



DISTRIBUTED IPD PROJECT-BASED LEARNING - A PHD SUMMER SCHOOL STUDENT'S PERSPECTIVE

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1. Introduction

1.1 Introduction on project-based learning

Project-based learning (PBL) has been present in education for many decades [Mills and Treagust 2003]. In PBL students gain knowledge and skills by solving and working on real-world problems and challenges, thus being inspired to obtain a deeper knowledge of the studied subject. Engineering and design education community joined the trend with increasing interest in PBL approaches for about twenty years now [Hadim and Esche 2002]. Nevertheless, it is more likely to encounter PBL within bachelor and master courses, rather than within formal postgraduate education. Many studies of PBL report on the benefits of the approach regarding gaining both theoretical and practical knowledge and skills. Moreover, students' perspectives are used to improve the PBL approach and to explore the aspects of education in which PBL can contribute the most.

Globalization and technological development did not affect only the industry, but also the engineering education [Vukašinić and Fain 2014]. Contemporary means of communication and collaboration offer new approaches to traditional and project-based learning. One example of this phenomenon are students that are joining virtual teams. These students collaborate with colleagues outside the classroom, often in-between different universities or countries.

Although researchers are often very keen on and have experience in international collaboration, the effect, benefits and drawback of globally distributed project-based learning are still not fully explored. By having been enrolled in PBL as both students and researchers, the authors of this paper saw a chance to give their insights on PBL in the field of Integrated Product Development (IPD). This research resulted in a set of findings and perspectives during the several phases of a project in which PBL approach and IPD methodology had to be applied. These findings help to answer the question, if the IPD philosophy can be experienced effectively through project-based education, by giving recommendations for this field of research.

1.2 Distributed IPD project-based learning

A group of five international PhD students enrolled into a two-week Integrated Product Development International Summer School (ipdISS15). The aim of ipdISS15 is to provide a platform through which postgraduates working in IPD related fields can sharpen their understanding of current and emerging research issues in this interdisciplinary field. The summer school is organized by Professor Sándor Vajna

(Otto-von-Guerike University of Magdeburg, Germany) and Professor Jonathan Borg (University of Malta). A project-based learning approach was foreseen to teach doctoral students the basics of IPD during, and between the two weeks of summer school in Malta and Germany. The given subject of the project was to develop an innovative device for domestic use, able to iron a range of shirts automatically. Aims of the project were to motivate the students to organize, specify roles, adapt views on the engineering tasks and to prepare the collaboration for the following nineteen weeks until the second week on IPD summer school arrives. The project team consisted of five globally distributed students (Austria, Croatia, France and Germany). They had to set up a web-based collaboration environment and a proper working methodology to achieve the goal. Not to forget that this was the first time that the students worked together on a project. In this case, they had to create organizational knowledge which was non-existent before [Nonaka 1994].

2. Project introduction

2.1 The assigned product development project

The students were assigned a product development project to test and improve the knowledge gained throughout the summer school. The idea was to use and explore methods of IPD for the development of an innovative product, intended for an unexplored market. This required a special type of development assignment - a product that was complex enough to keep the team working for four months and offer development within all aspects of IPD. Summer school organizers decided to formulate the task as follows: an automatic shirt ironing device for domestic use. This device should save user's time by automatically ironing shirts of any size or material. The user should be able to store and use domestically. The team thus had to develop a mechatronic device by incorporating multidisciplinary and exploring product and process related data and knowledge such as ironing techniques, ironing markets, ironing services etc. The complexity of the project forced the team to work concurrently and in a multidisciplinary way in order to give proper outputs on time.

Summer school organizers were acting as consultants during the project. They helped to implement the IPD process and polish the outputs, but did not in any way affect or validate product ideas or technical solutions.

2.2 Background to IPD

The educational basis of IPD summer school was to teach the IPD fundamentals in the first week and to give the students an opportunity to apply the IPD methodologies on a virtual development project – an automatic ironing device. A proper working methodology and environment needed to be set up in order to develop the product in a given timeframe. Several roles were defined, based on the IPD model [Olsson 1985] shown in Figure 1, starting with the given development task.

