Educating future product developers in collaborative product development: lessons learned from the European-Global Product Realization (E-GPR) international course

Nuša FAIN
and
Nikola VUKAŠINOVIĆ
and
Roman ŽAVBI

Faculty of Mechanical Engineering, University of Ljubljana
Aškerčeva 6, SI-1000 Ljubljana, Slovenia

ABSTRACT

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. An appropriate response to these challenges is to create a solid basis for strategies to combat stronger competition, since existing educational programs have provided this only to a small extent. In our opinion, the E-GPR course carried out by 5 European universities reflects the tasks of professional product development teams and their work conditions as realistically as possible and will enable students attending the E-GPR course who will soon enter the professional world to later progress along a steeper learning curve. This paper focuses on the role of communication between members of virtual teams and presents experiences gathered during the organization, designing and performance of each year's courses.

Keywords: strategic alliance, integrated product development, virtual team, communication, collaboration

1. INTRODUCTION

Global economy is increasingly facing complex changes in the business environment arising as a result of globalization and localization. From the economic standpoint, globalization primarily means increased competition. The strategy commonly employed by contemporary companies, which enables them to simultaneously deal with the challenges of globalization and localization, is the so-called transnational strategy. It involves excentralization, i.e. 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 labor.

Companies wanting to follow the transnational strategy simply do not have all of the human, financial and technological resources required to fight increased competition readily at their disposal. The methods which provide access to missing resources primarily include foreign direct investments (i.e. greenfield investments and mergers and acquisitions) and strategic alliances (e.g. bilateral, multilateral and many bilateral strategic alliances of individual companies) [1]. The methods of implementing a transnational strategy which enable effective company functioning in conditions of increased competition result in the functional merging of geographically, organizationally and culturally dispersed human resources.

For these human resources, access to the broadest possible knowledge base means that the varied demands of a more international clientele can be met more easily [3]. In the view of many companies, developing global products necessitated drawing on the local expertise of individuals who reside in the countries for which new products were being developed (influence of localization) [4]. Naturally, this also applies to integrated product development as the 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, no matter their location [5, 6, 7, 8].

Research has confirmed that the development of innovative and competitive products and the use of information technologies will have a crucial influence on long-term success in the global market [9, 10]. The development of such products requires appropriately trained product developers who possess a broad spectrum of professional abilities (e.g. customer-oriented thinking, methods for systematic product development, application of information technology and communication tools, international team interaction).

The constraints on engineering problem-solving today are increasingly not technical, but rather lie on the societal and human side of engineering practice [11]. Beitz and Helbig [9] e.g. found large deficiencies in the fields of group interaction skills, ability to present and represent knowledge of the English language, and ability to translate thoughts into action. Similar shortcomings (e.g. lack of skills required to work in multidisciplinary teams and insufficient knowledge of English) were also identified by managers of development departments of Slovene companies in a survey conducted in 2006 for the needs of curriculum updating at the University of Ljubljana (UL), Faculty of Mechanical Engineering.

To summarize, 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, including [12]:

- 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 programs have provided this only to a small extent. Therefore, product development teams at the Delft TU, EPFL Lausanne and Faculty of Mechanical Engineering Ljubljana decided already in 2000 to design and conduct an international course, European-Global Product Realization (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.

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 product development. The main focus is to present the role of communication between members of virtual teams and experiences acquired during the organization, designing and performance of each year's E-GPR course. An indirect purpose of this paper is also to promote the course and encourage the development of similar educational programs which will enable more effective integration of university graduates in development teams for companies which are facing increasingly fiercer competition in the contemporary marketplace.

2. COLLABORATIVE DEVELOPMENT OF THE E-GPR COURSE

Setting up the team - strategic alliance of 5 European universities

The initial idea to design an international course came from the team at the Delft University of Technology, the Netherlands (TU Delft) and was also adopted by the Swiss Federal Institute of Technology, Lausanne, Switzerland (EPFL) and University of Ljubljana, Slovenia (UL) teams. 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. The main objective of this alliance is to design, organize and conduct a competitive international course in the field of collaborative product development. The 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 teams of the London City University, United Kingdom, and University of Zagreb, Croatia. Each of the partner teams from universities is responsible in its own environment for education in the field of individual product development activities (i.e. market analysis, product conceptualization, industrial design, 3D modeling, various engineering analyses and rapid prototyping, group decision making and manufacturing technologies, etc.). The knowledge and skills of the teams that are necessary for the organization and implementation of the E-GPR are complementary in nature and partially overlap, which enables constructive cooperation. The knowledge and skills of students from the participating universities and faculties are also complementary.

