INTRODUCTION OF METHODOLOGY FOR DISTRIBUTED COLLABORATIVE INDUSTRY-ACADEMIA PROJECT BASED LEARNING

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Keywords: project based learning, design education methodology, collaborative design process, distributed design

1. Introduction

This paper presents and discusses the developed concepts and the long term experiences and design education research results gained through conducting project based learning course since 2002 in academic virtual enterprise of six European universities. The course has been initiated by TU Delft, The Netherlands - Faculty of Industrial Design, EPFL Lausanne, Switzerland and University of Ljubljana, Slovenia - Faculty of Mechanical Engineering. Few years later three more universities joined - University of Zagreb, Croatia - Faculty of Mechanical Engineering, City University of London, - School of Engineering and Mathematical Sciences and University of Technology and Economics Budapest, Hungary - Department of Machine and Product Design. The basic concept and purpose of the course named European Global Product Realisation (EGPR) is to immerse the students in distributed collaborative multidisciplinary, multinational and multicultural environment with the main goal to simulate the real industrial practice situations as much as possible. The project task in EGPR course is to develop a concept and to produce a physical product prototype within one academic semester, starting from the market and innovation potentials research. 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 tightly collaborate with company which has to provide the definition of project task and finally the production and testing of several variants of prototypes. Actually, the course functions as new product development project which is being done exclusively for the partner company. In addition to pure technical content, such approach offers students deeper understanding of business and various social issues. Student teams consist of 5 to 8 members, with at least one member from each university and if possible from different disciplines. Elements of EGPR course comprise: (1) project definition – according to agreement with 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 sense of teaching, financial and timing resources; however, the partner universities managed to continuously develop and improve the course during past 13 years.

The new big step in course development has been done in October 2014 when joint educational project called NARIP (Networked Activities for Realisation of Innovative Products) and supported by ERASMUS+ funding has been launched. The main goal of the NARIP project is to develop, test and consolidate a design education methodology for collaborative new product development (NPD) in

dislocated, virtual environment. This task should be done based on all previous experience and research results gained during the history of EGPR course. Wide variety of different projects gave the teachers 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. Through the history of EGPR (Table 1) partner universities managed project tasks in many different areas and disciplines which also had a great diversity in complexity and research focus. Broader description of project tasks from 2005 until 2010 can be found in [Pavkovic et al. 2011].

The aim of this paper is to present and describe the developed CODEVE (Collaborative DEsign in Virtual Environment) methodology, giving the special focus on its educational and industrial application. In the first semester of 2015 the methodology was already developed to extents where it could be tested on a first generation of students. To illustrate the preliminary application of the methodology, detailed description of the 2015 project task is given in the third section of paper.

Table 1. The history of EGPR course

Year, host university	Partner company	Project task	Research focus
2015, Zagreb	INETEC d.o.o. - Zagreb	Remotely operated submersible device for inspecting of welds in nuclear reactor pressure vessel.	Complex mechatronic system, shared understanding between design teams
2014, Ljubljana	Bosch and Siemens Home Appliances	To develop the idea for a device which would radically ease the process of healthy meal preparation.	Future customer needs and trends in home appliances, social networks
2013, CUL London	Condor Project Ltd., Hull	To design and build a small aircraft to be flown by disabled pilots.	Ergonomics for disabled people, cross- team design communication
2012, Zagreb	Suman d.o.o. - Zagreb	To increase business opportunities by design and optimisation of various parasol products.	Product design vs engineering design, and the collaboration between them
2011, Budapest	Direct Line, Budapest	Development of an eco-friendly cycling interface/infrastructure for users of bicycles.	Community projects, ecology, environment and economy
2010, Ljubljana	BSH Slovenia - Nazarje, LIV - Postojna	Hand held blender which would target modern urban men. Innovative toilet flushing system.	Socio technical aspects of design, multitasking
2009, TU Delft	University Medical Centre Utrecht	Device and service to help patients and physicians through the rehabilitation therapy.	Biomedical engineering, fuzzy front end research methods
2008, Zagreb	TEHNIX d.o.o., Donji Kraljevec	Mobile autonomous ecological house - autonomy in respect to energy provided from the available alternative sources.	Sustainable energy, sociological factors of work in virtual design teams
2007, CUL London	Kesslers International Ltd	Technologically advanced point-of-purchase (POP) display which will be used in sales of a male grooming products.	Design integrated research for customer oriented products, integrating undergraduate and industrial research
2006, Ljubljana	NIKO, Železniki	Transport device to be used for civil engineering, furniture moving and other works performed in multi storey buildings.	Human centred PD for specific market, design for the bottom of the pyramid
2005, EPFL Lausanne	Avidor S.A., Lausanne	Device for vineyard treatment with micro spraying technology to reduce chemicals loss	Human- and environment-centred PD, development of holistic design competence
2004, EPFL Lausanne	Vlamboog, Netherlands	Innovative personal protecting and vision equipment for welding.	Navigation of active learning
2003, TU Delft	Vlamboog, Netherlands	Innovative personal protecting and vision equipment for welding.	Conceptualization and prototyping for company
2002, Ljubljana	Kolektor LIV, Vlamboog	Innovative vacuum cleaner (LIV), breathing protection units for welders	Redesigning and prototyping for global market

