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VIRTUAL PRODUCT DEVELOPMENT STUDY COURSES – EVOLUTION AND REFLECTIONS

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ABSTRACT
The product development teams become organizationally, geographically and culturally dispersed over the globe. The strategic alliance of several European universities has formed an "E-GPR" (European Global Product Realization) study course as a response to the product development challenges. The effective means for long-distance communication enabled intensive collaboration between competitive student teams. The industrial partners provided the project tasks to be solved within a short one semester time and required functional prototypes. We describe the setup of the course, the results, and provide some reflections. The course evolved during its repetitions over 7 consecutive years. The project work has been thoroughly monitored and the results have been assessed and quantified. The students should gain valuable experience in communication, organization, public presentation of work and prototyping and thus should better be prepared to tackle challenges associated with working in contemporary companies operating in a fierce business environment.

Keywords: Virtual product development, virtual team, engineering education, project based learning

1 INTRODUCTION
Integrated product development requires collaboration of all stakeholders in the product life cycle already during the early phases of product development, especially during product design. More and more stakeholders in the world are becoming organizationally, geographically and culturally dispersed (automotive industry is a typical example, e.g. Renault-Nissan and Ford-Mazda) [1, 2, 3].
Organizational, geographical and cultural dispersion is a consequence of adopting the so-called transnational strategy, which involves excentralization. It means centralization of activities in individual countries, for example centralization of developmental activities in countries with top-qualified research personnel mastering a certain technology or e.g. centralization of work-intensive manufacturing activities in countries with cheap labour. The transnational strategy is commonly employed by contemporary companies and enables them to simultaneously deal with the challenges of globalization and localization. Both globalization and localization induce complex changes in the business environment [4].
The changes in the business environment, responses of companies and the available information and communication technologies (ICT) pose a number of challenges to present and future product developers, as well as to educational institutions (universities, colleges and continuing education institutions within or outside companies), including [5]:

- work in geographically dispersed teams,
- work in multinational teams,
- work in cross-functional teams,
- work in multidisciplinary teams,
- working with a global customer base,
- developing communication skills,
- learning to apply and further improve engineering knowledge and skills,
- transfer of tacit knowledge,
- selection and every-day use of appropriate ICTs.

We believe that existing educational programs have not provided appropriate responses to these challenges. Therefore, product development teams at the Delft TU-Faculty of Industrial Design, EPFL and University of Ljubljana - Faculty of Mechanical Engineering decided already in 2001 to design and conduct an international course termed European-Global Product Realization (E-GPR), which should reflect the tasks of professional product development teams and their work conditions as realistically as possible. In this way, students would be better prepared to tackle challenges associated with working in contemporary companies operating in a constantly changing business environment.

The purpose of this paper is to describe the context of changing work conditions for product developers, which brings ever new challenges in the process of collaborative product development. The main focus is to present the setup of the course, evolution of the methods and the results and reflections made by a part of organizing team. An indirect purpose of this paper is also to promote the course and encourage the development/improvement of similar educational programs which will enable more effective integration of university graduates in development teams in companies which are facing increasingly fiercer competition in the contemporary marketplace.

2 THE APPROACH

The initial idea to design an international course came in 2001 from the Delft TU - Faculty of Industrial Design (TUD-FID) and was also adopted by the Ecole Politechnique Federale Lausanne (EPFL) and University of Ljubljana - Faculty of Mechanical Engineering (UL-FME) staff teams (partners). In order to prepare future product developers for challenges presented by the changing business environment as comprehensively as possible, these institutions decided to form a strategic alliance, whose main objective was to design, organize and conduct a competitive international course in the field of collaborative product development. Other objectives include the acquisition of experience and skills in such collaboration and creating of proposals for projects to be enrolled in domestic and international public competitions, along with their implementation.

In 2004, this partnership was also joined by the team of University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia (UZ-FME). In 2005, London City University, School of Engineering and Mathematical Sciences, United Kingdom (CUL-SEMS) joined the alliance.

Each of the partners is responsible in its own environment for education, research and consultancy in the field of individual product development activities. The knowledge and skills of the partners that are necessary for the organization and implementation of the E-GPR are complementary in nature and partially overlap, which enables constructive cooperation.

