Int. J. Engng Ed. Vol. 26, No. 1, pp. 178–194, 2010
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Use of Mixed Academic-Industrial Teams for New Product Development: Delivering Educational and Industrial Value*

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Companies are interested in new products which will bring them financial benefits. One of the more difficult decisions, if not the most difficult, is to ascertain which and what kind of products will in fact accomplish this goal. Product development processes develop towards increasingly systematic approaches. We have developed a new method which introduces better systematics to the opportunity search process and also gives individuals opportunities to be creative and to produce eureka ideas. The method was implemented by a mixed academic–industrial team and supported by easily accessible ICT. The execution of this project was not only a way to expand the company's product portfolio (i.e. deliver industrial value) in cooperation with academia and the government, but also a way to provide simultaneous education for the company's engineers and students (delivering educational value, where the learning challenges are to become proficient in the use of the method and to acquire team work skills in mixed academic-industrial teams) and temporary replacement of human resources.

Keywords: Product development; interdisciplinary project; architectures for educational technology system; cooperative/collaborative learning

1. INTRODUCTION

ACTIVITIES OF MEMBERS of the LECAD Laboratory at the Faculty of Mechanical Engineering, University of Ljubljana, include cooperation with companies in the fields of product development. In 2007, the representatives of a metal processing company proposed a project for the expansion of their existing product portfolio. The company produces a large series of mass produced metal products intended for use in offices (e.g. lever arch mechanisms, folder mechanisms, metal rods for hanging files, paper clips and drawing pins), wood industry and upholstery (various staplers and staples), as well as the construction industry (steel fibres for micro-reinforcement of concrete and construction staples). In addition, the company also offers the development and production of computer controlled assembly lines, sheet cutting and forming tools, and extrusion assembly lines. The company has obtained ISO9001 and ISO14001 certificates. Its main production programme involves the product range of office supplies; e.g. they cover 30% of the EU mechanisms market.

The main purpose for the need to expand product development was to reduce the company's market risks which were due to the fact that as much as 80% of the company's existing production programme consisted of only one product (with a few variants).

Generally speaking, companies are interested in new products which would bring them financial benefits and would also help society (the latter desire is becoming increasingly pronounced [e.g., 1]. One of the more difficult decisions if not the most difficult one is to ascertain which and what kind of products will in fact accomplish this goal. We believe that in order to do so, companies should adopt a systematic approach to the opportunity search, with focus on taking account of the characteristic features of their company. Opportunities may arise from new business orientations, cost reductions, simplification of operations, upgrading of existing products, new products platform, potential new production processes and services or new approaches to retail and marketing services [2, 3]. It depends on society's development and the company's business policy where it will pursue its activities and what type its business operations will be. The answer to the question of what exactly is an opportunity also depends on the development period and the research orientation of a particular researcher.

Processes and models for opportunity search are created in the business, as well as in the technical and development environments. The business environment focuses on a company or an individual business person. Therefore, the basic business activity also involves opportunity search.

* Accepted 4 September 2009.

Product development processes develop towards increasingly systematic approaches. Ardichvili [4] believes that non-systematically discovered opportunities are more successful and related investments bear fruit faster than opportunities recognised via a systematic approach. Eureka ideas are usually exceptional, but they are presented to the general public only after an individual has assessed them. They are realised only by the brave, entrepreneurial business persons. This is the reason why such ideas appear to be more successful. In contrast to Ardichvili, Laurie [5] has attached great importance to systematic discovering of new products and platforms opportunities. A company has no time to wait for a member of the development team to come up with a great idea. The development staff needs to look for opportunities constantly and systematically.

The systematic approach is also supported by Hayek, who said that general knowledge cannot be a source of new wealth because its broad distribution among potential imitators is antithetical to excess profits [6]. Conversely, specific knowledge holds the potential for wealth generation as a function of its limited, asymmetric distribution. Findings of Fiet provide initial evidence that constrained searches in domains where an aspirant already possesses specific knowledge yield a higher probability of success than random, unconstrained searches [7].

2. BETTER SYSTEMATICS

We have developed a new method which introduces better systematics to the opportunity search process and a constant possibility of iteration between individual steps. It also gives individuals opportunities to be creative and to produce eureka ideas.

The method called SETL (Social, Economic, Technological, Legislative factors) [8, 9] can be used to search for opportunities for new products taking into consideration a particular real business environment (i.e. this is a constraint), which is part of a comprehensive product development process. The method was developed after critical evaluation of other existing methods, e.g. IPD [10], iNPD [11], Stage-Gate [12], NGP [5], Opportunity Identification [4] and WOIS [13]. A review of these methods is given in Benedicic [8].

The method was implemented by a mixed academic-industrial team and its development was partially financed by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia. Research on institutional relations within innovation processes has shown that there are four main stakeholders which need to cooperate in order to enable successful new product development: universities (source of new knowledge and technology), the industry (production centres), the government (source of co-funding, e.g. via schemes for promoting technological development in industry) and users (adopters of products). The way in which stakeholders manage knowledge, apply information and communication technologies, and develop systems to enhance capability and competence has surfaced as a key factor in economic performance [14]. In addition, engineering education emphasises teamwork, project- based learning and close interaction with industry [15].

The whole project of the method's use by a mixed academic–industrial team was based on the above mentioned findings regarding successful product development, economic performance and engineering education. The execution of this project was not only a way to expand the company's product portfolio (i.e. deliver industrial value) in cooperation with academia and the government, but also a way to provide simultaneous education for the company's engineers and students (i.e. deliver educational value; the primary pedagogical objectives were to become proficient in the use of the SETL method and to acquire team work skills in mixed academic-industrial teams) and temporary replacement of human resources, which is a new feature. Because of a lack of staff and insufficient knowledge of systematic approaches to product development, the company could otherwise consciously try to expand its product portfolio via trial-and-error and could thus potentially put its future at risk.

The company could have approached the solving of these problems in a standard manner as well. For example, it could have hired an external consulting company to draw up and propose potential opportunities for the company, but in this case there would be no transfer of opportunity search methods from the consulting company to the engineers of the metal processing company. The company could also have hired an external company to provide education in the field of opportunity search methods, but in this case education would be done one the basis of case-studies and would not include the search for concrete opportunities for this company. Our innovative offer, on the other hand, included simultaneous transfer of new knowledge via project based learning (of both company engineers and students), actual product development and temporary replacement of human resources. In addition, government financing could be obtained by the company and the university to implement such an approach. Last but not least, through the participation of students the company was able to get to know its potential new human resources, while students were able to become familiar with a potential employer. Furthermore, the laboratory's researchers were given an opportunity to start the method's validation (i.e. check that it fulfills its intended primary purpose, i.e. to check:

1) whether the method enables the identification/ discovering of opportunities for new product

development when used by a mixed academic-industrial team,
2) whether it enables achieving of proficiency in the use of the SETL method and the acquisition of team work skills in mixed academic-industrial teams.