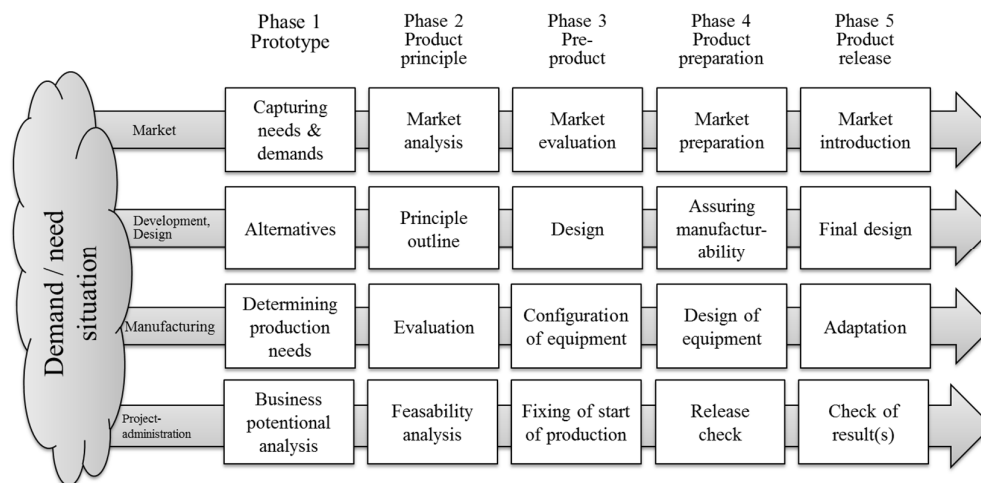


Figure 1. IPD model by Olsson [1985]

For each role (marketing & business, design, manufacturing, branding, project leadership & documentation) a team member was assigned as leader assisted by additional supporter roles. Regarding project's organization, a Gantt chart was developed by defining task names, responsibilities, deliverables, and timeslots. The team specified the task names inspired by Olsson's IPD model. In a group discussion, those tasks were distributed among the team members, resulting deliverables fixed, and needed time periods defined. Once the first week of summer school was over, the team distributed and started to work as a virtual team.

2.3 Virtual team, project environment and implemented tools

Virtual Teams (VT) are one of the eminent forms that has been adopted by organizations. The scientific, as well as the professional literature, had addressed the virtual teams concepts thoroughly, and it is in early 1990 that the first notion of virtual teams has appeared [Lipnack and Stamps 1997], [Anderson et al. 2007]. These authors have agreed to some extent that virtual teams are teams with geographically distributed members, cross-time and organization boundaries, are culturally diverse, utilize computer mediated communication to perform non-routine but interrelated tasks and are united around a common goal. Lipnack and Stamps [1997] defined VT as "groups that work across space, time and organizational boundaries with links strengthened by webs of communication technologies". Lurey and Raisinghani [2001] defined virtual teams as "groups of people who work together although they are often dispersed across space, time, and/or organizational boundaries". The virtual collectives framework proposed by El Badawi El Najjar et al. [2015] defined the virtual team as one type of the virtual collectives. The virtual team purpose is non-routine task, the conditions of membership are employees with specific skills, the members are bonded by the project's milestones, the diversity is heterogeneous but complementary, the structure is dynamic and formal, the life span is temporary and based on the project, and they interact following communication processes [El Badawi El Najjar et al. 2015].

The collaboration within the virtual team must be strengthened by information systems. It is, therefore, important to incorporate multiple communication media and e-collaboration tools as it has been observed to yield more gratification with the process, more balanced levels of participation, and more desirable results in contrast to the single communication mean.

Collaborative platforms are classified as knowledge management systems. 'Broadly defined, knowledge management systems (KMS) are a class of information systems aimed at supporting and facilitating the codification, collection, integration, and dissemination of organizational knowledge' [Bernard 2006].

A list of components is used to define the functionalities of a collaborative platform [Kondratova and Goldfarb 2004]: content, discussion forum, web-conferencing, learning modules, search functionalities, permissions and administration features.

Since the PhD students in this study were dispersed across the european continent, had to develop an innovative product, bonded by Olsson's IPD phases, were assigned with specific but complementary roles, had to report to their supervisors, established different communication channels, will disband once the project is closed, it can be concluded that they have indeed collaborated as a virtual team.