2.1 The alliance of multiple European universities

The selection of partner institutions is one of the crucial factors for success of the strategic alliance, as institutions can achieve agreed-upon goals only with appropriate partners. In essence, companies seek partners who have the missing resources at their disposal (in our case specific knowledge and skills), but they must also have certain resources which are interesting to potential partners. Without mutual and complementary resources, the partnership would be doomed to failure [6, 7].

Personal acquaintances before the beginning of collaboration are regarded as stimulative for virtual teams in industrial environments, and this was also the (positive) experience of the E-GPR organisational team. This is because the E-GPR course framework was designed at a two-day face-to-face meeting of all its members in Lausanne, in the autumn of 2001.

In the case of E-GPR, forming of the strategic alliance proceeded quite smoothly, primarily because team leaders were personally acquainted beforehand and because all members were motivated to create an attractive international course on collaborative product development. The majority of team members had already met face-to-face at various occasions before the course was organised, but they had never before collaborated on joint projects.

Preparation of details for each year's E-GPR course (e.g. list of topics to be covered by lectures, lecturers, participating companies, problems to be solved by students, date of the final workshop) have been agreed upon mostly via a video-conferencing system. These preparations are marked by a very high degree of harmonisation of university schedules, organisational team schedules, lecturers etc., and this requires immediate feedback that is enabled by synchronous communications. On the other hand, e-mails are used almost exclusively in the preparation of materials for individual video conferences.

2.2 Addressing the challenges

The organizers of the E-GPR course strived to develop a curriculum that would most realistically reflect the circumstances, activities and tasks of professional product development teams. A good approximation to the real environment can offer challenges that (future) product developers will actually be facing during their work. Integrated (i.e. concurrent) product development is a demanding and complex activity as it is, and its level of difficulty is additionally increased by the ever-changing business environment.

Challenges presented in the introduction included working in cross-functional, multidisciplinary, multinational and geographically dispersed teams. For such teams, the use of the term "virtual teams" has become widely established. A virtual team (one of definitions) is characterized by interdependence, shared values, and common goals. Additionally, its members are broadly distributed across geographies, cultures, time zones, or functional categories, and do not frequently meet face-to-face. They communicate mostly through electronic means, and their boundaries may be stretched by the inclusion of core and peripheral members and smaller teams subsumed by larger teams [8].

Virtual teams are being touted as the optimal way to work in 21st century to assist organizations (not only product development teams) in meeting the challenges of global competition. A recent study by the Gartner Group (international research company headquartered in the USA), stated that by 2008, 41 million corporate employees worldwide will operate in a virtual workplace at least one day per week [25].

Many companies have tried to develop products using virtual teams, with greater or smaller degrees of success [1, 8, 9]. These teams are supposed to provide many advantages over traditional teams, including the ability to bridge time and space (e.g. "follow-the-sun" product development), better utilization of distributed human resources without physical relocation of employees, ability to hire the best people regardless of their location, and organizational flexibility [10, 11].

Teamwork is an established method of product development, as individuals cannot master all of the scientific disciplines that are necessary for successful development. In the E-GPR course, multi-disciplinarity and cross-functionality are ensured by including students from various universities and faculties who possess different, but complementary types of knowledge, experience and skills. The geographic dispersion is ensured, as these teams consist of university students from three (five after the year 2005) European countries. This also ensures multinationality, especially because the majority of universities enroll students from third countries either on a full or temporary basis (within the framework of various student exchanges) and some of them participated in virtual E-GPR teams.

The set of products to be developed within the E-GPR course is drawn up by the representatives of the E-GPR partner companies (LIV d.d., Postojna-Slovenia in 2002, De Vlamboog B.V. -the Netherlands in 2002, 2003 and 2004, AVIDOR S.A.-Switzerland in 2005, NIKO Železniki-Slovenia in 2006, Kesslers International Ltd. UK in 2007 and Tehnix d.o.o.-Croatia in 2008, see Table 2). All of these companies are marketing their products in international markets and have access to an international customer base offered also to the E-GPR students.

Working in virtual teams, cooperation with the E-GPR partner companies (i.e. problem owners) and suppliers of various off-the-shelf components, etc., requires an intense use of communication skills. Students acquire these skills during their studies at individual universities, but the E-GPR course provides an opportunity for them to apply this knowledge and acquire experience and skills in a real environment.