The first application of the SETL method indicated that, used by a mixed academic-industrial team, it enables simultaneous delivering of industrial value (i.e. discovery of opportunities for new product development as the company's primary objective if a company desires to expand its existing product portfolio with the use of mixed academic-industrial teams) and educational value (i.e. achieving of proficiency in the use of the SETL method and acquiring team work skills in mixed academic-industrial teams). Difficulties with the implementation of in-depth analysis and open questions regarding the suitability of the described approach for student education are discussed below.

3. OPPORTUNITY SEARCH METHOD

The method is intended for small and medium-sized companies in particular. It is of utmost importance that a company's management recognises the need for systematic development of new products and is willing to invest in training its staff and the introduction of systematic development methods.

Andreasen & Hein argue that the comprehensive development process is initially less efficient and slower. However, gradually, as the company adopts a certain approach and develops its own development process on the basis of past experience, it becomes much faster and more efficient [10].

Opportunity search has been divided into four steps (Figure 1):

1) Boundary conditions for opportunity search: in the first step, the area of opportunity search is defined. The decision can be made in close co-operation with management, after the analysis

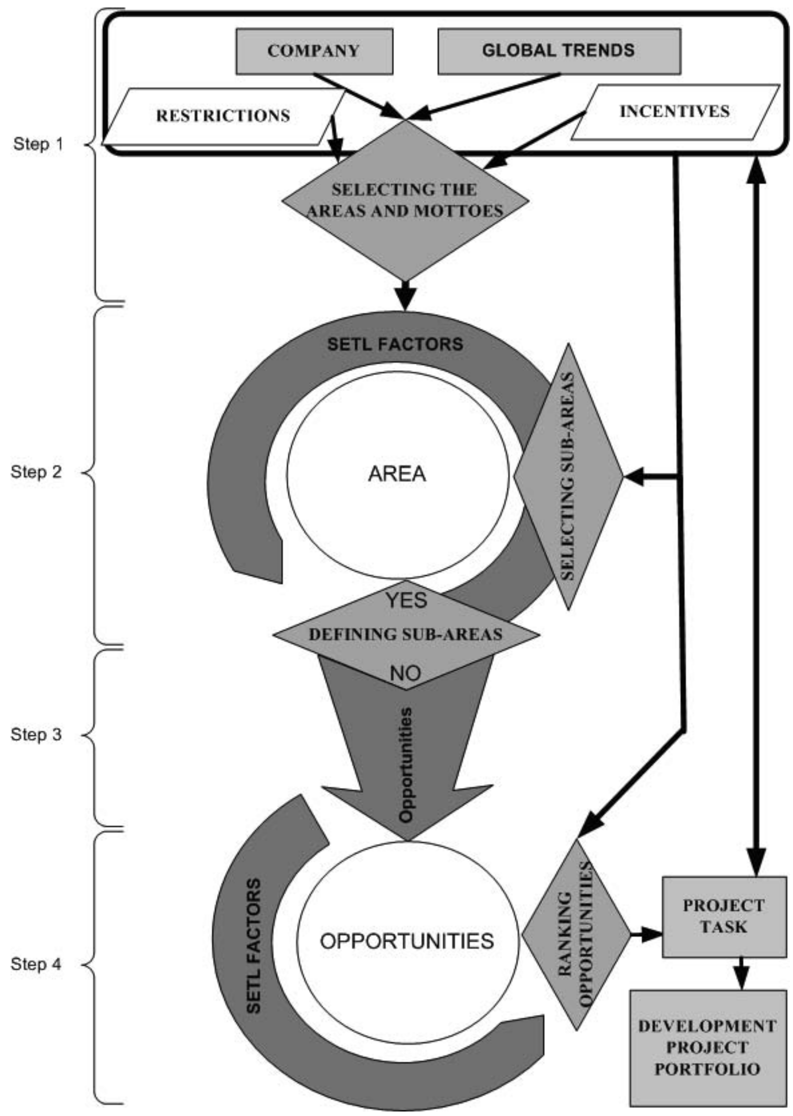

Fig. 1. Graphical representation of the SETL method.

of the company and existing recognised trends in the market.

2) Recognising opportunities: this step involves intensive gathering of information about a particular area from the viewpoint of four factors: social, economic, technological and legislative. We are looking for opportunities carriers represented by wishes, fantasies, work processes, trends and reference products in a particular area or sub-area. An opportunity has been recognised if opportunities carriers, together with the company's characteristic features, yield a positive financial value. An individual 'stores' the recognised opportunity in the domains of Recognised Opportunities and Eureka Ideas. Applying creative methods, we should work towards recognising additional opportunities. This step allows more detailed work and breaking down sub-areas into smaller, more specific sub-areas.
3) Elimination of irrelevant opportunities: irrelevant opportunities are eliminated based on the criteria and in co-operation with the company management.
4) Opportunities analysis: the most important step in which individual opportunities are confirmed after a detailed analysis. It is necessary to answer the question of whether the recognised opportunities are realistic or this was merely believed due to the lack of information. This procedure yields the suitability ranks of the opportunities and their descriptions, which can already lead to some requirements for a new product or service, but, most of all, it is considered during the process of planning and allocating the company's development projects.

3.1 Step one

Step one results in a selected sub-area and a guide for opportunity search on the basis of the company's characteristic features and market trends. It is among the most important steps because a proper or improper choice of the opportunity search area for new products can significantly influence the company's business operations and its future orientation. By selecting the opportunity search area and focusing on it, the possibility to discover opportunities in other areas is reduced. It is true that taking this approach can lead to missing out on some opportunities, but the high volume of information in the case of detailed search in all areas would considerably extend the necessary time for the opportunity search. In the case of a shallow search, some opportunities for the company would certainly be overlooked. If the search fails in the selected area, we can return to the first step and choose the next promising area. In this way, it is not necessary to repeat the method once again; we can choose the second most promising area and continue the opportunity search.

In step one, the area [9] and the guide are selected. This selection is possible only by taking account of the company's characteristic features and global trends. Taking the company's characteristic features, the opinion of its management and the current trends into consideration, the development team then decides on the suitable area. Before making the final decision, the team defines the restrictions and incentives, which represent the company's characteristic advantages and disadvantages.