2. CODEVE (Collaborative DEsign in Virtual Environment) methodology

It is commonly accepted that engineering designer and product designer practice is under transformation due to the changing global environment. Design and engineering education research performed showed 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. It can be defined as a process where a product is defined through the collective and joint effort of more designers. Various disciplines such as decision theory, social science, operation management, computer science etc. have been used to deal with the emerging collaborative design. Teams that are multi-disciplinary, multi-national and multi-cultural are being formed to enable an in-depth view on 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. Organizations have become more distributed across geography and across industries, yet have discovered the value of distant collaborative work. Those new conditions of business environment, being rooted in globalization, the explosion of new technologies, economy based on knowledge, and 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 needs, therefore those might not will be satisfied, eventually. Especially challenges of student projects being carried out in virtual teams in remote collaboration need effective response, because these projects are not parts of traditional designer curricula. All those written above challenge the HEIs to be able to adapt to this paradigm change in design setting, also to satisfy the emerging and changing knowledge, skill, and competence needs of the current situation [Vidovics and Horák 2015].

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 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 [Horváth 2006]. The series of lectures and presentations are provided for all participant students, whereas industrial project is carried out in 5-6 international, multidisciplinary virtual teams, all working on industrial assignment given by 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 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 and methodology 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 project year one in NARIP Erasmus + Strategic partnership consortium project. The research and methodology development activity here was three-fold. In the first place 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. In the third place 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. Detailed results and outputs are being discussed in section 3.

EGPR projects as realizations of the 'learning-by-doing' principle, according to their industry-academia character, have dual aims; on the one hand there are the knowledge, skill, and competence development teaching goals, and on the other hand the assigned challenge (global industrial, business or social problem) from the industrial partner has to be solved and delivered. Nevertheless, CODEVE is not solely a university course description, nor simply an NPD methodology. From a different perspective it has to be underpinned, that this design course is one of its 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, or even the scientific publications. The know-how and methodology include models and guidelines, also some specific methods and tools are recommended within the areas, as per summarized below.

NPD Methodology

Design process model

The design process model applied in the project is originated from the model of Pahl and Beitz (Roozenburg and Eekels 1995) but in an extended, adapted version. The first phase, depending on the type of project may deflect from Clarification of the task, and more turn into a Fuzzy Front-End (FFE)-type of problem definition. In the FFE-type developments lack in the product type initially. Once the product is defined in terms of 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, at least there is no design review in between. The third major adjustment is that there is a prototype making phase at the end. Eventually, the design process resembles more to the whole product development phase in the innovation model of (Roozenburg and Eekels 1995). 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. The NPD methodology was adapted to student projects carried out in teams.

Teams

In order to best simulate a real-life situation, the virtual enterprise of EGPR acts like a flat-hierarchy virtual company, where the R&D and design departments are the student teams. Partner company is the customer, whereas academic staff takes only some higher level management roles, otherwise facilitates interaction between company and student teams. The members of the teams are set before the project starts. Other than that, 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. Teams are mixed virtual teams, ideally with a range of different expertise and by nature in a geographically scattered setting. Team members from remote locations never meet in person during the project, only in the very final week, when all participants come together in the hosting country. As being 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. Project teamwork is done out of the compulsory university class time windows, it could be considered as homework. Therefore, scheduling and time management of team activities have to be done carefully. Common team meeting times are difficult to

find, so there has to be a lot of individual effort and time management to make useful and prosperous meetings happen. All in all, being a member in a virtual team requires a variety of personal qualities, a lot of attention and responsibility, flexibility, commitment and respect. On the support on these areas the reader will find more in the sections below.

