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SOME OBSERVATIONS ON WORK WITHIN A VIRTUAL PRODUCT DEVELOPMENT TEAM

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Abstract

The paper is based on experiences obtained at an international E-GPR course (European Global Product Realization). This international course was designed to give students systematic knowledge and experience in developing products for the global market. For global products to be successful, technology, marketing and industrial design need to be tightly integrated. Experience and knowledge from three universities and the participating companies were assembled and integrated. The course also provided students with initial experiences in working within a virtual product development team. It is believed that this type of work is of crucial importance for the globalization process.

Keywords: collaborative design, virtual classroom, communication, detail design

1. Introduction

The significance and role of product development for economic prosperity in industrialized countries have been acknowledged for quite some time (e.g. [1], [2], [3]). In order to be competitive in today's open world, companies are expected to employ engineers that posses a broad spectrum of professional abilities (e.g. customer-oriented thinking, methods for systematic product development, application of information and communication tools, international team interaction). Therefore, the knowledge, skills and expertise of engineers (i.e. product developers) are fundamental to the development of competitive products.

A question arises of whether the existing educational technologies enable the formation of such engineers. Many authors agree that new ways of initial and continuing education have to be developed and applied in order to meet the demands of industry (e.g. [1], [4]).

One such new way is the international education course E-GPR (European Global Product Realization), which was organized and managed by three universities: the Delft University of Technology (Faculty of Design, Engineering and Production), the Netherlands; Swiss Federal Institute of Technology, Lausanne (Department of Mechanical Engineering), Switzerland; and University of Ljubljana (Faculty of Mechanical Engineering), Slovenia. The first generation of students successfully completed the course in the spring semester of the academic year 2001/2002.

The operating principles of virtual enterprises have been borrowed to formulate the concept of an academic virtual enterprise. This concept enabled the organizers to integrate multiple remote locations into one virtual unit, to organize collaboration with academic institutions and industrial companies, and to share the knowledge, skills and expertise of various professionals with students. Knowledge accumulated in the global product realization practice of the participating companies and the three universities provided the basis for the course and the semester projects. In academic virtual enterprises, university students are viewed as evolving young professionals [5]. The spirit of strategies for the development of future educational systems presented in [1] is also characteristic of the concept of this course. A more thorough argumentation and detailed description of the E-GPR course can be found in [5].

The purpose of this paper is twofold. The first objective is to briefly present the course and the required technical infrastructure, and the second to make some observations on collaborative work within virtual product development teams from the students' and authors' point of view.

The structure of the paper is the following: In section 2, we briefly describe the course and the basic technical infrastructure. Section 3 presents and discusses some observations on work within virtual product development teams, together with a model for managing the decision-making process in virtual teams. Section 4 gives a conclusion.

2. E-GPR course description

Apart from the above-mentioned universities, the participating companies included a respiratory units marketer (Vlamboog B.V., The Netherlands), a recycling consultant (BIRD, Switzerland), a developer/manufacturer of vacuum cleaners (LIV d.d, Slovenia) and a developer/manufacturer of vacuum cleaner motors (Domel d.d., Slovenia).

The lectures and project work on this year's course took place twice a week (two academic hours), from the beginning of February till the end of May. Communication was conducted in the English language. Via lectures, students were provided with a systematic insight into the basic knowledge and given concrete examples of global products. The academic lectures, cases from industry and project work were interwoven throughout the semester, but project work played the central role for the students. It is well known that independence is the source of motivation and creativity, and this was clearly visible at intermediate presentations by the project teams. During the last week of the course, the students and their mentors met in person, finished various prototypes and presented them at the exhibition.

Project work was performed within international teams, which helped improve their team-work skills. Personal, hands-on experience is very important for development of skills in a virtual development team. The task was to develop two products (one half of the teams worked on a respiratory unit for welders and the other on a vacuum cleaner) and create various (virtual and physical) prototypes of these products.