The company's characteristic features definitely constitute the foundation for selecting the area and provide the guide for further opportunity searches. It is also necessary to acquire the characteristic data and information on the company and its business operations.

The company information and data which affect the selection of the area and the guide are as follows:

- Strategy: our method takes account of the company strategy as one of the elements that can direct the opportunity search in a specific area. A company's strategy and mission are indicative of its development trends. The strategy can predict the target market or even the product development tasks. It is necessary to be aware that the company's strategy can also change on the basis of recognised opportunities.
- Resources: the method takes account of natural, human, organisational and technological resources. By means of an analysis of available sources and their potentials, it is possible to assess a company's capacities. It is necessary to define the knowledge that a company can acquire through its connections with scientific institutions and also to define its strategic development. Some natural resources can serve as a direct source of new opportunities (e.g. availability of thermal water can trigger the growing of greenhouse strawberries).
- Production: it is necessary to be familiar with the company's existing production programme and its past products. There are two other important factors: the size class of the produced products and the type of production.
- Markets and channels of trade: these are very important when an area is being selected. Partial presence of a company in a certain market means that it already possesses some degree of understanding of and recognisability on the market. Because companies strive for increased growth with their new products, it is important to know the expected growth rate of a specific sector in the future, because this can be an indicator of the growth in sales of a new product. These are the key factors that need to be taken into consideration when selecting the area. The above-mentioned data by themselves can be indicative of a specific area, but they can also encourage us to define a new, adjacent area on the basis of them.

The management has and should have a decisive say in decision-making about the development of new products because in the long term this is closely connected with the company's success. In step one, our method requires the presence of the company management because selection of the area is of utmost importance. The choice determines the company's future development orientation and the management's role in this process is crucial. The management submits its opinion and, seeing the situation, comments on individual analyses and responsibly creates the basis for the execution of the method's subsequent steps.

Special attention should be paid to taking trends into consideration as early as when deciding about the area where opportunities will be searched. There are global trends, which affect different segments of our life. Global trends should be examined and applied to individual defined areas. Understanding these trends can facilitate decision-making about the area for future activities because a trend can make an area promising.

The most important part of the first step of our method is selecting the area where opportunities for new products will be searched. Through detailed analyses of the company and the market and global trends—which are to be applied to trends in the company's area—the necessary information is gathered. On that basis, the area of the opportunity search is assessed and selected. Before its assessment, the team, together with the management, should review the gathered information and supplement the list of defined areas with related or adjacent areas. To do this, they can use one of the creative methods. The team should first eliminate irrelevant opportunities based on the criteria it had determined together with the management. If more than one area remains, the team could apply the AHP (Analytical Hierarchy Process) method [16] with which it assesses and creates the suitability ranks for individual areas. The first area to be ranked is the selected area for further activities in step two.

Choosing the search approach is the next very important decision to be made. The approach should be defined after selecting the area in co-operation with the management. There is an abundance of information available on products, technologies and knowledge for any specific area. For this reason, it is necessary to choose an approach or way of thought about the information search process. However, it is useful only during the first cycle of step two. The approach can be the basic function of a particular product group, depending on the goal to be achieved with the new product. Should it fit into the existing platforms or should it fulfil a specific mission of the company? It is important that the approach has a broad sense. No defined approach is necessary if the search area is narrow. On the basis of the selected areas, the team and the management should decide whether it is necessary or not.

3.2 Step two

The opportunity search method helps companies improve the efficiency of their operations. It improves the chances of a successful opportunity search process, although the method is not a guarantee of success. The second step involves intensive data and information gathering in a particular area, based on four recognised influential factors: social, economic, technological and legislative (i.e. SETL factors). We are looking for opportunities carriers, represented by wishes, fantasies, work processes, trends and reference products in a particular area or sub-area. An opportunity has been recognised if opportunities carriers, together with the company's characteristic features yield a positive financial value. An individual 'stores' the recognised opportunity in the domains of Recognised Opportunities and Eureka Ideas. Applying the creative recognition method, this set is further compiled. Step two is a cyclic one, with each cycle adding to the volume of information and thus deepening the understanding of the areas or sub-areas. This step allows more detailed work and breaking down sub-areas into smaller, more specific sub-areas.

3.2.1 SETL factors

In order to understand opportunities, an adequate volume of quality information is required. Combining data and information from the market or the environment and the company itself can improve chances of successful discovery of an opportunity for the company, as well as structured and systematic search of information. The structure and volume of information necessary to discover an opportunity has changed with the development of methods.

Our method enables systematic and structured data/information gathering. Information is the basis for successful recognition of opportunities. An information set that is relevant to the company was chosen in step one, in which the company's advantages and disadvantages were recognised. In step two, the focus was on data and information from the market and the environment. Structured gathering of data and information was upgraded to four influential SETL factors:

1) Social factor: focuses on society and its changes. It is also necessary to pay attention to its interactions with other factors. We are interested in the current situation and the expected future developments.
2) Economic factor: this is the financial factor; its purpose is to assess the financial potential of the area and later also the potential opportunity.
3) Technological factor: among other things, this factor necessitates a good understanding of current technologies, scientific discoveries and future technologies. These can become important sources of new opportunities.
4) Legislative factor: recently, this factor is becoming increasingly important for the opportunity search, as well as for devising new products. Some laws can encourage a trend in a particular area; also trends can dictate the adoption of

new legislation. New discoveries and radical innovations can also give rise to the adoption of rules and laws and vice versa.

The source of data and information is of utmost importance. The more diverse, the greater the volume of different information, which enhances the probability of finding diverse recognised opportunities. There are primary and secondary sources. Original information gathered with a special purpose is obtained from primary sources. Information originally gathered for other purposes is obtained from secondary sources. Gathering of information and data from primary sources is a difficult job, as it takes a lot of direct personal communication, which in turn requires more human resources. Because the gathered data often involves personal opinions, it is necessary to convert it from a personal formulation to an impersonal or general formulation. From obtained information, it is possible to deduct some other information, which may even have been confidential. At the beginning of the opportunity recognition step, secondary sources are the main source for data and information search. They do not require personal communication and are mostly accessible without major problems. The big volume of available information and data is more of a problem, because it is necessary to extract the most important parts. Which sources are used and to what extent depends on the research area and its potential division into sub-areas. In any case, secondary sources are more widely used in the initial phase because one is still getting familiar with the area and defining its boundaries. Primary sources play the most important role later because the most influential volume of information and data can be expected from direct conversations with users, specialists and others, and from observing work processes. The definitions of opportunity tell us by themselves that we are not looking for direct opportunities but the so-called opportunities carriers. An opportunity carrier is the starting point, sometimes also an idea without material and concrete embodiment.