Integrated product development, which is intended to solve selected problems in an E-GPR partner company, is a process that enables the application of knowledge acquired during studies in individual universities as such, but participation in a team of students who possess complementary knowledge and work with experienced instructors and professional engineers from E-GPR partner companies offers opportunities for further advancement of their engineering knowledge and skills.

An important characteristic of integrated product development is a high share of tacit knowledge. Tacit knowledge is personal, hard to formalize and highly context specific, and as such it is difficult to transfer or share. For example, experience, intuitions, insights and hunches are of tacit nature. Spender suggested that tacit knowledge could be understood best as knowledge that has not yet been abstracted from practice [12].

E-GPR enables transfer of tacit knowledge between individual students, as well as between students and instructors, via virtual teams engaged in project work (learning by doing) supported by a coaching system. Knowledge transfer is also facilitated via ad-hoc based team member interaction with other

team members, instructors and professional engineers from the E-GPR partner companies. These modes provide possibilities for individual knowledge transfers, which are believed to be a successful way to transfer tacit knowledge within organizations and among collaborating organizations [13, 14].
Nowadays, integrated product development cannot be done without ICT. E-GPR also involves their intense use: from computers and other hardware of various capacities through various local and international communication networks to varied system and user software (e.g. 3D modelers, FEM, CFD and visualization software). In the E-GPR, emphasis is especially on the use of ICT and less on its selection, which depends on a number of various factors (e.g., company size, available company budget and the respective industry sector in which a company operates).

2.3 Course outline

The E-GPR educational institutions designed an educational course comprised of lectures on specialized topics and project team work supported by selected companies. The course concludes with a one-week closing workshop and presentation of functioning partial or complete physical prototypes that have been produced by virtual teams. In this last week, all students meet face to face for the first time.
The curriculum is prepared in such a manner as to constitute a well-rounded package and ensures a high degree of realism of working environment for product developers (details in [15, 16]). Image materials for the lectures are accessible at the project home page a week before each lecture. The students are thus able to prepare for the lectures in advance and participate in them more actively during Q&A sessions. All lectures are recorded and the tapes/DVD's are available on the server [17].
The lectures take place twice a week (formally four academic hours per week). Communication is conducted in English. Via lectures, students are provided with a systematic insight into basic knowledge and given concrete examples of global products. Academic lectures, cases from industry and project work are interwoven throughout the semester, in which the lectures act as navigated learning elements for the project work. The communication between partners was accomplished by means of videoconferencing.
The reason there is such a large emphasis on realism is that we desire to show the students (i.e. future members of product development teams) the challenges that professional product development teams are faced with every day. The project work is very intensive and plays the central role for the students. Intensity of effort is one of the characteristics of successful product development and also important for later retrieval of product development knowledge: the more material is processed – the more effort used, the more processing makes use of associations between the items to be learned and knowledge already in the memory – the better will be the later retrieval of the item [18]. It has also been shown that participation in project work through direct experience is the most important source of developing project competence [19, 20]. The design process knowledge has been implemented throughout all the E-GPR courses, since such knowledge is useful regardless of the type of products to be developed. It means that design process knowledge is of universal character and hence transferable from one product area to another. It is not surprising that design process knowledge was percieved by companies as more important than product knowledge [21].
The set of tasks (i.e. products to be developed) is drawn up by the representatives of the participating companies. Each virtual development team is composed of students from all the five (three in the first three years) participating universities. Table 1 illustrates the extent of E-GPR project work and the aims distributed over several phases.

Table 1. The aim of project reviews and the issues to be addressed

Review #	Aims of project review	Issues to be addressed in the report
1	Presentation of findings in the problem definition phase of designing a stairway load transport system. Additionally, the management issue of the design group should be shown by presenting	Analysis of company needs and understanding of the design task. Market research, available methods used for transport devices. Review of equipment available on the market. Requirements & objectives. SWOT analysis of the company. Functional model of the transport machine. Constraints – boundaries within which the transportation system is designed. Managerial issues of the group: Scope-Spending-Scheduling. Work