They had to utilize several collaboration tools and methods. A scrum methodology was used to split up the development task into smaller working tasks to be able to work in parallel and independently. This method allows the team members to self-organize and to develop the product iteratively. In the beginning, a two week period ("sprint") was chosen for web-based team meetings. This period was reduced to a weekly sprint, because of the short project time.

With respect collaboration tools, the authors decided to use Skype™ for telecommunication (video and audio conference calls), Google Drive™ for managing and syncing files, Google Docs™ for word processing, Google Spreadsheet™ & Google Slides™ for spreadsheets and presentations, Doodle® to manage scheduling and Conceptboard™ as a collaborative online whiteboard.

3. Project realization

In this section, the authors present their perspectives and findings during the several phases of Olsson's IPD model. The focus is on the first three phases, but project phases four and five are also considered.

3.1 Market exploration (phase 1: Prototype)

As mentioned in Olsson's model for IPD, the first activity to start with is to capture the market need and the identification of a potential business. To better understand the market opportunities, the market analyst initiated a questionnaire to survey the customer's needs, their requirements, and their attitudes toward the ironing habits. A user model was co-defined within the team to ensure that the survey will cover all potential clients. The market survey was developed using Google Forms™ and principally diffused through the social media. It is critical to have diversified samples set to guarantee the results authenticity. Figure 2 captures the analysis of business potential on the left chart and illustrates the market need on the right chart.

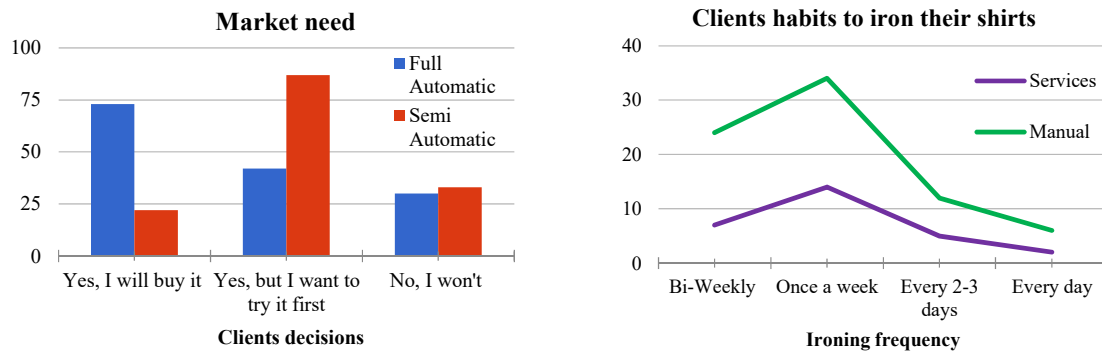


Figure 2. Clients are willing to buy the product (left) and to automate the ironing task (right)

The market analyst faced several challenges when designing and carrying out the market survey. To get a conclusive amount of information, a certain number of persons must participate in the survey. In this use case, social media was used to spread the survey resulting in addressing mainly regions of Europe and MENA.

3.2 Requirements elicitation and functional design (phase 1: Prototype)

Concurrently to the survey, students tried to assess competitors' products in order to see if there are pertinent needs that were not captured. In the same time, students did not want to be influenced by the implementation of competitors' technical solutions since they wanted to make a new design, from scratch. After getting enough information for the first iteration, it was decided to validate the first set of requirements in order to identify the main functions of the product and verify if there are incompatibilities in the functional design using a Quality Function Deployment (QFD) [Akao 2004] (Figure 3).