3.2.2 Creative opportunities recognition and decision to continue

At the end of each cycle in step two, there is creative recognition of opportunities. Studying secondary and primary sources generates different opportunities that are 'put aside' to a purpose-built area. However, these opportunities alone are not sufficient and it is necessary to recognise more of them. The starting points for the process of creative recognition of opportunities include data and information, the so-far recognised opportunities, various eureka ideas and opportunities carriers, all of which have been recognised on the basis of the data and information collected during the preceding work. By using creative methods, we are trying to encourage creative thinking within the team and in each individual.

The volume and quality of data and information symbolised by the main part of the step two diagram (Figure 1) are constantly complemented, but there is a point when it is necessary to decide whether to continue or not. It would be possible either to continue with step three or a new cycle of detailed information and data gathering. In the event of deciding to continue with the information gathering process, a decision has to be made on whether to do this at the same level or to go deeper into the research area, i.e. to sub-areas. There is a possibility that in the eureka idea sphere a new area appears that proves suitable for further research. If the decision is taken to narrow the scope of research to a smaller number of sub-areas, their number should be reduced on the basis of the criteria determined in co-operation with the management. These are set according to step one. The criteria can also be determined independently by the company management, but it is best to do it together with the team. In the case that more than one area remains, the AHP method should be applied in order to assess the sub-areas and obtain the suitability ranks of individual sub-areas for further search.

3.3 Step three

In this step, unsuitable opportunities are eliminated according to the criteria set together with the company management. These criteria should enable a clear distinction between suitable and unsuitable opportunities. An opportunity which has been designated as unsuitable according to any criteria should be eliminated unless the company management has a different opinion despite the assessment. Note that all four factors (i.e. SETL factors) should be taken into consideration. This step also allows the possibility of expressing eureka ideas.

3.4 Step four

Before the final definition of what exactly is a suitable opportunity, it is necessary to examine all opportunities closely and recognise the potential of each one. It is necessary to answer the question of whether the recognised opportunities are realistic or this was merely believed it due to the lack of information. The procedure results in the suitability ranks of the opportunities and their detailed descriptions, which can already lead to some requirements for a new product or service. In step four, the opportunities are analysed up to the point where the company would be able to include them in the range of its development projects. If we want to further analyse individual opportunities and determine the suitability of an opportunity, it is necessary to carry out a detailed analysis on the basis of SETL factors. Closer attention should be paid to primary sources because in order to confirm an opportunity carrier, a more personal contact with the users is required.

We determined the so-called opportunities parameters and defined more precisely which data and information should serve as the basis for quality decisions regarding the potential of found opportunities:

- The opportunity carrier: confirms whether the needs, improvements, work processes etc. that represent opportunities for new products really exist.
- Users and their benefits: how the user sees the opportunity and the benefits it will bring.
- Trends: analysis of how trends encourage the opportunity. Has a particular trend started developing recently or is it already declining?
- Competition: it is also necessary to check the competition's capacities, abilities and dangers.
- Selling potential: size of the market should be determined and sales should be estimated.
- The necessary resources: should be defined to see whether the company has enough of its own resources available. If not, it should be ascertained which other resources are potentially available and where the company should look for them.

3.4.1 Ranking of the opportunities

Ranking of the opportunities is one of the most important decision-making phases for the further product development process. A wrong decision can cause major financial losses for the company and also lead to bankruptcy in the case of big projects and big risks. Opportunity ranking is the end of step four and the opportunity search method. The authors believe that this is a very suitable starting point for further activities in subsequent development phases of the comprehensive product development process. Despite having determined the opportunity rank, the company's management should decide either on their own or together with the team which opportunity they will pick to continue the development process. Harmonisation with the development project portfolio also needs to be done beforehand. The data gathered on each opportunity should be broad enough to enable proper ranking of the opportunity within the development project portfolio. Opportunity ranks can be determined by means of the AHP method, based on the comparison of opportunities.

4. IMPLEMENTATION OF THE METHOD

Management of the company in question decided to implement this method. Its results could have significantly impacted the company's business operations, for example, its financial operations, changed its strategy and caused its reorientation to other areas. It is important to note that this method is essentially adapted for teamwork. Teamwork is an established method of product development, as individuals cannot master all of the disciplines that are necessary for successful development. This method can also be implemented by an individual, but he/she would have to invest more effort than a whole team because of having to stick to the prescribed methodology consisting of individual steps. In addition, individuals have long been unable to master the knowledge which is necessary for product development and the opportunity search.

On the basis of positive experience with the E-GPR project [17, 18], good agreement between the theoretical and practical level of the project with the students' competence level and the previously established high level of student motivation (their participation was voluntary), a proposal was presented to the company management to include engineering design students (8th semester) into the opportunity search team. The goals of including students in the team were multiple:

- Project-based-learning as a pedagogical tool within a real industrial project,
- Inclusion of new members into the team who are not burdened by being part of the company and its characteristics (e.g. manufacturing technologies, product portfolio, corporate culture),
- Temporary alleviation of the lack of product development staff that the company is currently facing.

The potential advantages and disadvantages brought by new team members into project implementation are listed in Tables 1 and 2.

5. TEAM

The product development team consisted of the core team and the extended team. The core team included the:

- R&D manager: he was a member of the company management, therefore communication with the management was very good and there were no difficulties. Communication with the management is always of key importance for successful use of the method, because it is the company management that adopts decisions which enable the continued performance of activities envisaged according to the opportunity search method. He had some prior experience in project management and in the way various teams within the company functioned. He was particularly experienced in the area of costs calculations for products, as well as in product design and introduction of new products in the production process. He also acted as the leader of company team members (as a permanent member).
- Instructor-team leader (co-author of the SETL method): he was trained for methodological management of the opportunity search process for new products. Because of his good knowledge of the technology, he was also responsible for coordinating the work of all team members. In addition, he performed the usual tasks within

Table 1. Potential advantages and disadvantages of company team members

Team members—Company	
Advantages	**Disadvantages**
Knowledge of the company characteristics	Mental fixation to existing product portfolio
Engineering experience	Not-invented-here syndrome
Cost awareness	Lack of knowledge about systematic product development methods
High competence level of 'home' domains	

Table 2. Potential advantages and disadvantages of student team members

Team members—Students	
Advantages	**Disadvantages**
Basic knowledge of systematic product development	Lack of industrial experience
Knowledge of ICT tools	Lack of appropriate competence level
Not bound by company constraints (e.g. product portfolio, manufacturing technologies, markets, available human resources)	Lack of seriousness

the team. He was a company employee (and at the same time also a researcher at the University of Ljubljana, Faculty of Mechanical Engineering). This was not vital for implementation of the method, but it did prove beneficial in facilitating more fluent communication between extended team members and the company management, as well as in coordinating the work of team members who were company employees and student team members.