	organizational tools, such as the Gantt chart and the calendar.	breakdown structure; Gantt chart, Calendar of activities
2	Presentation of the conceptualization phase of product development. The developed concepts should be evaluated against requirements.	Report on at least three different(!) concepts which are reasonably feasible and manufacturable within the scope and resources of the EGPR course. Specification of advantages and drawbacks of all listed concepts. Addressing the fulfillment of each requirement stated by the company. Specification of criteria with which the team believes it is possible to assess the concepts. Estimation of the necessary resources and time needed to manufacture the prototype. Estimation of prototype costs. Estimation of product costs in mass production.
3	Presentation of the final designs which will be carried forward for prototype development during the workshop week. The design should be finalised by this time and the manufacturing plan should be prepared.	Elements of the final design. Analysis of the manufacturing or procurement methods needed for components in the final design. Cost estimates for manufacturing or procurement. Time schedule for completion of prototype components.
Final	During the workshop, the team will assemble and test the prototype and present the project and its final results. Each team will have Power Point and poster presentations at the workshop, and the final report will be submitted one week after the workshop.	Market analysis and customer evaluation. Evaluation of competitors' products. Project objectives and requirements. Process of product conceptualization and definition. Description and validation of design proposal. Prototype explanation and product features. Material selection and sizing considerations and actions. Manufacturing considerations and actions. Consideration of costs, sustainability and life cycle. Conclusions and assessment of fulfillment of the project objectives.

3 THE TASKS DESCRIPTION OF PAST PROJECTS AND THE RESULTS

The E-GPR project courses were organized for several years in a row. During years, new partners joined the enterprise. Each year, an industrial member was selected in order to support the enterprise and provide a unique project task. Each partner contributed 2-3 staff members and 4-15 students. The Table 2 lists the organizational characteristics of each course.

Table 2. EGPR participants and tasks

Year	Project task	Industrial partner	Academic partners	Nr. staff members	Nr. students	Final WS location
2002	Vacuum cleaners + Welding protection	LIV d.d. SLO + De Vlamboog B.V. NL	NL, CH, SLO	3+2+3 = 8	8+6+6 = 20 2+3 teams	SLO Ljubljana
2003	Welding protection	De Vlamboog B.V. NL	NL, CH, SLO	3+3+3 = 9	10+10+16 = 36 4 teams	NL Delft
2004	Visualization masks + Welding protection	De Vlamboog B.V. NL	NL, CH, SLO, CRO	3+3+4+2 = 12	10+6+14+12 = 42 2+3 teams	CH Lausanne
2005	Vineyard eco-spraying	Avidor S.A. CH	NL, CH, SLO, CRO, UK	3+3+3+2 +1 = 12	6+13+14+8+2 = 43 6 teams	CH Lausanne

2006	Stair transport	Niko d.d. SLO	NL, CH, SLO, CRO, UK	3+2+3+2 +2 = 12	8+10+12+14+4 = 48 6 teams	SLO Ljubljana
2007	Male grooming products display	Kesslers international Ltd. UK	NL, CH, SLO, CRO, UK	1+2+1+2 +2=8	5+6+2+4+4=21 4 teams	GB London
2008	Mobile eco house	Tehnix d.o.o. CRO	NL, CH, SLO, CRO, UK	1+2+2+1 +2=8	5+7+9+12+10= 43 5 teams	CRO Zagreb

In year 2002, two industrial partners were selected, LIV Postojna SLO and deVlamboog NL. The project tasks were: "Development of an innovative vacuum cleaner" and "Development of an innovative portable respiratory unit for welders". Two prototypes of vacuum cleaners and 3 prototypes of portable respiratory units were developed.

In year 2003, a single industrial partner deVlamboog NL supported the course. The task was less constrained: "Development of a Welders' protection tools". Team 1 developed new mask type and integrated welding torch, fresh air supply and contactless energy supply for respiratory unit. Team 2 developed an external fresh air supply unit with intensive filtering. Team 3 developed an external welding fumes' suction unit. Team 4 developed an innovative portable respiratory unit and a welding digital visualization mask mockup.

In year 2004, deVlamboog supported the course with higher expectations. Two tasks were given: "Development of visualization masks" and "Development of portable respiratory units with design optimized for mass production". Teams 1 and 2 developed welding helmets with integrated small electronic cameras and electronic head mounted LCD displays, which enable welders' eye protection, light adaptable viewing and recording of images for later inspection. Teams 3, 4, and 5 developed portable breathing protection units, which were optimized in terms of engineering design, performance, and assembly, number of parts, standardization and mass production costs.