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 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. These teams are supposed to provide many advantages over traditional teams, including the ability to bridge time and space, better utilization of distributed human resources without physical relocation of employees, ability to hire the best people regardless of their location, and organizational flexibility [e.g. 13, 14].

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, multidisciplinarity 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 several 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 participate 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 Postojna, Slovenia, De Vlamboog BV, the Netherlands, FEI Company, the Netherlands, AVIDOR, Switzerland and NIKO, Zelezniki, Slovenia, Kesslers International, United Kingdom, Tehnix, Croatia). 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 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 [15]. 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 [16, 17].

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 and 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).

3. COMMUNICATION EXPERIENCES WITHIN E-GPR

The common basis for work in geographically dispersed multidisciplinary cross-functional teams (i.e. virtual teams) is communication, which is necessary for effective collaboration. Communication comprises recognizing the need for information, designing of messages, selection of the communication media, sending of messages, the recipient's understanding of the message, and reply. When selecting the communication media, team members can choose from two large groups: synchronous (e.g., face-to-face meeting, video conferencing, telephone conversation, chat via chat software) and asynchronous media (e.g., e-mail, fax). Apart from the content of communication, effective collaboration also depends on the frequency of exchanged messages and their length. It can be intuitively inferred that there is no collaboration without communication, because the flow of ideas would be too slow or absent altogether and the relations among the members could not develop. However, too frequent and prolonged communication (in extreme cases, the entire time of working on a project could be spent only on communication) reduces efficiency. For example, Patrashkova and McComb have confirmed a curvilinear relationship between communication (measured by frequency and duration) and performance (i.e. on-schedule performance) [18]. Due to the specific nature of virtual teams, communication between team members has certain special characteristics, which may lead to low efficiency. Face-to-face communication involves spoken language, accompanied by voice intonation, facial expressions and body language. However, regular face-to-face meetings, which are considered to be the richest form of communication, are not possible in the case of virtual teams due to the geographic dispersion of team members. Multinationality brings different languages into virtual teams, along with differences in national and regional cultures, which may interfere with effective communication. Good knowledge of the language chosen for team communication is essential, as it enables quick flow of information and understanding of received information. Communication barriers arising from geographic dispersion may also be largely eliminated by using state-of-the-art information and communication technologies (ICT). During preparations for creating a strategic alliance for the organization and designing of the overall E-GPR program, as well as each year's E-GPR course and its execution, much experience was collected and in 2007 the crucial role of communication in virtual teams was confirmed by a survey among the participants of the course (figure 1).

Execution of E-GPR

Lectures: Yearly E-GPR course consists of lectures and project work. Lectures are done over a video-conferencing system and in fact they are the least problematic activity during the E-GPR project. Using additional tools, e.g. NetMeeting®, complex information can be exchanged as well, e.g. 3D models, spreadsheets, graphical and numerical results of various analyses. Graphical information may even partially compensate for poorer knowledge of the foreign language and thus facilitate understanding. In each of the media rooms, trained technicians operate local cameras of the video-conferencing system during Q&A sessions. The assistance of skilled technicians is indispensable, as it enables other participants to focus on the lectures. Detailed layout of the E-GPR courses can be found in [20].

Projects - team formation: Each E-GPR virtual product development team is composed of students from all five participating universities. E-GPR teams are specific in that some students participating in these teams come from the same faculty and can make arrangements on cooperation in individual teams face-to-face; this makes arrangements easier, as students already partially know each other from cooperating during the course of their studies. These students form so-called partial teams. On the other hand, selection of students from other participating universities is a greater unknown. Complete teams (composed of partial teams) are formed during the so-called brokerage process, which is conducted via a video-conference. On the basis of video-conference presentations of the partial teams, the questions and answers that followed, and their preferences, as well as the assistance of moderators (i.e. participating lecturers), students form complete teams of 5 to 10 members.