2.1 Team work

Project work was performed within international teams, each consisting of students from all the participating universities. Students from each project team were geographically dispersed across Ljubljana, Delft and Lausanne, therefore they were forced to use modern methods of communication: videoconferencing, e-mails and a joint Internet server. They had different background knowledge, which was complementary and as such very important for each team. The students from the Delft University of Technology, for example, were well versed in market analysis, conceptual product design and industrial design. At the Faculty of Mechanical Engineering, Ljubljana, there is greater emphasis on engineering knowledge, e.g. 3D modeling, various engineering analyses and manufacturing technologies. Participants from Lausanne were students enrolled in the curriculum for the study of product life cycle with emphasis on recycling. These various types of knowledge have nicely complemented each other and it was particularly interesting to observe the formation of this years' project teams. They were created by knowledge brokering, based on the students' individual presentations given at the initial videoconference.

2.2 Technical equipment of virtual classrooms

The lecture rooms in Ljubljana, Delft and Lausanne are appropriately equipped and have created a joint virtual classroom. The most important component is the videoconferencing system (compatible with H.323 and H.320 protocols), roughly consisting of a digital camera that follows the speaker, a TV set, a videoconferencing multi-point server and ISDN/IP connections. High-quality images require rapid transmission of large amounts of data, which was made possible by three ISDN telephone lines. Lectures are ordinarily accompanied by image materials. High-quality graphics transmission is achieved by projecting computer images onto a screen. Computers for projection are visible on the Internet (IP number) and are interconnected using dedicated software. In this way, the lecturer can present pictures (prepared by presentation software) simultaneously at all locations. With a bit of camera operating skill and appropriate coordination by a moderator, we have managed to eliminate the distance between Ljubljana, Delft and Lausanne. During the course, the lecturer and audience at all three locations could hear and see each other, pose questions and feel like they were in the same classroom. The cameras in each classroom could also be operated by students from other locations. Students used videoconferencing and the Internet for their communications (less dynamic, but cheaper). These arrangements can be further improved with some additional investments. By switching from ISDN to leased academic lines, for example, we will be able to improve the quality of transmitted images and at the same time reduce the currently considerable telephone costs. When the TV set is replaced with an additional LCD projector, communication will feel even more real, as everyone will be displayed in real size.

Data exchange was performed mainly via a joint server and a homepage created specifically for this project (http://www.e-gpr.nl). This server contains a collection of all project-related documents, from presentation of project objectives to schedules containing data on lectures, picture materials for the lectures and daily notices. Information on all participants enrolled in the international school is also collected in order to facilitate their communication. Access to this data is possible only via personal passwords, while the general presentation is freely accessible. Communication between the participants took place in many different ways: via e-mails, chat rooms and regular videoconferencing.

2.3 Workshop and exhibition

The pinnacle of three months of project work was a one-week workshop in Ljubljana, which was concluded with a presentation of the results (i.e. deliverables). The objective of this workshop was to complete the production of parts and components, assemble functional physical prototypes and prepare final oral presentations, reports and posters showing e.g. certain aspects of marketing, global product features and product evolution. In addition to functional physical prototypes, the students also prepared image studies, virtual prototypes and physical concept models.

To make physical prototypes, both newly developed (e.g. various housings and covers, RC - remote controls) and existing parts and components (e.g. vacuum cleaner motors, flexible tubes, brushes, batteries, fans) were used. For new parts, vacuum forming, water-jet cutting and 3-axis milling were mainly used.

The level of elaboration of the products (i.e. deliverables) was unexpectedly high (Figures 1, 2, 3 and 4). This can be traced back to the advantages originating in the multi-disciplinary composition of the teams and the immediate feedback from the company experts (e.g. LIV d.d., Slovenia, Vlamboog B.V., The Netherlands) [5].

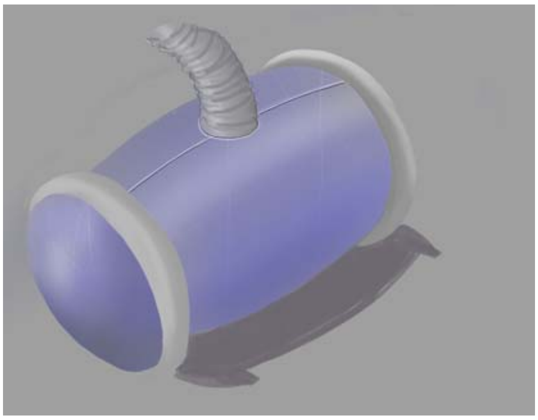

Figure 1. Freehand sketching and rendering of vacuum cleaner exterior.