Project Preparation

Partners

For a successful project there has to be sufficient number of partner universities involved, plus one industrial partner has to be selected. The selection criteria for higher educational institutes are not too complicated: among others professional background relevant to product development, sufficient human resources (students and academic staff), willingness and readiness for continuous collaboration. Design project management and coaching experience is preferable, a good standard of IT infrastructure and knowledge is also desirable. Huge time differences may be an issue. Partner company however has to be carefully selected. Commitment is in the first place. As 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, on the other hand the company expectations and possible benefits will also have to be clearly stated. IP rights are an issue which needs to be taken care of. Partner company is generally selected from the host university's country to enable better conditions in the prototyping phase. For all participants good understanding and fluency in the common working language (most often English) is a necessity. Ideally there are permanent contact persons from each partner; in practice one from the company, at least one coach and one professor from each university. Further external, supporting and guesting partners could join the virtual enterprise, in the consensual agreement with the others.

Course documents

The most outstanding, official course document is the Project proposal / Design assignment. This is being prepared by the company in collaboration with the host university, 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 task to be performed by student teams, lists the deliverables with respective specifications, and also counts phases, milestones with deadlines. The other important document is the Course calendar / schedule. In this document the course activities are broken down to weekly basis; the weekly two classes via videoconferencing are assigned with titles, types of session, responsible and session moderator. Academic and professional lectures and presentations, design review presentations of students', preparatory and consolidation meetings may use up the available timeslots. The Course calendar should be finalized before the course starts, and should not be changed only in case of absolute necessity. The challenge in scheduling the course is to free up the regular timeslots for all participants, mainly for those who do not have the course officially introduced into the local curriculum. Otherwise examination periods, breaks and holidays, other local specialities have to be taken into account and have them synchronized for the benefit of all. Throughout the project the calendar is being shared online, so one might embed it into their personal digital calendar.

Student recruitment, team forming

Student recruitment is mainly done locally, as local staff is in a convenient position to reach local students. Recruitment is preferably done at lectures and seminars personally, to better support this not only the compulsory course documents are used but also a short presentation is compiled as a teaser. Otherwise online and printed advertisement is a common way to draw the students' attention to the course. Local student selection can be very difficult. University program, background, motivation, commitment, language skills, etc. could be assessed. According to the experiences personal engagement, intrinsic motivation, and goal-oriented, good team-player personality is desirable. Even though student selection is the responsibility of the local university, quality selection can only be made from sufficient

pool of talented applicants. Team forming is a common activity of all HEI partners. Preferably from each location pairs of students are delegated for a balanced and constant contribution. The criteria of the team possibly being multi-cultural, multi-language, and multi-disciplinary are applied, too. In the mixed dislocated teams there should not be any parties over-represented. Fine-tuning of team set-up is done when the applicant list is final and all institutional and personal preferences are noted. Team list comprise student names, year and program of studies, and obviously contact details. The teams list is the initial document to enable students to contact each other, and also a database for responsible staff members to create the student accounts for the course related IT applications, e.g. mailing lists, shared workspace, etc. Although lists change every year, there exists a developed template for starting.

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. The CSCW solutions have to be tailored to the needs of the course. Most importantly, for synchronous collaboration professional videoconferencing system with a MCU (also with recording functionality) is used at all locations for good visual and audio quality in lectures, interactive sessions and presentations. In addition to that, which is more independent from the location, other video calling applications are in use, especially in team's work. There is an official tool used for desktop and application window sharing, which is again extended by other means with similar functionalities by the students. 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, also a whiteboard application is in use officially. On top of that, students apply a variety of generic applications. IT applications can also be grouped by the purpose of use. Students seem not particularly challenged by communication situations, also they are familiar with some cooperative tools; project management, documentation, task assignment, data management is within their comfort zone. As design being a creative activity, collaboration is found to be very challenging and demanding in terms of CSCW use. There is a significant shift from co-located practice to dislocated collaboration; therefore, students need to develop their new manners of working in the new setting. 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, even though the tools are available, but they might not be familiar with them. There has been a thorough document developed titled the "IT guide", which describes the official and optional IT solutions in details, furthermore there are chapters dedicated to proprieties and good manner in virtual environment.

