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EXPERIENCES BASED ON SIX YEARS OF THE E-GPR COURSE

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ABSTRACT
The world is in the middle of the globalization process that, among other things, forces companies into acquisitions and mergers, and strategic alliances. This leads to the merging of geographically, organizationally and culturally heterogeneous human resources, including product developers. Market and organizational changes, the integrated product development process, and available information and communication technologies (ICT), present a number of challenges for future product developers. An appropriate response to these challenges is to create a solid basis for strategies to combat stronger competition, since existing educational programmes have provided this only to a small extent. European-Global Product Realization (E-GPR) course is one of possible educational programmes; the paper presents some experiences based on running the course.

Keywords: Engineering education, Collaborative product development, Virtual enterprise, Virtual team

1 INTRODUCTION
Global economy is increasingly facing complex changes in the business environment arising as a result of globalisation and localisation. From the economic standpoint, globalisation primarily means increased competition. Localisation primarily means responding to the requirements of local markets, which is done by companies via local differentiation of their products and services. Local market requirements are usually the result of cultural differences, which are reflected in different value systems, habits and social norms [1, 2, 3].
Companies are thus exposed to many often opposing demands which are represented by the business environment. The strategy commonly employed by contemporary companies, which enables them to simultaneously deal with the challenges of globalisation and localisation, is the so-called transnational strategy. It involves excentralisation, i.e. centralisation of activities in individual countries, for example centralisation of developmental activities in countries with top-qualified research personnel mastering a certain technology, or e.g. centralisation of work-intensive manufacturing activities in countries with cheap labour.
Companies wanting to follow the transnational strategy simply do not have readily at their disposal all of the human, financial and technological resources required to fight increased competition. The methods which provide access to missing resources primarily include foreign direct investments (i.e. greenfield investments and mergers and acquisitions) and strategic alliances (bilateral (e.g. Renault-Nissan)), multilateral (e.g. Star Alliance) and many bilateral strategic alliances of individual companies (e.g. General Electrics has concluded strategic alliances with partners in various areas of its business operations, e.g. with Honda (development of jet engines for business planes), with Harrison Western Companies (development of comprehensive solutions for purification of mine waste water), with Magnum Hunter Resources (pumping of oil and natural gas) and with iSixSigma LLC (designing of methods for increasing the quality of medical care at the global level) etc.) (Figure 1) [1].

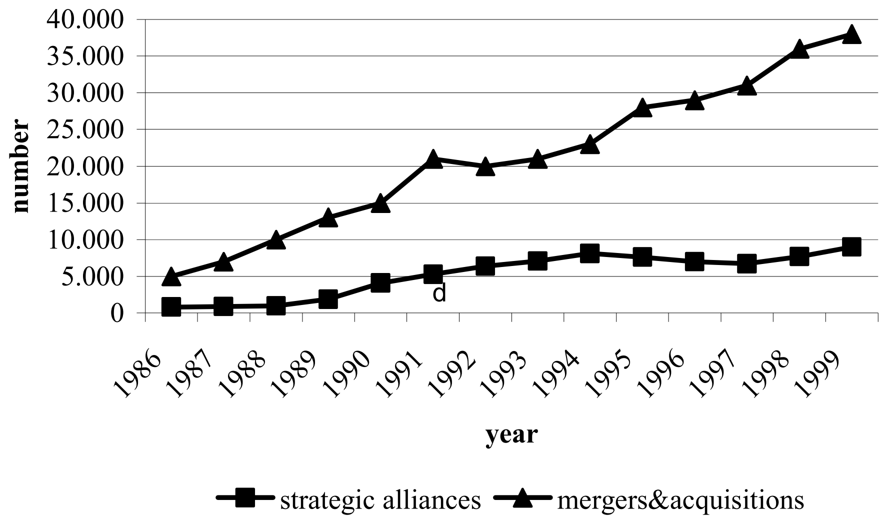

Figure 1. Movement of the number of mergers and acquisitions, and strategic alliances in the period 1986 -1999 [4].

The methods of implementing a transnational strategy which enable effective company functioning in conditions of increased competition result in functional merging of geographically, organisationally and culturally dispersed human resources.

For the above-mentioned human resources, access to the broadest possible knowledge base means that the varied demands of a more international clientele can be more easily met [5]. In the opinion of many companies, development of global products necessitated drawing on the local expertise of individuals residing in the countries for whom new products were being developed (influence of localisation) [6].