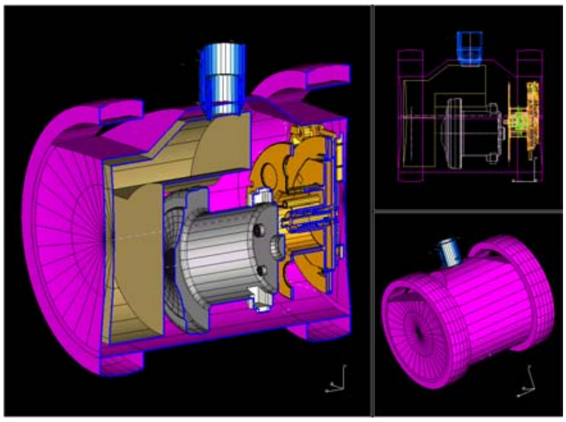

Figure 2. Virtual model of vacuum cleaner assembly.

Figure 3. Vacuum cleaner of one of the project teams at the final presentation.

Figure 4. Vacuum cleaner prototype (at the front) and one of the mock-ups (in the background).

3. Some observations on work within a virtual product development team

During project work, it turned out that some students (those giving proposals) naively expected that all product-related proposals/desires/requirements can be communicated verbally, by freehand sketches (e.g. Figure 1) or even by gestures. Communication problems primarily involved students who were modeling parts of individual products, as they had their own understanding/perception of the proposals they received - in the majority of cases, what they thought they were told was not in accordance with the expectations of those giving the proposals, etc. Such misunderstandings caused delays primarily during the phase of detail design.

Figure 5 shows the connection between the developmental phases and presentation format for the results. Initially, freehand sketches play an important role in the exchange of ideas. During the design phase, 3D models are indispensable because they enable clear spatial presentation and subsequent prototype production. During the production phase, technical drawings assume the role of a contract and contain all details on machining, tolerances, etc. [6]. Problems were encountered primarily during the transition from the conceptual design phase to embodiment design. At this point, industrial designers from Delft delivered their information to design engineers in Ljubljana. The spatial distance between two teams with different ways of thinking made information transfer even more difficult. Industrial designers are used to expressing themselves via freehand sketches, because this is the quickest way to write down an idea or a principle. 3D modelers used by design engineers, on the other hand, require a detailed geometric description and for free surfaces also in-depth modeling knowledge. The transmission of sketches via electronic media was time-consuming and not necessarily unambiguous. However, sketching will remain important for personal records of ideas and for exchange of information during creative dialogues.

During project work, students were missing a tool (e.g. a 3D modeler) that would be suitable for both industrial designers and design engineers. One of initial possibilities to solve this problem could be to supplement the existing modelers with a user interface of a more intuitive nature, which would be adapted to the needs of industrial designers. Unified computer-assisted modeling throughout all phases is still much more important for virtual product development teams than for teams which can meet in person at any time. The project was concluded with a prototype, therefore the transition to manufacturing documentation cannot be evaluated.

Another problem - also related to detail design - was postponement of detail design as far ahead to the future as possible; it was found out later that this postponement was the main reason for the lack of time during the final workshop in Ljubljana. It is believed that the reason for this probably lies in a lack of simplified detail design methods, as students had difficulty facing an activity that is not supported by methods.

