these presentations the prototype testing is carried out, which also counts in the assessment of students.

2.4.2 Scholarly work

Throughout the years EGPR has provided a great opportunity to carry out experiments and research activities on each separate project. Besides having a distinct research focus in each year, the internal processes and phenomena were kept monitored by scientific quality methods. The latest findings and lessons learnt were periodically presented at relevant scientific conferences and also papers were submitted to journals. This activity serves dual goals; on the one hand it significantly contributes to quality assurance of the project, on the other hand it enables academics to extend their research work and research supervising activities both locally and within the EGPR community. After NARIP started, the approach has slightly changed. The main goal of the NARIP project is to develop, test and consolidate a design education methodology for collaborative new product development in dislocated, virtual environment. From the former experiences and best practices found, now a consolidated methodology is being proposed (CODEVE). This methodology is currently being implemented and refined, and appears to be working well. Further testing and feedback will be integrated in order to achieve the final outcome of NARIP, which is expected to be presented in a form of a book.

3 OUTPUTS OF 2015 NARIP – EGPR PROJECT

Besides the CODEVE methodology which was the core NARIP/EGPR 2015 output, and working prototype of the 2015 industrial project, the project resulted in a large number of various outputs related to the core activities. There were at least 25 sets of different official project documents including: course instructional documents, lectures presentations, lecture recordings, intermediate reports, intermediate presentations, CAD models, posters and booklets. Three papers have been published on this subject so far: [4], [7] and [8].

The industrial project in 2015 was also very valuable for the students' further academic career. At least 5 students continued their work on a developed solution even after the project's official end into their final bachelor graduation work. In summer 2015 they conducted a series of research and development activities to evaluate and optimize solutions presented at the workshop in Zagreb. The activities included redesign of some prototype components and analytical and numerical calculations to determine stress-strain conditions in some critical elements.

However, the most valuable outputs are various project guideline documents and project survey results, which testify to the applicability and repeatability of the CODEVE methodology into real industrial-academic NPD projects. The struggles of the students at the beginning of the course, which were described in previous sections, created an urgent need for better instructions about different steps of new product development process. Therefore, project staff prepared detailed guidelines and project instructions for each project phase and distributed them to the students at the beginning of each phase.

The guidelines were derived from general CODEVE methodology to specific project needs, so the students received clear projection of the methodology onto the real new product development process.

4 CONCLUSION AND FUTURE WORK

In the first project year we thus developed and demonstrated the applicability of the CODEVE methodology in a real industrial-academic environment. The supporting documents, which clearly describe each step in the collaborative design process in virtual environment, illustrate the details of the path taken to achieve the desired final result of the new product development project – a full scale prototype, ready for testing and demonstration. However, the information loop has to be closed and a thorough analysis of all methodological steps and aspects of the project is necessary, if we want to modify or improve and upgrade the methodology in the future. The feedback information was gathered from the project staff, industrial partners and students throughout the whole project process using different techniques. There were regular interviews and meeting between industrial partner representatives and local staff analyzing and discussing different forthcoming project risks, limitations and possibilities for improvement. The academic staff held regular weekly meetings to report the status updates of each team and cross-team activities to each other, with the primary goal to identify potential problems, project delays or conflict situation at the earliest possible moment. All the issues discussed have been recorded as the minutes of the meetings. The feedback from the students about the different aspects of the project was gathered by conducting informal interviews and weekly team meetings during the project lifetime, and more thoroughly by the survey at the end of the project.
CODEVE is not solely a university course description, nor simply an NPD methodology. From a different perspective it should be emphasized that this design course is one of a kind; here the R&D activities, the design and innovation processes and outputs are in good balance and just as important as the project itself, with all the project management considerations, the visibility of the project through the presentations and other PR activities, and the scientific publications.

ACKNOWLEDGEMENT

The project in 2014 was a part of Erasmus Lifelong Learning program and has been funded with support from the European Commission. The project in 2015 was a part of Erasmus+ Strategic Partnership program and has been funded with support from the European Commission. This communication reflects the views of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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