In year 2005, Swiss company AVIDOR was supporting the project task "Development of vineyard eco-spraying device". The aim was to design systems, whose predominant characteristics should be smaller consumption of the spraying agent per vineyard area square unit. Team 1 designed a special liquid micronizator, which disperses liquid into very fine spray (Figure 1). Team 2 designed tubular spraying units with nozzles and fans, mounted at two different heights. Team 3 designed system for foam spraying with very targeted deposit (Figure 2). Team 4 used tenth cover over the nozzle unit to prevent loss of spray into air. Team 5 designed energy efficient system with self rotating rods with nozzles. Team 6 provided a prototype with sensor driven hydraulic drive, which adapted the amount of spraying to the geometrical configuration of the plants.

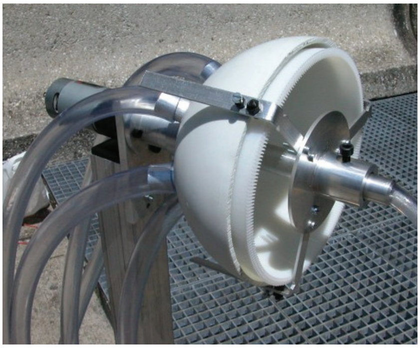

Figure 1. Spraying media droplet micronizator

Figure 2. Foam spraying

In 2006, Slovenian company NIKO provided the project description: "Development of a device for transport of loads up to either 150kg or 300kg up and down the stairs". Team 1 provided a prototype able to use either human power in an efficient way or a small electro drive. Team 2 designed a solution with a pneumatic piston drive and a compressed air within a diving bottle as a source of power (Figures 3 and 4). Team 3 manufactured a heavy-duty caterpillar drive for 300 kg load. Team 4 designed light-weight cart with gearbox and standard electric drill drive. Team 5 engineered light-weight caterpillar driven cart with easy-load system. Team 6 designed a geometrically flexible caterpillar drive for heavy loads.

In 2007, the project definition by Kesslers International was: "To develop a technologically and technically advanced POP (point of purchase) brand specific display which would be used for displaying male grooming products produced by a brand at the premium range ". The teams developed various concepts: e.g. team 4 provided " The moving blocks" concept (Figures 5 and 6). The concept's main features are (i) drawing attention by movement, brand promotion and simplicity, (ii) interaction with a customer by skin testing and an advice giving questionnaire, and (iii) clearly showing male grooming characteristics, while still attracting female consumers.

In 2008, the Croation company Tehnix provided the project definition: "Development of a self-contained energy units for an energy-independent dwelling unit". One of the concepts was presented as a dwelling unit built on standard sized TEU container equiped with alternative energy sources (solar panels and wind turbine) and charactarized by high mobility.

Figure 3. CAD model pneumatic drive

Figure 4. Prototype pneumatic drive

Figure 5. "The moving blocks" concept (CAD model)

Figure 6. Prototype

Typically, the manufacturing of the prototypes started after the last (third) project review, when the details of the solution have been approved by both the staff and the industrial company partner representatives. The manufacturing progress was monitored by the staff members. Several aspects of the E-GPR manufacturing may be observed:

- The complexity of the solutions was constantly rising from 2002 to 2006. The difference may be illustrated as follows: in 2002 the prototypes consisted of several parts, while in 2006 they consisted in average of close to 100 different parts to be assembled. Another example: the only

moving parts in 2002 were the air blowers bought on the market, whereas in 2006 there were custom made mechanisms designed to transfer high loads.
- The fulfillment of originally posed requirements was more thoroughly checked. While in 2002 the requirements were not exactly posed, the project in e.g. 2006 was very precise concerning the prototype performance in terms of speed, load, dimensions and prototype weight.
- The manufacturing documentation was becoming more complete. A lot of improvisation was done in 2002 during the last three days of prototype manufacturing and assembly without any technical documentation. In e.g. 2006, the majority of the parts were made of steel or other metals, whose manufacturing required precise technical documentation well in advance.
- The completeness of the prototypes prior to the start of the workshop was higher. While in 2002, the majority of the part manufacturing was performed in four days during the Workshop, in e.g. 2006 due to the high number of complex parts the majority of the parts had to be designed and documented well in advance and manufactured prior to the start of the Workshop (see comparison of CAD model and prototype for 2006 on figs 3-4).