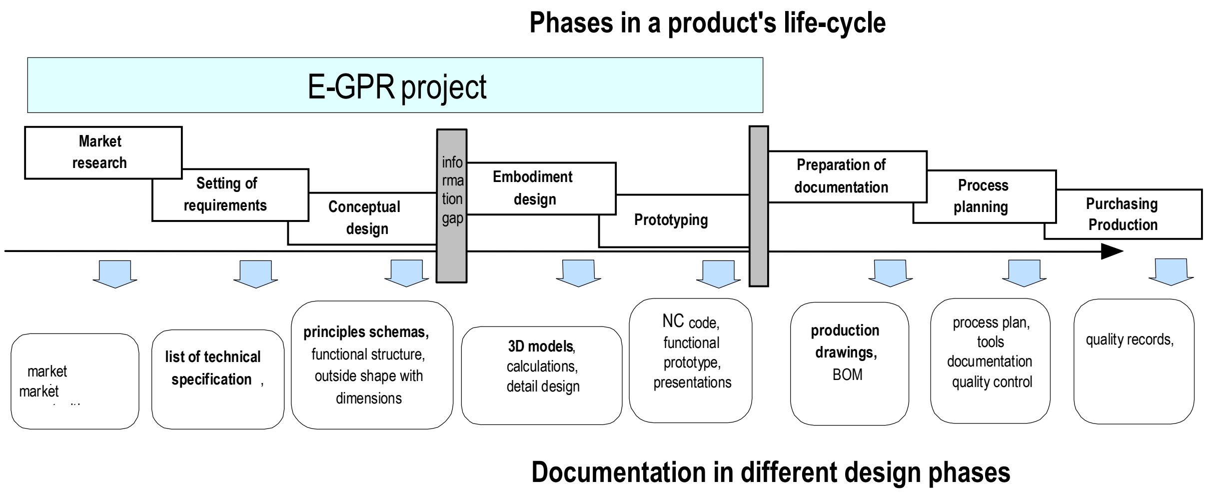

Figure 5. Connection between developmental phases and presentation format for results (documents).

Naturally, the problem of product-related proposals/desires/requirements was solved by applying the technical documentation rules, which enabled a singular interpretation of the proposals/desires/requirements. The problem of the postponement of detail design was eliminated (when indicated by the students) by the intervention of experienced supervisors; that, however, can only have a short-term effect.

3.1 Detail design

Detail design is not important only because of its influence on the quality of function fulfillment of the product as a whole, but also because it is associated with a considerable consumption of resources (time, money, etc.). It therefore has great potential for rationalization through development of simplified detail design methods (e.g. [7]).

When discussing detail design, it is important to be aware of the fact that it should be studied from several different viewpoints [8], [9]. Mortensen divides them into property viewpoints and product life phase viewpoints [8]. Property viewpoints include the strength viewpoint, vibration viewpoint, heat dissipation viewpoint, etc., meaning that detail design is discussed from the viewpoints of strength, vibrations, heat dissipation, etc. Accordingly, life phase viewpoints include the manufacturing viewpoint, assembly viewpoint, transportation viewpoint, usage viewpoint, maintenance viewpoint etc. The introduction of property and life phase viewpoints enables the execution of detail design starting from various viewpoints and thus improves the quality of detail design, because it includes into the synthesis process the expectations/requirements/criteria of all the stakeholders participating throughout the product life cycle.

Mortensen&Andreasen find that there is no valid theory of detail design as yet and that consequentially no quality methods are available for supporting detail design [7]. In fact, this is the basic reason for current problems related to detail design. This problem is even more critical when non-standardized parts are designed, because their detail design is not supported by technical handbooks, standards and guidelines, as is the case with standardized parts.

One of the available approaches to finalizing detail design is supported by catalogues, handbooks and guidelines, which also show various positive (i.e. good solutions) and negative examples (i.e. poor solutions) from various viewpoints. However, design catalogues and handbooks do not support the synthesis of new parts (from scratch). The use of catalogues, handbooks and guidelines primarily leads to standard, but proven solutions. In the case of the E-GPR course, the use of these means should be more emphasized.

A long-term solution should be based on a theory of detail design, and Mortensen&Andreasen's proposal [7] provides a sound theoretical basis for further development of methods for supporting this type of design.

The approach is based on wirk element concepts and allocation of wirk elements to parts (e.g. [10]). One of the problems lies in the fact that the concepts are not widely known, which limits the speed of development of appropriate method(s).

3.2 Working in a virtual product development team as seen from students' viewpoints

The opinions of E-GPR students working in virtual product development teams were gathered. Some results of the survey are presented in Table 1. The answers are organized into three groups: course characteristics from the technological and human points of view, and the advantages of working in virtual teams. The students had different roles in their teams, therefore they focused on different activities. In general, their experience was very positive. It was challenging and stimulating to work in an international team.

Nevertheless, there are still some technical limitations. Working in a virtual team is more time-consuming, because all work results need to be transformed into electronic form and transferred to other team members. Videoconferencing rooms were not available at all three universities all the time, which limited the communication. Telephone calls were avoided due to high costs. Therefore, students were forced to use slower and sometimes less dynamic ways of communication, such as e-mail or Internet chatting. Limited channels of communication without touch and smell, facial mimics, body language or even spoken word make communication slower. Complaints about unreliable telephone connections referred to videoconferences, which were sometimes interrupted. Problems with file exchange formats were mainly the result of different software types (or different versions in case of the same software) used at the three universities and errors in the translation software. Good news is that the quality of communication will improve with the development of technology, and the costs are expected to decrease in the near future.