- Student team member: there was only one 8th semester student with experience in team work, which he acquired through prior studies. His role was primarily to facilitate the communication between the core team and students from the extended team, as well as to coordinate the work of individual students. He was a kind of a student team leader.
- Advisor (co-author of the SETL method): this was a staff member of the University of Ljubljana, Faculty of Mechanical Engineering, who was available for solving methodological problems and providing advice on the use of individual ICT tools (e.g. patent databases, AHP tool) and search strategies. His main task was to facilitate learning from experience by leading ongoing reflection sessions during the steps of the SETL method.

Extended team:

- Production engineer: within the company, he was responsible for the development and optimisation of production processes. This function is very important for the company because the majority of products from its existing portfolio is manufactured in over 10 million units per year.
- Marketing manager: she was responsible for marketing in the field of civil engineering, B2C (Business to Customer) communications, B2B (Business to Business) communications and capturing of customer requirements.
- Maintenance manager: he was responsible for the servicing and maintenance of a part of the existing product portfolio, but he also has rich experience in the use and production of these products.
- Three students.
- Various invited experts from the company and from academia.

The company management agreed with the mixed composition of the team and the basis for such composition, i.e. to alleviate the lack of human resources in the company and simultaneous project based learning for company professionals and students.

5.1 Implementation of the first step

During the implementation of the first step, five team meetings were conducted, i.e. one a week. Based on other obligations of company team members and the expected scope of work, this was the optimal frequency and number of team meetings. Due to the key role of the company management in the first step, the management had to be available to the team to provide quick replies, so that waiting would not interfere with further work.

The first meeting was convened by the team leader, so that team members would get to know each other (members of the core team and students from the extended team). At the meeting, the members became acquainted with the project task, rules of work, communication methods and the roles of individual members. It is believed that the introductory meeting also contributed to the establishment of initial trust and improved the team members' focus on task execution. Trust is one of the essential components of successful co-located teams (and also virtual teams, which might be formed in the case of a geographically distributed search for opportunities). Trust primarily means having faith in other team members that they possess the knowledge, experience and skills for 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 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 [19]. Successful teams are characterised by a high degree of trust, because among other things, it reduces the need for control and supervision, thus lowering operating costs [20].

After the first meeting, a one-day workshop was conducted at which a systematic approach to product development was presented to team members, along with the opportunity search method as a way to find new products. At the end of the workshop, the team leader distributed work for the first step of the method. At further meetings, team members presented the results of activities envisaged for the first step of the method. Information sharing within the team facilitated feedback, further (refined) the search and even triggered new ideas.

At the last but one meeting during the first step, the team defined the limitations and the advantages through the use of brainstorming and determined the relevant areas. In doing so, it took into account data about the company, its markets and its trends. It also prepared a proposal of assessment criteria (for the AHP method) in the defined areas. Finally, the team also prepared a report for management, so that it could prepare for the last meeting of the team.

The last meeting was intended for the discussion about the proposed areas, supplementing/confirmation of the assessment criteria, assessment of individual areas of the opportunity search using the AHP method, and selection of the highest ranked opportunity.

In general, the prerequisite for a successful last meeting is/was good knowledge of the team's report. After the end of the meeting, the team leader also supplemented the report with the latest results and agreements.

The complete team for the first step consisted of the:

- Core team
- Students from the extended team.

The choice of students as members of the extended team proved to have been especially appropriate, as due to their small knowledge of the company they had to do a thorough research of individual company characteristics. The R&D manager who was also a member of the company management was very helpful in providing information, as he knew the company's operations and its organisational structure thoroughly, as well as persons within the company who possessed certain types of knowledge.

5.2 Implementation of the second step

The starting point for the second step was the selected area (i.e. construction). The principle of work was similar to that from the first step, but in this case the work was done independently by the team members. Each of them sought data and information on secondary and primary resources. It should be emphasised that at least during the first cycle, working in pairs is not recommended, because search is mostly conducted in secondary resources. As for searching in primary resources, especially through interviews and work process inspections in this project work was done in pairs in order to enable more reliable, comprehensive (different viewpoints) and easier recording of data and information.

At the beginning of the second step, the moderator briefly presented the activities in this step, and a workshop was also organised to search for data and information on the Internet and in electronic resources (e.g. Search Strategies, Tools, Resources). In terms of resources, we focused on statistical databases, patent databases and digital libraries. A workshop was also organised about the use of the AHP method.

In terms of the volume of work, the second step was the most difficult one. The defined area of search was very wide and the majority of team members had no direct experience in the field of construction. Therefore, three cycles were performed in the second step, and the meetings were regularly attended by an invited technical manager of a construction company (member of extended team), who clarified certain unclear points related to the field of construction. Initially, the questions were general, but through deepening of knowledge they became highly specific, which was shown in the fourth step. In this way, a large quantity of data and information was obtained, and certain opportunities were recognised within them.

Each individual cycle in the second step lasted approx. four weeks i.e. four meetings. The focus of the meetings was on reporting of search results and the resources planned to be used in the second step, as well as on discussion. The acquired information was shared among team members and the information obtained in this manner often served as a resource for further search, initiating new ideas and search resources.

The moderator took care of the scheduling issues related to presentations of the team members. Along with the advisor, he also provided consulting related to search in information resources.

At the last meeting of each cycle, the team leader used brainstorming to generate ideas or opportunities. Based on the analysis and discussions about the generated opportunities, the team proposed another cycle (and later a third one). At the first meeting of a new cycle, the company management was also present and confirmed the team's proposal about an additional cycle. In general and in this case, the prerequisite for high quality decision making is/was for the company management to read the report prepared by the team at the end of the first cycle.

The reason for the performance of further cycles lay in previously poor knowledge about and large scope of the researched area. It was therefore decided not to continue in all sub-areas, but to choose only three of the best assessed ones. By doing so, the width of the opportunity search was reduced. The information and data thus became more focused and detailed. Using the AHP method, the assessment was done and the sub-areas were ranked.