Naturally, this also applies to integrated product development as a prerequisite for the existence and progress of many companies. 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 [e.g. 7]. Increasingly more stakeholders in the world are becoming organisationally, geographically and culturally dispersed (automotive industry is a typical example, e.g. Renault-Nissan, DaimlerChrysler and Ford-Mazda) [e.g. 8, 9, 10].

To summarise, it can be said that changes in the business environment, responses of companies to these changes 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 [11]:

- work in cross-functional teams,
- work in multidisciplinary teams,
- work in multinational teams,
- work in geographically dispersed 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 application of appropriate ICTs.

An appropriate response to these challenges is to create a solid basis for strategies to combat stronger competition, since existing educational programmes have provided this only to a small extent. Therefore, teams at the TU Delft, EPFL, and University of Ljubljana decided in 2000 to design and conduct an international course, European-Global Product Realisation (E-GPR), which will 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.

Table 1. Organisational team of the E-GPR course

Member	Institution	Educational Program	Time period
1	Delft University of Technology, Faculty of Industrial Engineering, the Netherlands	Industrial Design	2002 – present
2	Swiss Federal Institute of Technology, School of Engineering, Lausanne, Switzerland	Micro-Engineering and Communication systems	2002 – present
3	University of Ljubljana, Faculty of Mechanical Engineering, Slovenia	Mechanical Engineering	2002 – present
4	City University London, School of Engineering and Mathematical Sciences, United Kingdom	Electrical Engineering	2004 – present
5	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia	Mechanical Engineering	2004 – present

The purpose of the paper is to describe the context of changing work conditions for product developers, briefly introduce the course which should provide realistic work environment, present some findings based on the survey conducted among E-GPR students and comment on the results. An indirect purpose of this paper is to promote the course and encourage the development of similar educational programmes which will enable more effective integration of university graduates in development teams for companies.

2 FOUNDATIONS OF THE E-GPR COURSE

The E-GPR course can be classified as third-generation approaches, which extend the contextual scope by integrating advanced educational concepts with ICTs, to achieve the best possible results and to create a pro-innovation attitude in the education of engineering students. The course is organised as a virtual enterprise. A virtual enterprise is a temporary alliance of autonomous, diverse and possibly geographically dispersed organisations (e.g. universities, laboratories, companies) that come together to share skills and resources in order to better respond to business opportunities (educational challenges in our case), and whose cooperation is supported by ICTs [12]. A media room that supports virtual collaboration is shown in Figure 2.

The new educational concept is to shift the responsibility of learning to the students, with the instructors playing only the supporting role of advisors and also establishing the framework, objectives and boundaries of the course/project. For these reasons, the theoretical and methodological framework of the E-GPR course rests on the following three hypotheses ([13]; where details on the course can also be found):

- opening the conventional educational institution towards an academic virtual enterprise,
- consideration of university students as evolving young professionals, acting as academic knowledge producers and facing practical engineering problems,
- putting creative problem-solving and disciplinary research in the position of the ‘engine’ behind academic learning and teaching.

Figure 2. Media room in Ljubljana.