Other identified problems (from the human point of view) will require more attention. Most of them can be solved by developing special skills among members of virtual (international) teams. A model for managing the decision-making process in a virtual team is presented in the next section. Team members should be inventive and should be able to work independently. One of the best ways to acquire good skills and personal attitudes is via personal experience, such as during an E-GPR course. Students are now familiar with the usage of communication equipment and able to organize work in a virtual environment. They also gained basic experience in communicating with other companies and are well aware of the limitations.

Table 1: Technical and human limitations and advantages of working in virtual teams according to a survey among students involved in the E-GPR project.

% of students	**Technological characteristics of E-GPR courses**
56	Communication in a virtual environment is time-consuming
44	Limited access to communication equipment
31	Unreliable telephone connections
25	Incompatible software and file formats (sketching and 3D modeling)
25	File transfer (large files)
12	Graphical editor for concurrent work

% of students	**Human characteristics of E-GPR courses**
50	Limited communication channels
37	Missed a meeting in person at the beginning of the course
25	Long response time
19	Difficult coordination of work and decision making
12	Cultural differences
12	Motivation of passive members
	Advantages of working in international teams
56	Different people bring together new ideas
50	Availability of specific knowledge

Personal acquaintances before the beginning of cooperation are regarded as stimulative for virtual teams in industrial environments [11]. In the case of the E-GPR course, meeting in person before the start of the course had to be omitted due to high costs of travelling and accommodation, as well as lack of time.

Cultural differences proved to be almost non-existent: e.g. work attitude, responsibility for accepted decisions, and commitment to team goals were consistently high. The same was true of team member motivation.

The main advantages of working in international teams, as seen by the E-GPR students, are that new, different ideas and specific knowledge from different universities are brought together by the team members.

3.3 Decision making in a virtual team

The survey completed by the students participating in this project showed that decision making was recognized as a problem. At times, there were conflicts between team members regarding particular solutions and it was very difficult to move forward. The coordination of work and decision making are important parts of any project, but the virtual environment requires a much more precise definition and implementation of the decision-making system.