The data and information about individual SETL factors were deepened. In addition to secondary resources, primary ones were also used. A survey was done in construction bureaus about the knowledge and use of reference products and coming trends. Furthermore, several interviews were conducted with construction site managers, along with two construction site inspections. A few new reference products which would be appropriate for the company were recognised. In observing the work processes, a need was also recognised to improve the work process of reinforcement mesh binding. The list of recognised opportunity bearers was lengthened. By using the creative method of brainstorming, other new opportunities were recognised. The set of recognised opportunities was assessed as appropriate to continue with the third step.

The team's composition in the second step was similar to the one from the first step, but a technical manager of a construction company was additionally invited to join the extended team (as an expert and also a representative of users). His assistance was indispensable in discussions about the results of activities in the second step, and he was a rich source of information on the selected field (i.e. construction).

The entire process of the second step lasted 11 weeks. The first cycle lasted three weeks, and the second and third one four weeks. During this time, the team made a remarkable progress in terms of knowledge of the construction field. Unfortunately, there was no construction fair during the period when this method was implemented in which the team members could additionally deepen their knowledge and obtain a more comprehensive view of the construction field.

The result of the second step was the set of opportunities (e.g. tunnel building, transportation aids, dilatation elements, noise reduction in buildings, special rebar connectors).

5.3 Implementation of the third step

The third step was the least time consuming and was intended for discussions about the found set of opportunities and the exclusion criteria, as well as about the exclusion of inappropriate opportunities as any further analysis of inappropriate opportunities represents a loss of time and an increase in costs. Company management agreed with the two sets and, together with the team, they excluded the inappropriate opportunities. The remaining ones were transferred to the fourth step for an in-depth analysis. When the company management believed that a certain opportunity was completely inappropriate, it was excluded irrespective of the exclusion criteria. The opposite also applied: when company management believed a certain opportunity to be appropriate (e.g. due to their 'gut feeling'), it was not excluded irrespective of the result of its assessment.

The result of the third step was therefore a set of appropriate opportunities, which were to undergo further analysis.

In the third step, the team's composition was wider. Additionally, company members from the extended team (production engineer, marketing manager and maintenance manager) also participated with knowledge that had previously not been available to the team. This was done on the moderator's proposal due to more difficult interdisciplinary work (which became demanding especially in the fourth step). The whole team consisted of ten members. It was composed of the team core and extended team members (who were permanent) and it had a fitting, interdisciplinary composition. It is believed that the composition of the team also reduced the influence of the not-invented-here syndrome.

5.4 Implementation of the fourth step

In general, the fourth step requires an in-depth analysis of selected opportunities, with emphasis on primary resources which necessitate personal communication. The data also need to be more accurate in this step. In this particular project, because of such work methodology and a need for more accurate data and information, the fourth step was planned to take eight weeks or eight meetings. Collecting of information from primary resources was done in pairs in order to increase the reliability of data and information gathering. At the first meeting, the instructor/team leader briefly presented the activities of the fourth step and distributed the work tasks.

At each subsequent meeting, the team members reported the ongoing results of the analysis of opportunities and search resources. Discussions at these meetings often led to searches through new resources. The moderator provided advice on the selection of search resources, the necessary depth of analysis of individual opportunities, and solving of any unclear issues related to the method. Temporary members from the extended team (various outside experts) mostly commented on the analysis of individual opportunities.

At the one before last meeting, permanent team members prepared a proposal of criteria for ranking the analysed opportunities. A report was also prepared for the company management, with emphasis on:

- Findings from the third step,
- Analysis of individual opportunities from the fourth step,
- Proposal of criteria for ranking the established opportunities.

In general and in this case, the prerequisite for successful last meeting is/was good knowledge of the team's report, especially among the company management. At the end of the opportunity search process, the management thus had to adopt a decision about the opportunities for new product development. After discussing the analysis of individual opportunities and confirming the assessment criteria, all permanent team members and the company management assessed each single opportunity. On the basis of individual ranks, the common rank of opportunities for new products was then determined (Table 3).

In the fourth step, the team's composition was similar to the one from the third step. A professor from the University of Ljubljana, Faculty of Construction Engineering and Geodesy, was also invited to participate as a member of the extended team. The analysis of selected opportunities always has to be thorough. Therefore, all established unclear points have to be eliminated. The elimination of unclear points largely depends on the selection of highly proficient temporary team members of the extended team (i.e. experts).

In our estimate, the implementation of the whole method lasts at least 21 weeks, but 31 weeks at a maximum; in this company it lasted 25 weeks (Table 4). The team members faced the greatest time constraints in the second and fourth step. In general, this depends on the level of difficulty of the area and the analyses that are necessary for evaluating the suitability of individual opportunities.

Table 3. Rank of identified opportunities for new product development (the first three opportunities were kept secret to public because of the classified nature of information)

Rank	Opportunity
1	*Opportunity A*
2	*Opportunity B*
3	*Opportunity C*
4	*Special rebar connectors*
5	*Noise reduction in buildings*
6	*Transportation aids*
7	*Dilatation elements*

6. OUTCOMES

This project demonstrated that a mixed team using the opportunity search method for the development of new products (i.e. the SETL method) and employing widely accessible ICT, is capable of achieving the desired outcomes. Since the project was multipurpose, its results were also multiple: ranking of opportunities, inclusion of opportunities into the set of developmental projects, development of competencies among industrial engineers and engineering students and contribution to the validation of the opportunity search method for new product development.

The large significance of a company's characteristics for its opportunity search is evident from the method's description (primarily step 2). However, it should be emphasised that the use of the method is not bound to and constrained by the specific nature of the company in which it was successfully tested. One of the indicators of its independence from company type is its successful use during the opportunity search for a small mountain farm (on the basis of its results, the farm's owner decided to breed Scottish cattle, and this is already providing additional income) [8]. In this case, it was not about searching for opportunities for new product development, but searching for new/additional activities for a farm viewed as a micro company. The composition of a team is influenced by the organisation of a company.