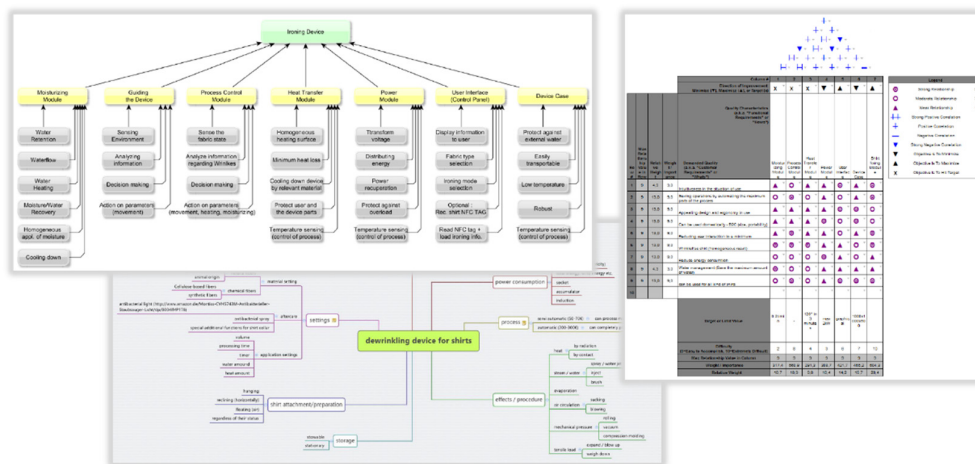


Figure 3. Functional structures and QFD

This way a large set of the requirements was validated. Some requirements were removed as they were incompatible with the majority of the requirements, redundant regarding other requirements, or weren't answering the need.

Another step in the project was detailing the identified functions to get in as much detail as possible. Detailed function structures provided a good basis to move from functional design to detailed design, and propose a set of alternative solutions that could answer the needs. The team ended up with a set of seven alternatives, which varied in the scale of innovation.

Main challenges resulted in continuously scrutinizing, adapting and testing the elicited requirements on all seven alternatives throughout the project time.

3.3 Possible solutions and alternatives (phase 2: Product principle)

The market and the feasibility analysis aimed to position the product regarding price and whether it can gain market shares and be competitive. The product selling price was defined through a target cost approach - in other words through the market survey. This cost has directly impacted the manufacturing choices on the technology, the material and the process. In an integrated approach, it is highly recommended to consider all product aspects concurrently to reduce any future conflicts. The market analysis results are illustrated on Figure 4.

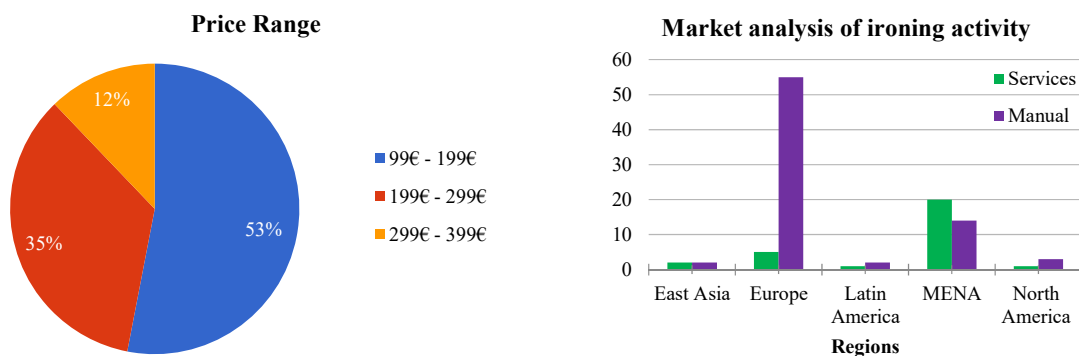


Figure 4. Feasible price for the clients (left) & European clients are the product's market (right)

Some of the developed set of alternatives were hard to implement since part of their needed components were either not available in the market, the technologies are not much evolved to develop such a solution, or the manufacturing processes are too high considering the aimed costs.

From these different theses, the team tried to get the best solution by making a good synthesis of what was proposed in various alternatives. So, naturally, they wanted to evaluate the different alternatives. The best way of validating was sticking with the requirements that were captured in the early stages of the design, and by using various criteria (see Table 1) with the corresponding indicators in order to have a certain scale on which scores could be compared.