Funding

Although student project is a non-profit initiative, significant costs may arise, especially in the phase of realization, and also in connection with student and staff mobility and the closing workshop week events. As the host university changes each year in a rotation, on 4-5 years average the extra costs of being a host could be kept down and most importantly could be planned. It also has to be taken into account that the teacher per student ratio is very high at all locations, hence the cost effectivity on staff members would appear high as well. There exists a general agreement on how the expenses of the project are being distributed, yet there is always an opportunity to invite sponsors or to apply for funding.

Project Support

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, whereas professional presentations are held by external experts, professionals, and certainly the representatives of the partner company for all participating students. In terms of topics there is 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. These lectures are being broadcasted to all locations via professional videoconferencing system, also the lecture slides are streamed simultaneously. All lecture materials are backed up and accessible for participants. The series of lectures and presentations are carefully planned in line with the logic and need of the current project, in advance to the course start, and all are indicated in the Course schedule.

Coaching and project management

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 basically 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 analyse the possible risks on the level of the whole project. If necessary, this round of people initiate additional review points, prepare additional guidelines or protocols, or even has the authority make decisions or apply shortcuts, etc. This kind of continuous monitoring, quality control, and flexibility enables to reach the maximum effectiveness of all contributors and ensures that project goals are met successfully. In the project repository there exist 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.

Project Closing

Closing workshop

The project is generally 16-20 weeks long in total; it is divided into four phases according to the development process applied, each 4-5 weeks long. The last phase, the Prototyping phase begins still in 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 wider audience in a form of a big 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 preparation of the workshop week mobility is shared between the partners; travel is organized by sender party, accommodation and meals are organized by hosting university. The workshop program is generally enriched by social events, which is normally taken care of the partner company. In the majority of the time available prototype fabrication and assembly is done, towards the end of week prototype testing comes in focus. On the last day the results of the whole project are presented.

Project presentation and project visibility

The peak point in the project is definitely the closing presentation and exhibition. This is a big scale event held at the host university campus. Actually, the closing day comprises of a series of presentation events. As EGPR being a university course, there has to be an academic-type presentation held for final assessment and marking. A slightly different presentation is expected from student teams for company management with the stresses adjusted to them. Either as the part of one those presentations the prototype testing is carried out, which also count in the assessment of students. Eventually, a public event is held, where the highlights of the results are presented briefly, also representatives of all partners address the audience. This event is being broadcasted via videoconferencing creating an opportunity for those staff members who could not be present on the spot to follow the event and to address participants. At the exhibition all prototypes are presented along with clarifying technical and marketing posters. Most often students prepare flyers for take away. Techers also exhibit a poster to give a project overview for the quests. Acknowledgments for support are expressed, and official certificates of project

participation are handed out. For all the work to be done at the events on the final week there are proven protocols and document templates are available. The intensity and form of project visibility depends whether it is course or off-course period. In general, EGPR-related webpages are maintained at most locations (a central NARIP portal was also started in late 2014) to provide general information for visitors anytime. When the course is on, web presence increases; new and up-to-date content is posted on the webpages, also an intensive use of social channels is being propagated. On the workshop and the final presentation and exhibition besides the media interest a lot of pictures are taken, which are also going to be shared in social platforms. It has to be stated, that locally, for each partner it is already a great achievement to successfully participate in the project, so there is continuous effort to promote the project within the home country. To make the project also visible internationally among European academics and scholars worldwide the series of EGPR projects and the latest results are periodically presented on relevant scientific conferences, symposiums and workshops, and also papers are submitted to scientific journals. The need for this kind of visibility was increased with the NARIP Erasmus + agreement.

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 on 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) and this methodology as being hypothesized to be working well should be tested and fed back to have the final outcome of NARIP, which is expected to come out in a form of a book.

3. NARIP - EGPR 2015 experimental project

In 2105, first year of the NARIP project, partner universities selected INETEC d.o.o. company from Zagreb, Croatia as the industrial partner who will provide and support the new product development task for the course. INETEC is renowned for technological and service excellence in the nuclear industry, providing systems for nuclear power plant examination and repair services, supported by intensive research and development programmes. The project task has been defined as development of submersible remotely operated device (ROD) for inspection of welds in a nuclear reactor pressure vessel (RPV). RPV has to be periodically examined in order to find if micro-cracks have appeared and/or propagated. Inspection is being done with non-destructive testing methods such as ultrasound or eddy current testing. The welds in the RPV are susceptible to cracks and they are the scope of the inspection. Overall, 35 students, 7 professors, 6 coaches and 4 administrative staff members participated in the project. It was fully funded by 'Networked Activities for Realisation of Innovative Products' (NARIP) under the ERASMUS+ KA2 Strategic Partnership Grant Agreement.