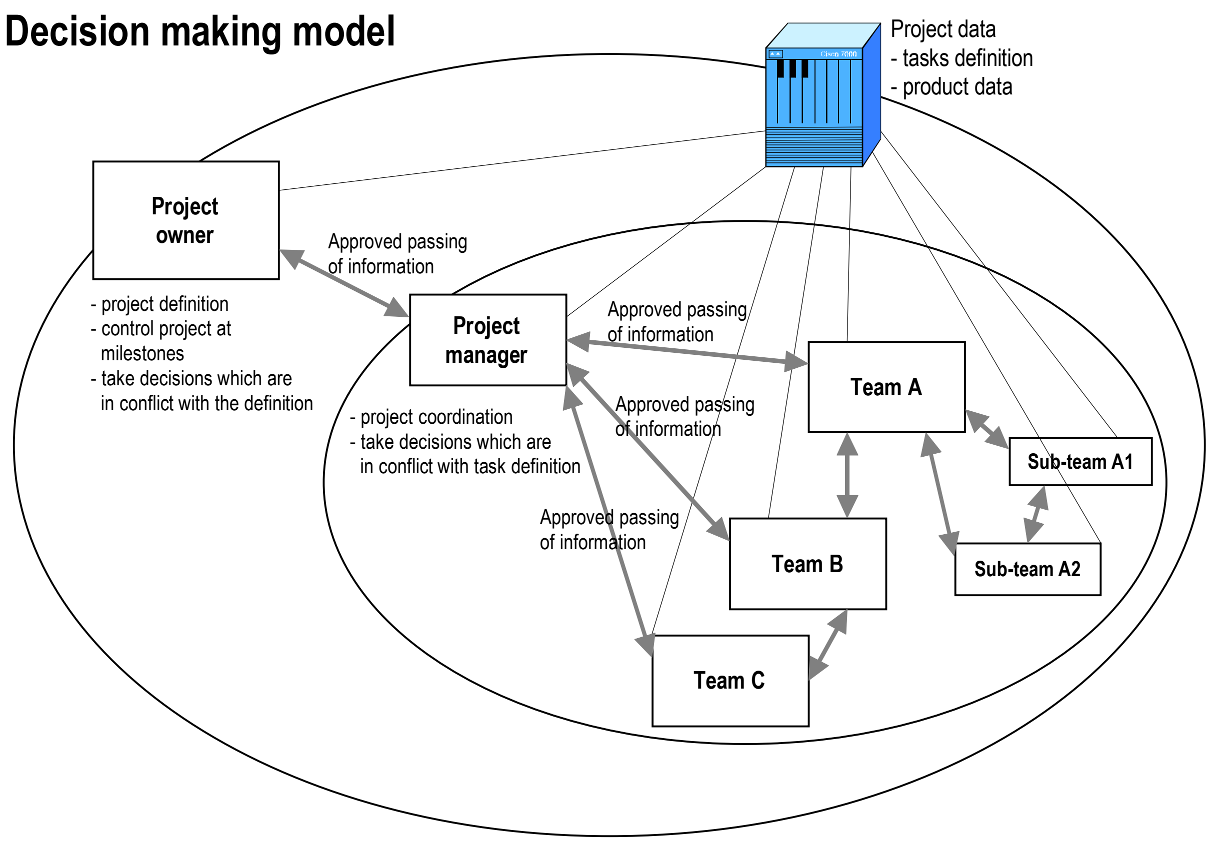

Figure 6. Decision making in a virtual team.

A model was set up according to the experiences gained during the E-GPR course. Figure 6 shows the elements of effective running of virtual product development teams. The project owner prepares the project definition and this controls project execution with the predefined milestones. Project owner members are senior managers who have knowledge about the market and the manufacturing possibilities. In our case, the project definition was determined by the participating companies (LIV d.d and Vlamboog B.V.). If new findings surface, which are in conflict with the project definition, the project owner should make a decision on how to continue.

The goals should be clear and well understood at all levels. Every task given to the project sub-team should be documented and checked if it was properly understood. It is good practice to hold a short videoconference with two-way communication and gain approvals. Virtual product development is based on empowered members and small teams who should be aware of their tasks.

There should be a project manager who will organize regular meetings to inform the team managers about the entire project. Independence of the teams will make them more productive and cross-communication between the teams offers a new potential for creativity. Interteam communication is therefore indispensable, especially during the conceptualization phase.

There is a clear decision-making hierarchy:

1. within teams
2. joint decision between two or more teams (the project manager is informed)
3. project manager
4. project owner

There is a common project server, at which all project data is kept. The project data includes project and task definitions, time schedules, current product data, concepts, 3D models, the latest testing reports and detailed technical documentation.

4. Conclusions

The E-GPR course provided students with knowledge, skills and initial experiences in working within a virtual product development team. It also gave the academic staff an interesting insight into the processes during the project execution. Among other, the students could appreciate the high applicability and the importance of technical documentation rules as an indispensable ingredient of common language within a virtual product development team (otherwise, the course on technical documentation rules is not a popular subject among students).

Detail design also proved to be a burning issue, and the long-term solution for this lies only in the development of simplified detail design methods that would provide students and professionals with a good basis for this task. The paper indicates one of the possible directions for the development of such methods, which is based on the concepts of wirk elements and allocation of wirk elements to parts. The E-GPR project work confirmed strong influence of detail designing on product evolution. This is yet another reason to strive for faster development of appropriate detail design methods.

Decision making was recognized as a problem. Virtual environment requires a much more precise definition of the decision-making system. The model was set up according to our own experiences and we will pay more attention to this aspect in the next E-GPR course. Each project should have a project manager and there should be a clear way of solving conflicts. Every task given to the project sub-team should be clear and properly understood.

The organization of this course was a large undertaking. We believe that we are setting the foundations of a form of education that has a chance to become widely popular. Individuals who have acquired the necessary knowledge and personal experience in working in virtual teams are expected to be more successful in the global race.

It has to be kept in mind, however, that the above observations are based on only one generation of students, which is far from enough for generalizations. These observations are the authors' (one from the University of Ljubljana and the other from the Domel d.d.)

interpretations of the E-GPR project work and may differ from the observations of instructors/experts from the other participating universities and companies.

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