All team members and the company management assessed the project as valuable and successful. The authors were well aware of the usual weaknesses of self-report data, but the questionnaires were the easiest way to collect information about initial impressions of the project's stakeholders. Using a questionnaire (with the five-point Likert Scale), the satisfaction of project participants was verified among students and company representatives. Although the selected sample was very small (students n = 3, employees n = 5) and the obtained results are therefore not representative, certain conclusions can still be drawn from the analysis of responses about the efficiency of the used method and the satisfaction

Table 4. Parameters of SETL method implementation in the company

	Duration [weeks]	Workload per team member [hours]	Number of core team members	Number of extended team members	Time consumption per step [hours]
Step 1	5	25	4	3	175
Step 2	11	95	4	4	760
Step 3	1	3	4	6	30
Step 4	8	52	4	7	572
Sum	**25**	**175**			**1537**

of project participants. Company representatives (M = 3.33) demonstrated slightly lower agreement with the statement that the used method was simple, systematic and easily reviewable than did the students (M = 4.2). However, both groups agreed that no specific prior knowledge was necessary for using this method (M = 4.6) and also confirmed that team work stimulated the search and extraction of data and information, and the recognition of opportunities (M = 4.33 or M = 4.2). A difference in responses (with significance defined as average responses deviating by 0.5 point or more) was found for the assertion that the acquired knowledge would enable better quality of work on the next project; the students (M = 4) were not as sure of this as were the company employees (M = 4.6). Regarding the claim about acquired knowledge, however, the situation was quite the opposite: the students were convinced (M = 5) that they could not have acquired such knowledge in any other way, while the employees were less sure of that (M = 4.2).

6.1 Opportunities for new product development

The most important thing for the company (e.g. its management and its shareholders) is to get results. It was for this reason that the company decided to implement the above-mentioned project, i.e. identification of opportunities for new product development. Without such project results, the company's future would have been at risk and there would probably have been no results at all, because the company does not know how to do systematic product development, and neither does it have sufficient human resources for such development.

The result of the project was ranking of opportunities for the development of new products. The company management included the top three opportunities into its set of developmental projects. In our opinion, this is a relevant and quantifiable measure of success and contributes to the validation of the opportunity search method for finding new products. It was written in the Introduction that within the framework of the beginning of validation, the authors were interested to see whether the method enables the discovery of opportunities for the development of new products when used by a mixed academic-industrial team.

The implementation of similar projects in other companies with other teams, and the results achieved there would certainly provide a clearer picture of the value of this method.

For each opportunity that was selected by the company, one product was subsequently developed through the company's further cooperation with the LECAD Laboratory (i.e. via the use of mixed teams), either up to the level of partial prototype (for the opportunities A in C) or comprehensive prototype (opportunity B and an additional one—'transportation aids' (Figure 2)). As part of product development, patent applications for opportunities A and B have also been filed with the Slovenian Intellectual Property Office. It is believed that the acquisition of government co-financing for continued development of new products arising from the opportunities identified as part of the project is an additional indicator of the quality of the method's results.

The issue of intellectual property is a potential problem of this work method (i.e. the use of mixed industrial-student teams): is it the property of the company, the students, the participating university staff or the University, or should it be owned jointly by all the relevant stakeholders? In order to avoid the problems related to intellectual property, these things need to be agreed upon in advance, at the beginning of the project, taking into account the rules and regulations of the company, the University and any other participating institutions which will provide the experts (i.e. invited extended team members) for the project. In our case, the authors of the patents were the core and extended team members, and there were no invited experts. The students had no financial rights.

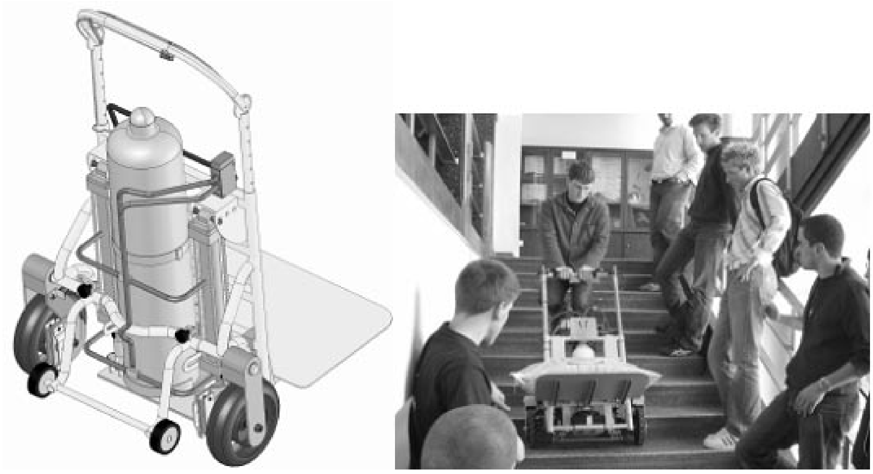

Fig. 2. 'Transportation aids' opportunity: a 3D model and testing of the prototype.

7. EDUCATION

The project was performed in the form of project based learning, using teamwork within an industrial setting, which is characteristic of modern education of both engineering students and industrial engineers (i.e. corporate training). Each step of the method was accompanied by reflection sessions to analyse and evaluate the activities (e.g. what was done and why) within the specific steps. The reflection sessions were performed to facilitate learning through experience for engineering students and industrial engineers; Hirsch and Mckenna suggested that reflection also provides an opportunity for team members to abstract principles about factors that contribute to high performing teams [21]. The sessions were led by the advisor (a core team member).

Project-based learning addresses transfer of knowledge, which may be defined as the ability to extend what has been learned in one context to other, new contexts [22, 23]. This is an important component of engineering competency development [24]. Emerging evidence suggests that project based learning encourages and supports collaborative work [25]; it also improves retention and enhances design thinking [26].

An important characteristic of product development is a high share of tacit knowledge. Tacit knowledge is personal, hard to formalise and highly context specific, and as such it is difficult to transfer or share. For example, experience, intuition, insights and hunches are of tacit nature. Spender suggested that tacit knowledge could be best understood as knowledge that has not yet been abstracted from practice [27]. The project enabled the transfer of tacit knowledge between individual students, as well as between students and professional engineers from the company, the advisor and invited experts. Knowledge transfer was also facilitated via ad-hoc based team member interaction with other team members, the advisor, invited experts and professional engineers from the company. These modes provided possibilities for individual knowledge transfers, which are believed to be a successful way to transfer tacit knowledge within organisations and among collaborating organisations [28, 29].

The company team members were familiarised with the SETL method and actually used it in the mixed team during their search for opportunities for new product development. They were able to personally experience cooperation with students and also acquired experience concerning the role of this method in searching for new product opportunities.

A similar consideration applies to the students, i.e. future product developers: to them, participation in the project was an opportunity to engage in multidisciplinary teamwork and project based learning, and to learn about the application of this method in industrial conditions. This approach enables students to gain the knowledge, skills and experience needed for their professional life. Through the project, the students were also able to experience first-hand the importance of what they were learning.