Table 1. Validation of several alternatives (SCx)

Criteria	W	SC1	SC2	SC3	SC4	SC5	SC4a	SC6
Realizeable in time frame	0,1	0,2	0,44	0,4	0,3	0,34	0,4	0,34
Innovation level	0,125	0,55	0,35	0,4	0,425	0,4	0,475	0,3
Amount of possible profit	0,125	0,375	0,5	0,45	0,375	0,425	0,475	0,325
Level of complexity of electronics	0,05	0,11	0,2	0,18	0,17	0,14	0,2	0,2
Level of complexity of mechanics	0,05	0,12	0,21	0,2	0,12	0,17	0,21	0,13
Level of complexity of informatics	0,05	0,12	0,2	0,2	0,17	0,18	0,22	0,2
Meets target market	0,1	0,38	0,4	0,38	0,32	0,36	0,38	0,32
How easy is it to use	0,1	0,32	0,36	0,44	0,26	0,44	0,34	0,38
Amount of possible time saving	0,08	0,256	0,256	0,304	0,224	0,336	0,288	0,192
Level of process performance (ironing result)	0,17	0,544	0,578	0,646	0,442	0,578	0,646	0,544
Complexity seen from manufacturing POV	0,05	0,08	0,19	0,21	0,16	0,13	0,21	0,14
Total	1	3,055	3,684	3,81	2,966	3,499	3,844	3,071

The validation took into consideration business aspects and different manufacturability issues and technological deployment, more than actual requirements extracted from customers' needs.

A better way to finish the stage of conceptual design would have been to develop a morphological chart, a tool that could help the team develop more innovative concepts. The team decided to evaluate all alternatives with new defined criterias, but not the elicited requirements. This decision was made because of available time-resources.

3.4 Detailed design (phase 3: Pre-product)

One challenge the market analyst faced was the production volume. It is recommended to have regular discussions with the manufacturing manager about the production capacity. It is also essential to determine the sales volume in function of the production capacity. In the end, both sales volume and profit margin were optimized. The market evaluation is presented in Table 2.

Table 2. Market evaluation for the product profits

Product Type	Price Range	Potential Clients	Cost Base	Selling Price	Profit Margin	Net Profit
Full Automatic	99€ - 199€	61	180€	199€	19€	1,159€
	199€ - 299€	40	180€	299€	119€	4,760€
	299€ & 399€	14	180€	399€	219€	3,066€
Semi Automatic	50€ - 70€	55	50€	70€	20€	1,100€
	70€ - 90€	32	50€	90€	40€	1,280€
	90€ - 110€	22	50€	110€	60€	1,380€

The team entered the detail design phase with a well-defined concept. Multiple concepts were considered, with the final one being a combination of functions from the different concepts, which most of them were implemented in the two best evaluated concepts. The team agreed on the functionality of the device and answered all opened questions that the evaluated concepts left behind. The selected concept in the form of a 3D model of the device was, on the first sight, just a step away from the final CAD embodiment (Figure 5). From that point on, the team assumed that the detail design phase will be a series of straightforward tasks and can be carried out through individual work. But the team could not be more wrong.

The detail design phase started and the number of CAD parts was increasing. And so did the number of new questions that directed the course of detail design and the final appearance and functionality of the device. A large number of questions were, again, not a result of a poorly developed concept. The concept was very detailed and well thought-out. These questions resulted from the nature of product development, with detailed design phase not being an exception. One of the main benefits of Integrated Product Development is assuring that the issues are solved by experts and by combining the multiple perspectives of relevant disciplines. Nevertheless, why was applying IPD so hard in the case of detailed design? Why was it hard to combine the perspectives of the team when encountering issues?

The problem was not in sharing the question. Nor was it reaching the other person, or even gathering the whole team. A set of communication tools used during the project enabled contacting someone and getting a quick response most of the time. The main problem was in distributed collaboration. Detailed design includes means such as CAD models, catalogues and paper sketches that are still hard to share and discuss if the team is distributed. Calling a meeting to discuss a detail in the CAD model will take far more time than just asking someone in the same room for an opinion. And once the meeting starts, sharing a model creates an additional amount of confusion. This is due to the lack of shared understanding and knowledge that can be achieved via existing communication tools. Similar phenomena are described in the literature as communication latency, explaining that issues possible to be resolved in minutes or hours by a collocated team take days or weeks in a distributed environment due to difficulties of finding the right person, initiating contact and discussing possible solutions [Herbsleb et al. 2000], [Larsson et al. 2003].