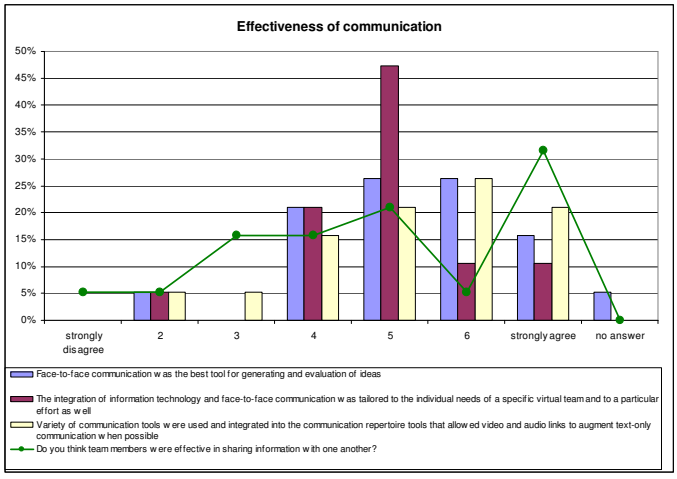

Figure 1. The effectiveness of communication during E-GPR 2007

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Trust is one of the essential components of successful virtual teams (figure 2). Trust primarily means having faith in other team members that they possess the knowledge, experience and skills based on which they were chosen for the team, as well as believing that they will use this knowledge, experience and skills in order to achieve common goals within the agreed-upon time limits, that they will constructively cooperate with other team members and will pass information that is important for decision making to other team members [21]. Successful teams are characterized by a high degree of trust, because among other things trust reduces the need for control and supervision, thus lowering operating costs [22].

When virtual teams are formed from members who do not have a common history (which mostly applies to professional product development teams [23] and also to E-GPR teams), trust needs to be established from the beginning. This requires intensive, constant and frequent communicating and additionally increases the need for communication [24]. In a virtual environment, the physical context and cues are missing, which means that greater effort is required for the development of interpersonal relationships within a team, which consequentially increases the need for communication – electronic socializing [25]. Electronic socializing is each year's popular activity within E-GPR teams.

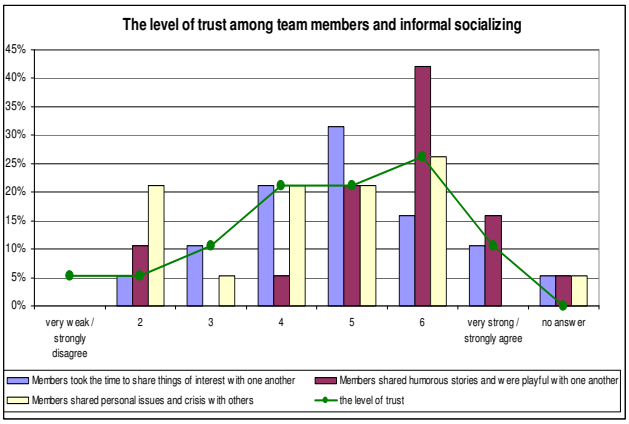

Figure 2. The level of trust and informal socializing during E-GPR 2007

Much information is exchanged among the majority of students concerning hobbies, the type of music they like and the movies they watch, etc. Since 2005, students have fully adopted the use of MSN® messenger in building interpersonal ties within E-GPR teams [26]. Electronic socializing is a constant activity because trust has to be maintained throughout a team's life-cycle. In all of the courses conducted to date, students did not met in person until the final workshop. The main obstacles in this respect were always the costs of such meetings (primarily the costs of travel and accommodation).

Projects - conceptualization and concept evaluation: During the period when the team is searching for new ideas and proposals, a high degree of creativity is required. Optimal communication enables the development of synergy, which ensures the team's creativity [28]. The technique of creative thinking usually requires face-to-face communication as it provides better effectiveness and team creativity [29, 30]. Some researches have shown that video-conferencing can provide similar levels of creativity as face-to-face communication [32, 33].

Experiences from all previous E-GPR generations have confirmed the usefulness of video-conferencing in the conceptualization phase and the concept evaluation phase. In many cases students have generated ideas before video-conferences dedicated to conceptualization. Some studies have shown that anonymous brainstorming gives better results than the traditional method [34], since there is no pressure from any criticism (a larger number of ideas and greater satisfaction). It is also possible that in this way some students have avoided inhibition in concept generation felt by presence of other people. However, it needs to be stressed that in this case there is no socialization of team members and no oral communication within the team, which reduces its effectiveness and satisfaction [34]. Having this in mind, we have decided not to favor any of the methods for idea generation; we have let the students to choose a method or mix of methods.

Video-conferences served as an opportunity for discussion, improvement of prepared ideas and also for generation of new ones. During video-conferencing E-GPR students have almost always used sketches shared via NetMeeting®, plasticine models, Lego® bricks or similar aids to support their ideas.

Usefulness of sketches and physical models during conceptualization is not only intuitively understandable, but it is also in line with the observations of Mulet and Vidal [35], who report that the use of visual or model presentation of ideas within a team significantly improves the number of developed useful ideas. The team's creativity is higher and the results are by far more useful.