4 THE IMPROVEMENTS TO THE COURSE

To gradually increase the quality of the course, the staff was carefully selecting appropriate measures and intensified preparatory activities, project progress monitoring and final workshop organizational activities. We believe that the following actions had an important impact on the improvement of the course results:

- **Organizational efforts increased.** In 2002, only 3 staff preparation meetings were held to prepare the course details. In e.g. 2006, 14 staff meetings were held prior to the course start! During preparation meetings, the numerous official documents have been prepared and consolidated, the alternatives discussed, selection of an industrial partner was judged and confirmed, and assessment schemes were consolidated and future actions defined.
- **The preparatory documentation was improved.** In 2002, only three documents describing the course were issued. In 2006, 10 such documents were prepared in advance. The staff prepared a formal agreement between the partners, course description, project task description, course time schedule, the selection of academic lectures, the expected content and quality of the student reports and presentations, assessment schemes, testing conditions and so forth. All documents have been made public prior to the start of the course. The intent was to present all aspects of the course to the participant candidates in a best possible way.
- **The communication equipment accessibility was improved.** In 2002, Ljubljana partner, for example, was using single videoconferencing device, attached to ISDN phone lines with 384 kB/s. In 2006, Ljubljana was using 3 such devices, connected to internet with 768 kB/s connection. No limitations regarding the time schedule of connections were posed to the students. Students were encouraged to use the videoconferencing as much as possible.
- **The project task definition has been improved.** The E-GPR staff helped companies to formulate the acceptable set of requirements, which were clearly identified and were feasible within the scope of the project. In 2005 and 2006 official field testing of the prototypes was carried out with multiple functional tests to quantify the performance. In 2006, the prototypes were evaluated for speed, load, weight, overall dimensions and the expected mass manufacturing costs.
- **The advanced prototyping techniques were made more accessible.** In 2003 vacuum thermo-forming was extensively used to manufacture the prototype housings. In 2004, direct 3D printing from ABS was made available by Croatian partner, which allowed design of complex part integrating multiple functionalities. In 2005, 3D printing was exploited once again. Hydraulic drives provided extensive source of power for the energy consuming prototypes.
- **Active monitoring of the students' work.** Nr. of project reviews has been increased from two to three. The amount of reporting material has been severely constrained in order to save students' time but to keep the staff informed (Table 1). The formal team leadership has not been established, however, each team was assigned an active staff member to monitor the progress and to act as an advisor. During the manufacturing stage, checking tables were provided with components and level of completeness listed.
- **Manufacturing help provided by industrial company partner.** In 2005, 2006 and 2007

industrial partner provided extensive manufacturing help to the students. In 2005, help was provided only during 4 days of the final workshop. In 2006, majority of the parts were provided by industrial partner prior to the workshop, and extensive help was provided also during the workshop.

All above improvements were based either on experience gained during the course leadership and organization or by acquiring the information by student questionnaires at the end of each course. Each partner contributed several staff members to help in organization, who worked partially on the course. We estimate, that at least one instructor per partner should be engaged full time in E-GPR preparation and execution, whereas during the culmination of the Workshop, help of others is necessary.

5 REFLECTIONS ON THE E-GPR COURSE FROM THE UL STAFF PERSPECTIVE

During the formation of the organizational team and designing of each year's detailed programs, as well as during the execution of the E-GPR course, it was found that quality of communication is one of crucial elements for successful and creative functioning of virtual teams. Quality refers to both the content of passed messages and to their transfer. Technically adequate sketches and equations reduce the possibility of misunderstandings and lack of clarity and thus facilitate the dissemination of information. For complex parts, which require 3D design, the CAD modelers are adequate to design (i.e. to implement ideas), visualize, verify and communicate ideas to other team members; it was also found that implementing to much detail early in the process might hamper creativity and flexibility, and develop resistance to introduce necessary design changes. The quality of transfer, on the other hand, refers to appropriate infrastructure (local and international data communications networks) and communication equipment, as well as its appropriate handling and use. Interruptions, slow operation and inadequate handling and use of equipment divert attention from communication, and this has a negative impact on both the quality of discussions and on decision-making.