Rather than frequently asking for meetings and thus raise even more issues, the detailed designer often had to go through the decision-making by himself. Finally, the designer states: "One of the most

frustrating things that could happen to me as a detail designer was making a series of decisions on my own". Therefore, when distributed, it was hard to maintain and follow the guidelines provided by the IPD. The problem of "remote questions" was not faced only in the detail design phase, but was most emphasized due to the effect on the final product design. [Sosa et al. 2002] identify three major types of geographic barriers to the communication processes from the literature: 1) physical distance; 2) overlapping working time; and 3) cultural/language differences. With working time and culture not being a problem in this project, physical distance had a major impact, thus supporting [Sosa et al. 2002] hypothesis that communication frequency decreases with distance, independently of the communication media used. "Physical proximity can facilitate collaboration through facilitating informal communication. By 'informal communication' we mean communication that is relatively unplanned, in contrast to scheduled project meetings and other planned interactions" [Kraut et al. 2002].



Figure 5. Design evolution in conceptual and detail design stages

3.5 Manufacturing plan (phase 4 & 5: Production preparation & product release)

It's important to prioritize a segment of clients who have a burning need for the developed product and thus willing to buy it. The target market is illustrated in Figure 6.

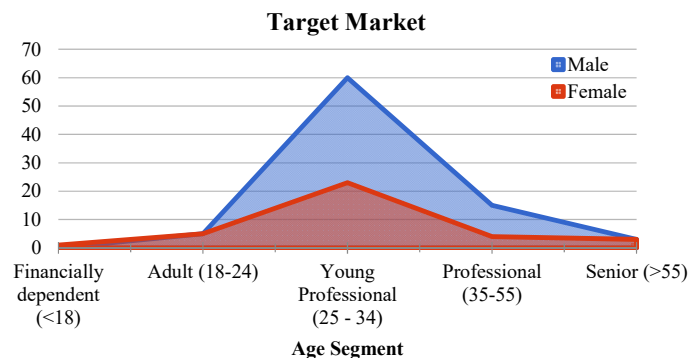


Figure 6. Target market

The next marketing activity was to develop a business model. It's a systematic and a synthetic model to represent the product added value for all the stakeholders including the clients. Moreover, the business model justifies the product revenue stream and its cost structure. By having the business model in mind, the next step was to develop a business plan to describe in details the operational aspects. Through this

plan, the team answered questions related to the differentiation factors over the competition and how they will achieve the sales strategy. The product sales strategy was developed for the upcoming year. The sales strategy also took into consideration special discounts for holidays, early customers or to ramp up the revenue stream.

The following activity was market preparation for product distribution. The team agreed that the first distribution channel will be via online retailers. An additional channel was identified via a partnership with hotels. This channel reaches the professional travelers who may require to have an urgent ironing solution for a given meeting. In the end, there was the possibility that the product may be bundled with other devices and brands.

The team faced problems in several phases of IPD's manufacturing activity string like the configuration and design of equipment and the adaption. The team managed to evaluate several manufacturing technologies and to define the most suitable ones (for the chosen final design), but were struggling to find realistic manufacturing costs.

4. Problems identification

As stated before, during the whole period of the IPD project, the team underwent a considerable amount of problems. At that moment they were focused on the project, and didn't have enough time to step back from it, in order to identify these problems, their causes, and their consequences. At the end of the project, and in the scope of communicating on this experience, the authors had enough material to think about IPD as a methodology, as well as the problems that they faced. This resulted in the classification of several IPD problems, and some of them were related to project-based learning. The authors tried to identify the main PBL problems encountered and then relate each problem faced in IPD to the corresponding one in PBL. The result is a compilation of problems they faced regarding project-based learning and which will be analysed subsequently:

1. Lack of complementary expertise or knowledge
2. Complexity of the project proposed
3. Availability of the team members and time allowed for the project
4. Collaboration between team members
5. Rigorous application of project management techniques

One of the most significant problems the authors noted is the lack of shared knowledge, but it can be considered as a double-edged blade. In fact, for PBL this is the opportunity to acquire new knowledge by mixing the different points-of-view of team members, and evolve to a high level of collaboration while gaining shared experience also. However, constituting new teams from scratch, means that the shared knowledge between team members is close to zero and that they have to build it. This can be a drawback when addressing complex projects limited in time.