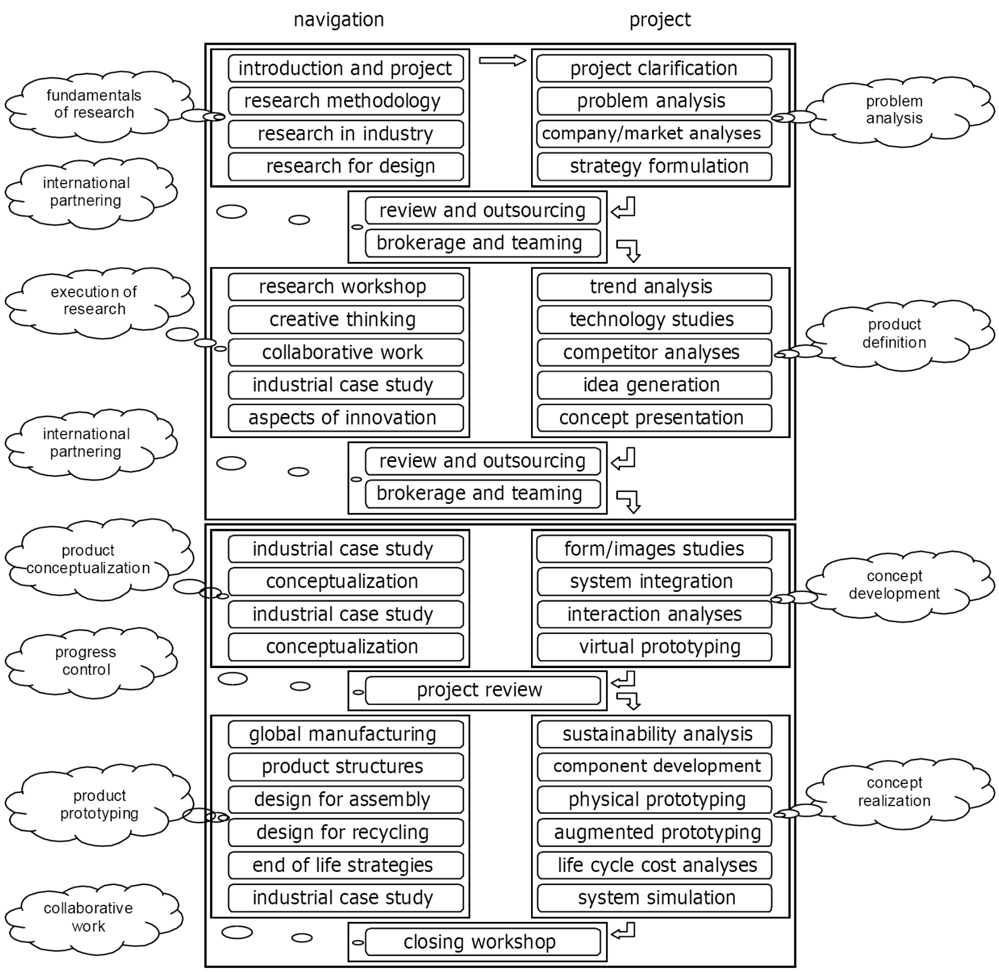

Figure 3. E-GPR course layout [14]).

Students were supposed to actively participate in the knowledge exploration and utilisation process, and to evolve into creative professionals who:

- co-operate in goal-driven learning of the subject materials and in developing the skills of

problem-solving, collaboration and co-ordination;
- solve real-life engineering problems in communities of practice by using the most advanced technologies;
- learn the principles of remote collaboration, knowledge brokerage, capacity acquisition/outsourcing and provision of services;
- transfer their results and experiences directly to industry, and publish them in international journals and proceedings.

The E-GPR course layout, which ensures a high degree of realism of working environment for product developers, is shown in Figure 3.

3 SOME FINDINGS OF THE SURVEY

The opinions and experiences of the students were collected using questionnaires. For the first two generations (academic years 2001/2002 and 2002/2003), there were problems contacting E-GPR participants, since most of them have graduated and cancelled their university email accounts. The basic reason for such and similar difficulties (e.g. preparation of uniform questionnaires) related to the performance of E-GPR analyses lies in the fact that during preparations for the course there was no emphasis on the idea that the E-GPR course itself could serve as a research project in which the performance and behaviour of individual teams and team members could be observed.

Nevertheless, it is believed that the acquired data confirm the impressions collected via personal communication over the years: students in general are very positive about having an opportunity to work in a virtual academic enterprise. For example, 33% of students who have completed the E-GPR course and returned filled-out questionnaires consider the course to be the most valuable one they have attended and 55% judge the course to be useful. In their opinion, the greatest benefit was obtained from two activities:

- Use of video-conferencing (58%),
- Designing in multidisciplinary teams (58%).