Here are some of the more important design requirements that were set in the project task:

- the device should move through the water in all directions: up and down, forward and reverse and rotate about vertical axis, near neutral buoyancy should be achieved,
- linear velocity in all direction should be at least 100mm/s, as well as scanning speed,
- device should be able to be fixed anywhere inside the vessel,
- two driven axes are needed for surface scanning - one scanning axis and one incremental axis - increment should be 10 mm, the scanning area is 300 mm wide along the weld.

Based on these requirements it could be concluded that all project participants were faced with a very challenging and complex task with respect to their design experience and available time. Usually, in all

previous EGPR projects expect in 2013, 5 student teams have designed and produced 5 different prototypes. Due to complexity of 2015 task, teachers changed the concept of the course towards designing and producing only one prototype, where each team has been responsible for 2 or 3 subsystems. In the first (research phase) teams were mildly directed to a particular set of interrelated issues, but also were given the freedom to propose ideas and visions in areas of all development requirements and functions. In the second, conceptual phase each team was more strictly directed to specific set of issues and identified problems. On the second project review each team has presented several conceptual solutions. Based on those proposals, company made a compilation to enable starting of detailed design phase from one common embodiment design. Basically this embodiment design included a selected configuration of device subsystems movement combined with selected fixation principle.

During the first phase of this project all participants faced many frustrating situations that aroused due to project complexity and geographical dislocation – e.g. nobody except the author itself has not been able to completely understand how a proposed conceptual solution is supposed to work. Scanned handmade sketches often were not understandable, even with textual explanations – also they were dispersed through several files – it was difficult to merge them and get an overview of whole product (concept) functionality. This was especially difficult for teachers and company representatives because often (when giving feedback) they were not able to properly decide whether the proposals were good or not. These problems have been much more noticeable in comparison to all previous EGPR projects and began to ruin (impair) the student motivation. At this point communication and shared understanding became critical factor of project success. To solve these problems, we had to introduce new tools and protocols in order to improve the communication and especially the process of building the shared understanding (Figure 1). Shared understanding has been equally important on the level of one team, as well as on the level of communication between teams where they had to exchange ideas and solutions of device subsystems that were strongly coupled.

To improve communication and solution explanations, teachers introduced organized usage of digital whiteboard tool which proved to be very successful. Everyday communication has been significantly improved - everyone could be updated about new developments on one common place. Instead of scanned handmade sketches students then began to intensively use screenshots of 3D models paired with comments, messages and short discussions (Figure 2).
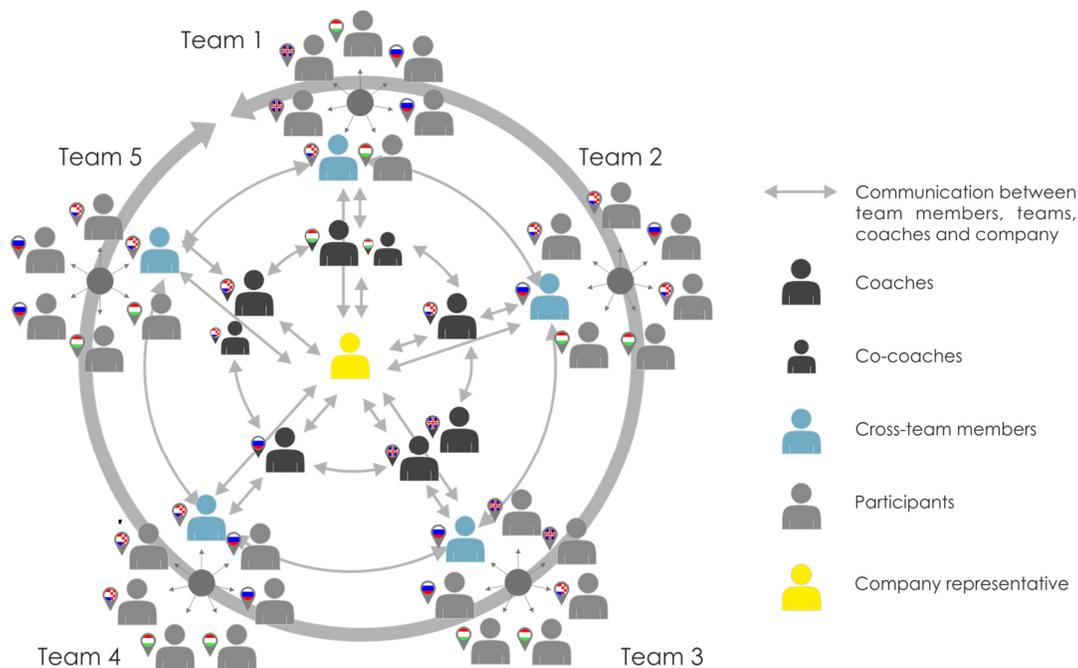