When the team decided to evaluate all alternatives with new defined criteria, they didn't take into consideration the elicited requirements, this was because of two different things: The first one was because the team members were working on the project as a second priority project and often had to be absent in very important meetings where decisions were made. The second one is regarding the lack of complementary knowledge since the team members didn't experience product development in the requirements elicitation phase, and didn't have the mechanisms to directly trace the alternatives choices to the requirements and the functional model.

The complexity of the project generated a big amount of work. The product decomposition as a system would have resulted in a related work breakdown structure (WBS) in project management that gathered a lot of tasks to be performed by the team members. They couldn't find an equilibrium between addressing the IPD learning issues and completing the project.

When addressing the detailed design, the authors thought of this phase as basically straightforward actions and tasks. The system hasn't been decomposed thoroughly into subsystems and components, and thus led to having big chunks of information related to several decisions that had to be made by the team, made only by the designers since the other members were not available, and at the same time, had a wrong perception of the detailed design process. In fact the designer states: "Without the perspectives, comments and suggestions of others teammates the design process turned out to be using my existing knowledge and experience without getting constructive information that allows me to learn. This way I

learned only as much as I would if it was my personal project". Information flows during the detail design can be summarized as information seeking of the designer within available external sources. Information flows between the designer, and the team were reduced to reporting the status of the design and getting short feedback on a weekly basis. The design process, design decisions, and design knowledge were not enhanced with the teammates' expertise. The PBL was thus focused on individual work skills and self-learning. Although self-learning, initiative and motivation [Mills and Treagust 2003], and forming judgements, decision-making and an ability for analysis and synthesis [Landata et al. 2013] are a desirable outcome of PBL. In the context of IPD the knowledge gain was limited by a single perspective and a single discipline.

Detailed design is by nature a very iterative process in classical product development, and thus time-consuming. IPD tends to be a less time-consuming iterative process since all product perspectives are integrated from the beginning. This might be one of the reasons that led the team members to the misconception of detailed design.

When getting to the manufacturing phase where the realization of the product was supposed to occur, the team found a lack of manufacturing knowledge that was expressed through the struggle of finding realistic manufacturing costs. This again, is due to the fact that the team was lacking complementary expertise or knowledge.

Finally, the authors found that the main problems have to be considered as a simplified equation, regarding project-based learning, where the lack of communication substantially and from a channel perspective leads to decrease the speed and reactivity of the working team which has a direct impact on the project delays, without mentioning the complexity of the product. Adding to that, the lack of complementary knowledge didn't help when addressing some situations unknown to all team members. These are the main perspectives that have to be taken into consideration when designing a PBL activity.

5. Recommendations and conclusion

Olsson's Integrated Product Development model proved to be a useful and comprehensive basis for planning the development of a new product. It takes into account different product development aspects and helps to reduce iterations caused by concurrent work through consideration of multiple product lifecycle aspects. Successful implementation of the IPD methodology can help to keep the project within the time frame. Regular and efficient communication turned out to be the key to a well implemented IPD methodology during the studied project.

The summer school helped the authors to gain knowledge and have an insight on IPD by experiencing the collaborative working environment in a geographically distributed way. They didn't realize how much difficult it was to manage this kind of activities in real time, but they stepped back and could analyse every step of that experience in order to come with personal recommendations.

Even if the goal of this summer school was to impregnate the members with the IPD philosophy, the participants from each team were very frustrated because of the inability to finish the project throughout all IPD phases.

A set of special knowledge and skills is fundamental to successfully work on a project within an virtual team. The team need to have a common goal, defined roles, well structured division of work, well developed personal contacts and trust within the team, a communication infrastructure and a strong leadership and decision making processes. Besides those skills discussed in [Tavcar et al. 2005], additional perspectives occurred in this project. The main recommendation of the authors is the equilibrium that have to be found in order to complete the learning of the students, and at the same time allow them to go as far as they can and want in order to avoid this frustration, by dealing with the 5 main PBL perspectives stated by the authors before.

Project-based learning confirmed to be an effective way for students to learn theoretically as well as practically. During the application of newly learned methods, students faced many problems that could only occur in practice (such as different cultures, working habits or personalities). Real-time collaboration between geographically distributed people is still an issue - even with evolving collaboration platforms.