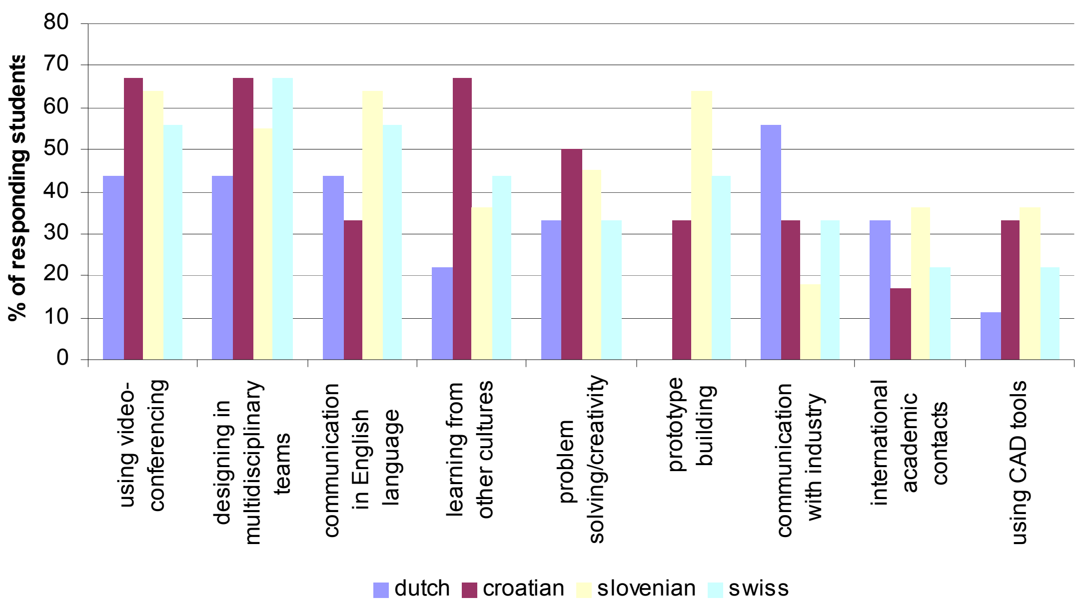

Figure 4. Collected data sorted by participating universities.

The following list includes other activities which are characteristic of collaborative product development:

- Communication in the English language (49%),
- Learning from other cultures (42%),

- Problem solving/creativity (40%),
- Prototype building (35%),
- Communication with industry (35%),
- International academic contacts (27%),
- Use of CAD tools (26%).

The data sorted by participating universities are shown in Figure 4 [11].
We are especially pleased to see that those types of knowledge, experience and skills which the organisers and designers of the E-GPR course consider important in facing the everyday challenges encountered by product developers working in global companies are the most highly appreciated.
Regarding factors which influence team creativity, let us emphasise three of the most important ones – in the opinion of students [11]:

- Time pressure (58%),
- Interindividual differences in skills and knowledge (50%),
- Limited communication facilities (47%).

These factors are emphasised because each generation of students mentions them as factors that most limit their creativity.
The E-GPR course has very strict deadlines, which are set prior to the beginning of the course. For deadlines set during the course, schedules of educational programmes of the participating universities and the amount of work to be done in between the milestones (i.e. deadlines) are taken into consideration. The aim of project reviews and the issues to be addressed by the set deadlines are summarised in Table 2.

Table 2. The aim of project reviews and the issues to be addressed

Review No.	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 organisational tools, such as the Gantt chart and the calendar.	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 breakdown structure; Gantt chart, Calendar of activities
2	Presentation of the conceptualisation phase of product development. The developed concepts should be evaluated against	Report on at least three different(!) concepts which are reasonably feasible and manufacturable within the scope and resources of the

	requirements	EGPR course. Specification of advantages and drawbacks of all listed concepts. Addressing the fulfilment 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 conceptualisation 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 fulfilment of the project objectives.

Strict deadlines are also typical of regular (professional) product development and they contribute to realism of the course which the organisers want to accomplish. In our opinion, another factor affecting the time pressure is the lack of any extensive previous experience with the use of 3D computer modelling. This means that much time has to be spent producing 3D models and they have many shortcomings; there is also much unnecessary explaining or even unintentionally misleading communication. Correct 3D models, on the other hand, are very understandable to other people and they enable quick evaluation of the design and appropriate engineering analyses, as well as a chance to point out potential feasibility issues.

Interindividual differences in skills and knowledge are to be expected in teamwork, but it is unclear from the students' responses whether they meant differences in the disciplines mastered by individual students or any other differences. It is assumed that the reason for this is the difference between the expected level of knowledge (students form an opinion about the level of expertise they expect from others at a video-conference, prior to team formation) and the actually observed levels, exhibited during actual work within the team. It is also assumed that teams formed by the existing E-GPR brokerage process are less efficient than would be teams with members selected by e.g. the instructors based on personality traits, intellectual styles, behaviour and professional competencies. To be able to build such teams, an adequate pool of students (in terms of number, diversity of talents and team roles) needs to be available [15].

Replies to the questionnaire showed that students put a lot of emphasis on communication. This is in agreement with findings on the importance of communication within virtual teams for team efficacy [16, 17, 18]. For example, Jarvenpaa and Leidner [18] find that the virtual environment strongly increases the need for communication because of a lack of trust and also because of uncertainties on whether other team members have read the messages, and if not, why not; are there technical problems or rather a lack of interest; are the messages interpreted correctly, etc. Kayworth and Leidner [19] find that response times in communication, interpretation of messages, coordination and supervision of team members are especially important in a virtual environment. However, they require abundant communication channels, which must be provided by technology. Trust within a virtual team is difficult to build due to lack of common past, cultural diversity, geographic dispersion and electronic communication [18]. The issues of trust within E-GPR teams are dealt with via so called electronic socialising (term coined by Zigurs [20]): exchange of information regarding hobbies, music, films etc. among virtual team members.