Figure 1. Organization scheme and communication channels in EGPR course
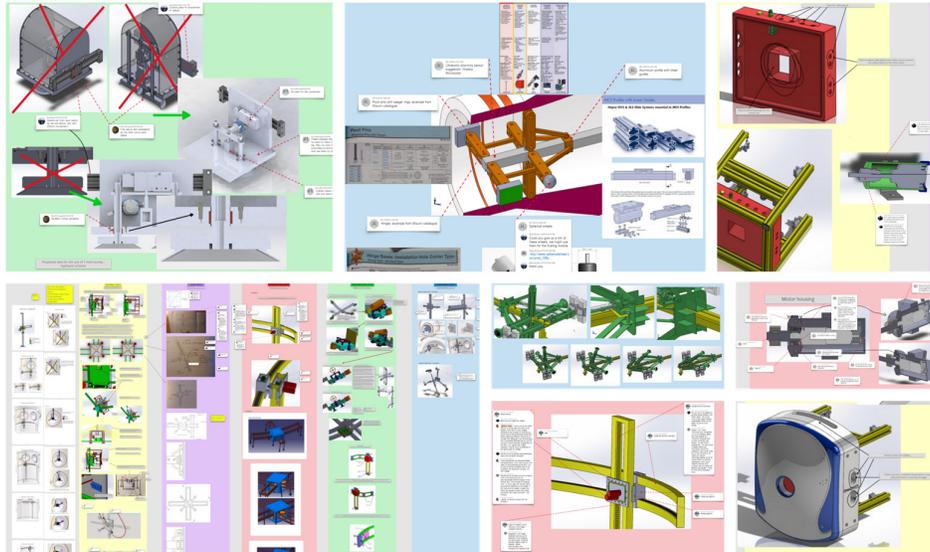
Figure 2. A screenshot of one section of digital whiteboard content

Graphical content displayed on the digital whiteboard has also been intensively used in videoconferencing meetings where it strongly contributed in generating and understanding new ideas as well as correcting mistakes and improving shown solutions.

Additionally, to further facilitate the communication a "cross team" has been formed including one member from each of 5 teams which has been responsible for communication between teams. This way students got very valuable insights and they experienced difficulties of distributed collaborative design environments. One of the students has been assigned the role of "knowledge manager" with the task to capture and record design rationale created during the whole project. For this purpose, IBIS diagrams have been used and stored together with the rest of the project documentation on a common server. To summarize, 5 student teams brought together 47 functional requirements. Final design was embodied with 788 components and documented with over 3000 documents while "knowledge manager" created a total of 58 IBIS diagrams, and a diagram of functional structure. Students, teachers and designers from partner company filled two digital whiteboards each of 50 m2 canvas size.
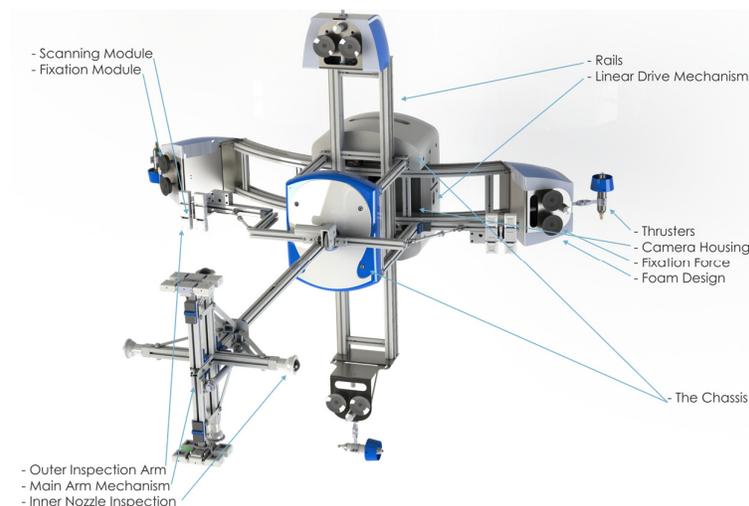
Figure 3. Completed CAD model of the produced prototype