Prototyping: Prototyping is the last phase of E-GPR in which communication still takes place via the use of ICT. In this phase, communicating is done mainly via e-mails, because prototypes are produced locally, depending on the available rapid prototyping technologies (e.g., vacuum forming, 3D printing, 3-axis milling of soft materials and water-jet cutting). Information on the status of production and prototype photographs is exchanged. Video-conferencing is used only at the phase beginning and helps E-GPR team members agree upon optimal technologies of prototype production, become informed of the availability and accessibility of appropriate equipment and then adopt their final decisions on the basis of this information.

Final workshop: The final workshop is intended for the final assembly, testing and exhibition of prototypes and public presentation of the work of all E-GPR teams (Figure 3). In this phase, all participants meet face to face for the first time and virtual teams become regular co-located teams.

Figure 3. Some creative results of E-GPR courses

4. LESSONS LEARNED

In an ideal case, a product would be developed by an individual possessing all the necessary knowledge, experience and skills. In this way, all problems related to team management, task assignment, coordination, communication, geographic dispersion, intercultural differences, differences in the motivation and level of knowledge of team members, knowledge transfer etc. would be eliminated.

However, the reality is quite different and team work is inevitable in product development. Due to globalization, which is most markedly characterized by increased competition, companies are designing new strategies for fighting competition and new organizational forms for implementing these strategies. This results in functional merging of geographically, organizationally and culturally dispersed human resources, which brings new challenges to teamwork.

Many studies have shown that product developers often face problems because they are not appropriately trained for working under new circumstances. 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 skills. In our opinion, the E-GPR international course is an appropriate program. Through its realism, it enables students to acquire the knowledge, experience and skills necessary to face challenges related to changes in the business environment. Furthermore, the learning curve of E-GPR students after their entry in the professional world is believed to be 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.

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, 3D models and equations reduce the possibility of misunderstandings and lack of clarity and thus facilitate the dissemination of information. 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.

Concerning work in virtual teams and communication within these teams, the significance of trust should be emphasized. Trust is the basis for effective functioning of these teams and if there are no face-to-face meetings, it needs to be established through intense communication, which however can temporarily reduce the efficiency of work in virtual teams. Personal experience of E-GPR participants has shown that it makes sense to enable face-to-face meetings of future virtual team members before these teams are actually formed. In this way, initial trust can be established. During the course of work, it needs to be constantly maintained and reinforced, but this is less time consuming and has a lower impact on the efficiency of teamwork.

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.

5. REFERENCES

[1] Barlett, CA, Ghoshal S. Transnational Management: Text, Cases, and Readings in Cross-Border Management, 3rd ed. Boston: Irwin McGraw-Hill; 2000.

[2] Narula R, Duysters G. Globalization and trends in international R&D alliances. Journal of International Management 2004; 10: 199-218.

[3] Boutellier R, Gassmann O, Macho H, Roux M. Management of dispersed product development teams: The role of information technologies. R&D Management 1989; 28: 13–25.

[4] McDonough EF III, Kahn KB, Barczak G. An investigation of the use of global, virtual, and colocated new product development teams. The Journal of Product Innovation Management 2001; 18: 110–120.

[5] Andreasen MM, Hein L. Integrated product development. reprint. Lyngby: Institute for Product Development, Technical University of Denmark; 2000.

[6] May A, Carter C. A case study of virtual team working in the European automotive industry. International Journal of Industrial Ergonomics 2001; 27: 171–186.

[7] Segrestin B. Partnering to explore: The Renault–Nissan Alliance as a forerunner of new cooperative patterns. Research policy 2005; 34: 657-672.

[8] Fujimoto T, Arturo Heller D. Recent trends in alliance-enabled capability building: implications for firm performance in the global auto industry: a dynamic view of the Ford-Mazda, Renault-Nissan, & DaimlerChrysler-Mitsubishi cases. In: Lung Y, editor. Proceedings of the Ninth GERPISA international colloquium on reconfiguring the auto industry: Merger & Acquisition, Alliances, and Exit, Evry: Universite D'Evry; 2001, p. 1-13.

[9] Beitz W, Helbig D. The future of education for product developers. In: Riitahuhta A, editor. Proceedings of the 11th International Conference on Engineering Design (ICED97), Zürich: Heurista; 1997, p. 493–8.

[10] Hundal MS. Engineering design education in the USA: Issues and challenges. In: Hubka V, editor. Proceedings of the 10th International conference on engineering design (ICED95), Zürich: Heurista; 1995, p. 318–323.