Regarding the type of communication, experiences from all previous E-GPR courses have confirmed the usefulness of video-conferencing in the conceptualization phase and the concept evaluation phase. Video communication is the only method of virtual communication that is closest to face-to-face communication. The confirmation is in line with The Media Naturalness Theory which regards face-to-face communication as most natural to humans; the theory states that a decrease in the degree of media naturalness of a communication leads to increased cognitive effort and increased level of ambiguity [22]. During the period of conceptualization when the team is searching for new ideas and proposals, a high degree of creativity is required. Therefore, face-to-face communication or an equivalent method of virtual communication is necessary. Some researches have even shown that there is no significant difference between the two of them [23, 24]. In other phases of product development (e.g. embodiment and prototyping), where less creativity and less information density were required, e-mails mainly suffice; video-conferencing was reserved mainly for taking final decisions.

5.1 Team roles

The formal leadership of the teams has been omitted so far. It would be a difficult task to select a leader among a team of e.g. 6 students and to enforce his/her role. In some teams a kind of rotational leadership was identified: a team member who mastered a specific activity took the leadership during the execution of the activity. However, where the disagreements between team members may pose a serious barrier for successful completion of work, an intervention of the staff was necessary.

It was found that one of the significant problems of all previous generations was related to assignment of individual roles and tasks, in spite of different and complementary knowledge of students from individual universities. A face-to-face meeting at the beginning of the course would solve the problem by providing students with a clearer understanding of the goals of the virtual team and facilitating the division of roles and tasks, as well as formation of the team's own management style and a common identity. Such initial meeting has been omitted due to budget constraints. Significance of initial face-to-face contacts has been proven by the E-GPR organization team, which had many personal contacts before its organization and team forming.

One of the possible drawbacks of the contents of previous lectures within the E-GPR course has been absence of lectures which cover team work, although learning about working in multidisciplinary teams is believed to be best done by working in such teams. Dedicated lectures on human dimensions of collocated and virtual collaborative work would enable students to understand key factors which influence communication and coordination in collocated and virtual collaborative work. Moreover, they would enable them to analyze critical situations accordingly and approach them using their gained experience.

5.2 Industrial partner

An important aspect of the course is the involvement of an industrial partner. To acquire the confidence and for pedagogical reasons, the academic virtual enterprise has to obey some rules of business, such as the performance of the product, deadlines, priorities, quality expectations, manufacturability and the budget constraints. Therefore, the time schedule has to be well planned and obeyed and the time allocated to particular phases of the project realization must be carefully chosen in order to follow the deadlines. Students have to be made aware of these facts. Monitoring of the students' work progress is thus necessary and many times an active participation of the staff is necessary.

After completion of the courses, some students complained on the amount of work, which was necessary for E-GPR compared to conventional alternative courses on their universities. However, they admitted, that the course was an unrivaled experience in intensive communication, using video-conferencing and related equipment, multidisciplinary team work and true completion of materialized prototype.

6 CONCLUSIONS

The paper has presented an international engineering design course organized and executed by a strategic alliance of three (later five) European Universities. The course begun in 2002 and the Universities' teams are finalising organisation of the eighth run in the spring 2009.

Many studies have shown that product developers often face problems because they are not appropriately trained for working under new circumstances [e.g., 26, 27]. Naturally, this finding also applies to students who intend to work as product developers, because existing educational programs only partially enable the acquisition of such knowledge, experience and skills. In our opinion, the E-GPR international course is an appropriate program. Through its realism and contents, it enables students to develop technical and also non-technical competencies, e.g. planning, estimation of time consumption, handling of changes, interaction with stakeholders and managing control. The non-technical competencies are becoming more and more important and acknowledged by companies. Holistic view of the product development process is probably the core value of the course.

The E-GPR course is believed to be better option than student industrial experience, because students would probably not have such high levels of responsibility within an industrial team as they have had within E-GPR student teams. We also believe that the learning curve of E-GPR students after their entry in the professional world is steeper - i.e. within a shorter period of time, they can become more effective product developers than those who did not participate in the E-GPR or another similar course. Our belief is partly based on the learned schema principle which is emphasized by the Media Naturalness Theory. It is also based on a large body of learning-curve research which has demonstrated that performance improves as a result of increased experience [e.g., 28, 29].

In our opinion, in addition to a realistic work environment for product developers, the E-GPR course also encourages collaboration between universities in the international arena, as well as between universities and companies in the international arena, and represents an opportunity for continuing education of professional product developers.

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