Development teams were multidisciplinary including mechanical engineers, product designers and naval architects. This raised additional challenge for teachers – to provide the issues for all disciplines. Although the product appearance for presented task was not the dominant issue, it has been considered

as the important feature that contributes to the market success. Particular attention has been paid to the device ergonomics – user interface for manipulation in 3D space, ergonomics and usability of connections between modules, primarily the way of assembling and disassembling the modules from the main device. The partner company provided subsystems and components for movement control and air supply. The produced prototype was successfully tested in the company laboratory in a pool simulating the reactor vessel. Figure 3 shows the developed prototype and the distribution of responsibility for subsystems between teams.

4. NARIP - EGPR 2015 outputs

Besides CODEVE methodology (which was the core NARIP/EGPR 2015 output) and working prototype of the 2015 industrial project - both were thoroughly described in previous sections of this paper, the project resulted in vast 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 were published on this subject so far: [Štorga and Pavković 2015], [Močan et al. 2015] and [Vidovics and Horák 2015].

The industrial project 2015 was very valuable also 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 are various project guideline documents and project survey results, which testify about the applicability and repeatability of 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 urged 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.

In the first project year we thus developed and demonstrated the applicability of the CODEVE methodology in real industrial-academic environment. The supporting documents, which clearly describe each step in the collaborative design process in virtual environment, testify the details of the path taken to achieve the desired final result of new product development project – 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 through the whole project process using different techniques. There were regular interviews and meetings between industrial partner representatives and local staff analysing and discussing different forthcoming project risks, limitations and possibilities for the improvement. The academic staff held regular weekly meetings, where they reported the status updates of each team and cross-team activities to each other with the primary goal to identify potential problems, project delays or conflicts in 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.

5. Outlook, future work

The successful implementation and testing of CODEVE methodology was just a beginning of three-year long ERASMUS+ supported project of development, testing, optimisation, formalisation and dissemination of NPD methodology for industry-academia collaboration in virtual environment. Based on survey finding from the first project year a novel teaching and training methodology will be developed and tested in the second project year to satisfy the emerging requirements of the applied

innovative methodologies and the virtual collaborative environment. The output of this period will be an open-access set of course materials (called DEGO BB-Design GOes Beyond Boundaries): course description, protocols and guidelines, and multi-media teaching and training materials upon the best practices found throughout the project. In the second project year there will be organized a second design project, and together with the first-year results it will provide sufficient data and sample materials that a pool of teaching/learning sources would be possible to set up. It is planned that a design type specific (closely related to the design assignment provided by the actual industrial partner) and a generic (applicable for all product design and development projects) set of materials will be established. The material elements referred here show difference of great significance from and point beyond the standard e-learning course materials. On the one hand, design education has to be build up around the learning-by-doing principle for which and extensive theoretical and practical (coaching) activity are necessities, on the other hand the synchronous and asynchronous communication and collaboration challenges have to be satisfied, independently from the locality. The DEGO BB resources will be introduced and made open for wide public.

Studies on the effectiveness of NPD process in companies from the countries of partner organizations discovered that the biggest challenge is in the end phases of the process, namely identification of the market needs on one end and commercialization on the other. Many well established companies effectively recognize markets needs but fail to translate them to the technical departments so that instead of ' the voice of customer' technical departments often get 'voice of marketing' which then can lead to and inefficient NPD and often ends in the wrong product. The study will be performed for the duration of the project to identify challenges that companies which are being involved in the projects face in identifying market needs and commercializing their products. The study will also address the use of tools in NPD and identification of correct tools for specific projects. The special emphasis of the future work will be given on methods, tools and technology that apply to virtual academic enterprise and virtual design teams. Findings of the study will be translated into actions, which could be tested in the proposed network and formulated in research publications and workshops. It is expected that this study will generate new knowledge and allow faster integration of students who finish this course into their future employees.

Acknowledgement

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