[11] Grimson J. Re-engineering the curriculum for the 21st century. European Journal of Engineering Education 2002; 27: 31–7, 2002.

[12] Žavbi R, Tavčar J, Verlinden J. Educating future product developers in virtual collaboration: 5 years of the E-GPR course. In: MacGregor SP, Torres-Coronas T., editors. Higher Creativity for Virtual Teams: Developing Platforms for Co-Creation, New York: Hershey; 2007, p. 48-74.

[13] Lipnack J, Stamps J. Virtual teams: People working across boundaries with technology. 2nd ed. New York: Wiley; 2000.
[14] Paul S, Seetharaman P, Samarah I, Mykytyna PP. Impact of heterogeneity and collaborative conflict management style on the performance of synchronous global virtual teams. Information and Management 2004; 41: 303–321.
[15] Spender JC. Organizational Knowledge, Learning, and Memory: Three Concepts in Search of a Theory. Journal of Organizational Change 1996; 9: 63-78.
[16] Inkpen AC, Dinur A. Knowledge Management Processes and International Joint Ventures. Organization Science 1996; 9: 454-468.
[17] Ylinenpää H, Nilsson N. Knowledge transfer and organizational competence building: a case study of two knowledge-intensive firms. In: Proceedings of the 5th Conference on Competence-based Management, Helsinki, 2000, p. 1-17.
[18] Patrashkova RR, McComb SA. Exploring why more communication is not better: insights from a computational model of cross-functional teams. Journal of Engineering and Technology Management 2004; 21: 83-114.
[19] IJsendoorf H. Application of computer aided systems, PD&E Automotive, E-GPR (2001/2001) Industrial case study, discussion, 2002.
[20] Horváth I, Wiersma M, Duhovnik J, Stroud I, Navigated Active learning in an international scientific academic virtual enterprise. European Journal of Engineering Education 2004; 29: 505-519.
[21] Nemiro JE. Creativity in virtual teams: key components for success. San Francisco: Pfeiffer; 2004.
[22] McAllister DJ. Affect- and cognition-based trust as foundations for interpersonal cooperation in organizations. Academy of Management Journal 1995; 38: 24–59, 1995.
[23] Kanawattanachaia P, Yoob Y. Dynamic nature of trust in virtual teams. Journal of Strategic Information Systems 2002; 11: 187–21.
[24] Iacono CS, Weisband S. Developing trust in virtual team. In: Nunamaker F Jr, Sprague RH Jr, editors. Proceedings of the 30th Hawaii international conference on system sciences, Piscataway: IEEE Computer Society Press; 1997, p. 412–420.
[25] Zigurs I. Leadership in virtual teams: Oxymoron or opportunity. Organizational dynamics 2003; 31: 339–351.
[26] Žavbi R, Tavčar J, Preparing undergraduate students for work in virtual product development teams. Comput. educ. 2005; 44: 357-376.
[27] Kasper-Fuehrer EC., Ashkanasy NM. Communicating trustworthiness and building trust in interorganizational virtual organizations. Journal of Management 2001; 27: 235-25.
[28] Leenders, RThAJ, van Engelen JML, Kratzer J. Virtuality, Communication, and New Product Team Creativity: A Social Network Perspective. Journal of Engineering and Technology Management 2003; 20: 69-92.
[29] Pečjak V. Ways to new ideas: techniques of creative thinking. Ljubljana: New moment; 2001.
[30] de Bono E. Serious Creativity. London: Harper Collins Publishers; 1992.
[31] Nemiro JE. The Creative Process in Virtual Teams. Creativity Research Journal 2002; 14: 69-83.
[32] Graetz KA, Boyle ES, Kimble CE, Thompson P, Garloch JL. Information sharing in face-to-face, teleconferencing, and electronic chat groups. Small Group Reearch 2003; 29: 714-743.
[33] Harvey CM, Koubek RJ. Toward a model of distributed engineering collaboration. Computers & Industrial Engineering 1998; 35: 173-6.
[34] Pendergast M, Hayne S. Groupware and social networks: will life ever be the same again?. Information and Software Technology 1999; 41: 311-8.
[35] Mulet E, Vidal R. Classification and effectiveness of diferent creative methods in design process. In: Culley S, Duffy A, McMahon C, Wallace K, editors. Proceedings of the 13th International Conference on Engineering Design (ICED01), London: Mechanical Engineering Publications; 2001, p. 363-370.