Furthermore, engineering and formgiving concepts are difficult to share due to limited communication channels [11]. This was especially true during the first E-GPR course in 2002, when less reliable internet connections were used for video-conferencing (very disturbing interruptions) and ISDN connections were slow (not enough of them were used simultaneously due to insufficient infrastructure and high costs). Furthermore, difficulties with video signal transmission caused frustrations and doubts as to the usefulness of ICT.

The responses were not that specific, but it is assumed that a high occupancy of local media rooms is the basic problem of technical issues related to E-GPR virtual product development. Students need to reserve them several days in advance, which prevents the use of video-conferencing (i.e. rich synchronous communication) in the case of unplanned complications where the problem context needs to be explained and a decision has to be made on how to continue work. In fact, only the team based in Ljubljana has its own media room that is fully reserved for the E-GPR project.

3.1 Limitations and difficulties within the course

Based on personal communication among staff members and students, at least five sources of limitations/difficulties can be identified that should be addressed in the future.

There are currently five partners within the E-GPR project. For several reasons, this number seems too high for this type of collaboration:

- Technical limitations: some local devices can host a maximum of 3 additional connections, so 4 partners can communicate simultaneously. Otherwise, an MCU has to be hired at some other sites, and this involves additional preparation for the technical staff (testing, reservations).
- The meetings (both staff and student) become very long, since every partner has to be given an opportunity to comment on the discussed matter. Often there were cases when a partner lost the connection and was unable to participate any more. After the lecture, all partners are given an opportunity to pose questions. A large number of partners means a long total time.
- It is difficult to adjust the course schedule to a large number of different academic calendars.

In all of the courses conducted to date, students did not meet in person until the final workshop. The main obstacle in this respect was always related to the costs of such meetings (primarily the costs of travel and accommodation). Students believe that an initial social contact would provide them with a

clearer understanding of the goals of the virtual team and facilitate the division of roles and tasks, as well as formation of the team's own management style and a common identity.
The potential solution concepts to solve the project task should be intensively communicated as early in the course as possible. There is a lack of knowledge among students on how to use appropriate tools to express their ideas. Only Delft students are properly trained to either sketch the design by hand or to use computer drawing tools, while other students generally make poor sketches. Even good knowledge of 3D computer modelling is not enough in the early stage, since it is time consuming to model details of the design in the conceptual phase, when there is a possibility for the concept to be rejected.
Staff members are expected to help students in the preparation and organisation of local team meetings and to offer some professional consulting support. In the final workshop, the staff should also actively help students finish the prototypes. However, currently there is no clear agreement between partners as to how much the staff should interfere with student work.
There is a lack of manufacturing facilities at many partner sites. Students should have better access to the manufacturing workshops during the course. Parts should be finished and painted beforehand, and only assembly and testing should be performed at the final workshop. If this ambitious aim is ever achieved, the E-GPR course could really be considered a completely virtual course with a materialised prototype that is manufactured on a world-wide basis (globally) and is only assembled locally.

4 CONCLUSION

Due to globalisation, which is most markedly characterised by increased competition, companies are designing new strategies for fighting competition and new organisational forms for implementing these strategies. This results in functional merging of geographically, organisationally and culturally dispersed human resources, which brings new challenges to teamwork.
In our opinion, through its realism, the E-GPR international course enables students to acquire the knowledge, experience and skills necessary to face challenges related to changes in the business environment.
Based on responses to the questionnaire, the opinions of surveyed students regarding the basic characteristics of the E-GPR course do not differ significantly between individual generations; the types of knowledge, experience and skills which the organisers and designers of the E-GPR course consider important in facing the everyday challenges encountered by product developers working in global companies are those which are the most highly appreciated. Opinions on the problems were also found to be quite consistent over time, which is a sufficient reason to upgrade the course or change it in a way that will alleviate these problems and gradually eliminate them altogether. Progress was also found in the field of communication infrastructure (greater capacity of communication networks), which enables greater usefulness of the video conferencing equipment, but the problem of high occupancy of media rooms still remains.
Based on the acquired experience and opinions of the involved staff and students, it is believed that participation in the E-GPR course provides a good basis for students to become more effective product developers within a shorter period of time than those who have not attended the E-GPR course or any other similar course.

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