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References

- Akao, Y., *"Quality Function Deployment (QFD): Integrating Customer Requirements into Product Design"*, New York, Productivity Press, 2004.
- Anderson, A. H., McEwan, R., Bal, J., Carletta, J., "Virtual team meetings: An analysis of communication and context", *Computers in Human Behavior*, Vol.23, 2007, pp. 2558-2580.
- Bernard J., "A Typology of Knowledge Management System Use by Teams", *Proceedings of the 39th Hawaii International Conference on System Sciences*, 2006, p. 155.
- El Badawi El Najjar, R., Blanco, E., Pourroy, F., Prudhomme, G., Maussang-Detaille, N., "Proposal of a Framework for characterizing Virtual Collectives in the Engineering Design", *Proceedings of the 20th International Conference on Engineering Design (ICED15)*, Milan, Italy, 2015.
- Hadim, H. A., Esche, S. K., "Enhancing the engineering curriculum through project-based learning", *32nd Annual Frontiers in Education Conference (FIE)*, Boston, USA, 2002, pp. 1-6.
- Herbsleb, J. D., Mockus, A., Finholt, T. A., Grinter, R. E., "Distance, Dependencies, and Delay in Global Collaboration", *Proceedings of the 2000 ACM conference on Computer supported cooperative work CSCW '00*, Philadelphia, PA, USA, 2000, pp. 319-328.
- Kondratova, I., Goldfarb, I., "Virtual communities of practice: Design for collaboration and knowledge creation", *Proc. of the European Conf. on Products and Processes Modelling*, September 8-11, Istanbul, Turkey, 2004.
- Kraut, R. E., Brennan, S. E., Fussell, S. R., Siegel, J., "Understanding effects of proximity on collaboration: Implications for technologies to support remote collaborative work", *Distributed work*, 2002, pp. 137-162.
- Landata, A. D., Morgado, P. L., Munoz-Gujosa, J. M., Sanz, J. L. M., Otero, J. E., Garcia, J. M., Tanarro, E. C., Ochoa, E. G., "Towards Successful Project-Based Teaching-Learning Experiences in Engineering Education", *International Journal of Engineering Education*, Vol.29, No.2, 2013, pp. 1-15.
- Larsson, A., Törlind, P., Karlsson, L., Mabogunje, A., Leifer, L., Larsson, T., Elfström, B.-O., "Distributed Team Innovation - A Framework for Distributed Product Development", *Proceedings of the International Conference on Engineering Design ICED 03*, Stockholm, Sweden, 2003, pp. 321-331.
- Lipnack, J., Stamps, J., "Virtual Teams: Reaching Across Space, Time, and Organizations with Technology", John Wiley & Sons, Inc., New York, NY, USA, 1997.
- Lurey, J. S., Raisinighani, M. S., "An empirical study of best practices in virtual teams", *Information & Management*, Vol.38, 2001, pp. 523-544.
- Mills, J. E., Treagust, D.F., "Engineering Education - Is Problem-based or Project-based Learning the Answer?", *Australasian Journal of Engineering Education*, Vol.3, No.2, 2003, pp. 2-16.
- Nonaka, I., "A dynamic theory of organizational knowledge creation", *Organization science*, Vol.5, No.1, 1994, pp. 14-37.
- Olsson, F., "Integrerad Produktutveckling-Arbeitsmodell", *Series 21 Produktutveckling*, Sveriges Mekanförbundet, Stockholm, 1985.
- Sosa, M. E., Eppinger, S. D., Pich, M., McKendrick, D. G., Stout, S.K., "Factors That Influence Technical Communication in Distributed Product Development: An Empirical Study in the Telecommunications Industry", *IEEE Transactions on Engineering Management*, Vol.49, No.1, 2002, pp. 45-58.
- Tavcar, J., Zavbi, R., Verlinden, J., Duhovnik, J., "Skills for effective communication and work in global product development teams", *Journal of Engineering Design*, Vol.16, No.6, 2005, pp. 557-576.
- Vukašinovic, N., Fain, N., "A Decade of Project Based Design Education - Is There a Future?", *Proceedings of the 13th International Design Conference DESIGN 2014*, Cavtat, Croatia, 2014, pp. 1441-1450.

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