It is believed that with this project the team members acquired several various competencies (e.g. focused extraction of data and information, searching through patent bases, online full text journal searches, collaboration, and teamwork). So far, this cannot be supported by in-depth analyses (e.g. statistical analyses), because it was the first project of this type and samples are simply too small for analysis. In addition, the "three horned dilemma" also needs to be taken into account: according to McGrath, there is no strategy that would simultaneously maximise generalisability with respect to populations (i.e. mixed product development teams), precision in the control and measurement of variables related to behaviour of interest (i.e. behaviour of mixed product development teams and individual team members) and realism of the context within which those behaviours are observed; the three-horned dilemma can only be handled by applying an appropriate combination of complementary methods [30], and only a convergence of findings obtained by applying such methods will ensure their veracity [31, 32].

It is also not known whether the participation of students in such projects is indeed the best way to educate them. The authors believe it is, but the level of authenticity of project based learning remains an open research question [26]. The difficulty related to solving of authentic problems using 'pure' student teams may be its limited power to impact on a solution, but the use of mixed academic-industrial teams within an industrial setting has removed this problem. Another issue regarding authenticity might be the lack of harmonisation between the theoretical/practical levels of a project and an insufficient competence of students. In our case, the level of harmonisation was evaluated as appropriate to include students. Team formation and team behaviour are other issues that deserve research attention. It is quite possible that the optimal composition of mixed teams in effective searching of opportunities for new product development is different from the one applicable to effective education of students (i.e. future product developers) and company professionals. A major problem regarding the team composition is also the fact that in SMEs, which constantly face a lack of human resources, there are very few opportunities to choose team members with various personality traits for specific functional roles needed in a team as proposed by e.g. Belbin [33]. In our case, for example, the participating students were already 'attuned' to each other, as they had worked together during the course of their studies, and this certainly contributed to the effective functioning of the entire team. The company professionals were also used to working with each other in the company, so that in our case there were no noticeable difficulties related to the personality traits of team members and their communication.

Furthermore, the learning curve of the participating students following their entry in the professional world is believed to be steeper—i.e. they will be able to become effective product developers within a shorter period of time than those who did not participate in the project. The authors base this belief on a large body of learning-curve research which has demonstrated that performance improves as a result of increased experience [e.g. 34, 35, 36].

The questionnaires (the last three assertions; see results and the remark regarding the representativity of results in Section Outomes) which were used to collect information about the initial impressions of the project's stakeholders show that the company's engineers and students highly valued the team work and the knowledge acquired during the project. This finding also represents a contribution to the initial validation of the opportunity search method for the development of new products, used by industrial-academic teams (regarding pedagogical objectives).

In addition to receiving education in the usual sense of the word, students were also able to familiarise themselves with the company during project implementation, and this had an effect on their later choice of employer. However, the company also got to know the students, which made its decisions about recruiting new human resources easier. In this particular case, two of the participating students will soon be employed by the company and will thus continue their work in the field of product development.

8. ROLE OF ICT

Nowadays, integrated product development cannot be done without ICT. It is evident from the description of steps of the opportunity search method (see the Opportunity search method above) that the practical implementation of this

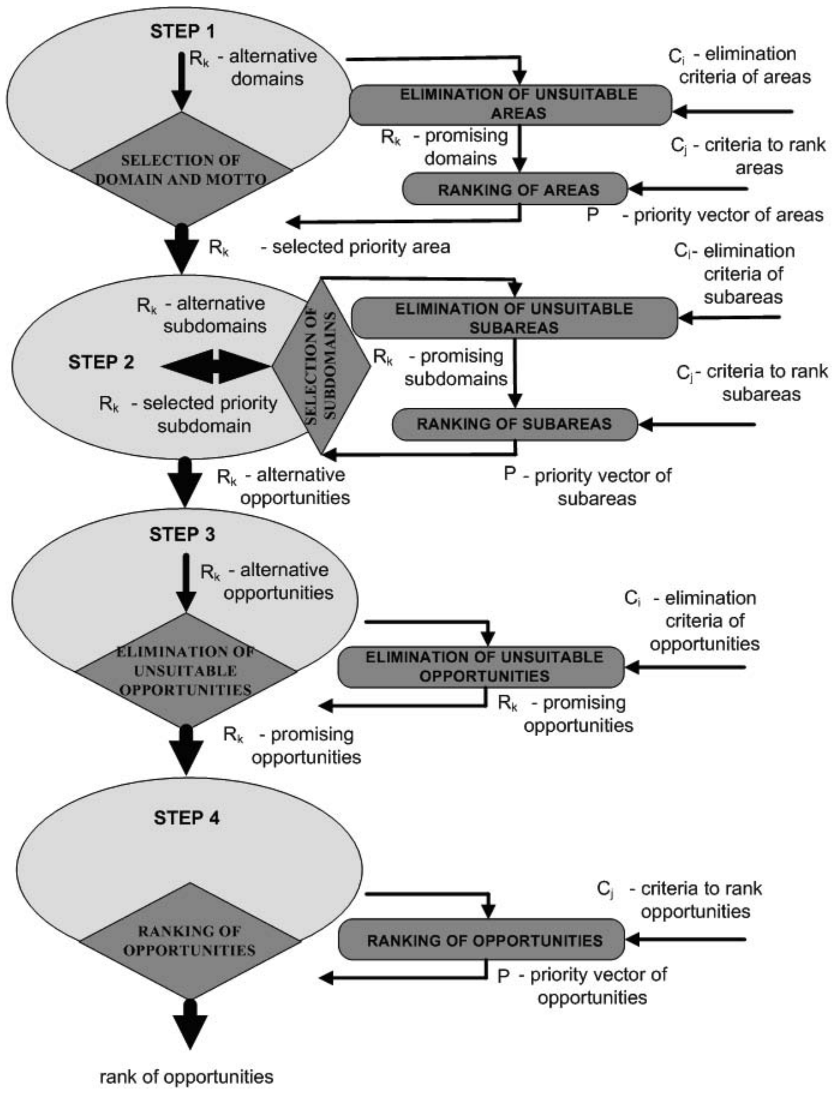

Fig. 3. Decision making within the SETL method steps.

method involves searching through and the analysis of a multitude of data and information, as well as communication, discussions and decision making based on the results of these analyses and discussions (Figure 3). For these activities, general ICT was used (e.g. web browsers, digital libraries, online journals, patent databases, e-mails, internal and international data networks), and only in decision making did we employ our own, purpose-made decision support software developed on the basis of the AHP method [37].

Although the laboratory had its own videoconferencing equipment (which the company did not have), all presentations of intermediary results, discussions and decision making were done face-to-face. Due to the company's relatively small distance from the University, this was not a large problem in terms of time and costs. In the case of geographically dispersed teams, however, in which face-to-face communication is impractical, costly or even impossible, the use of videoconferencing equipment is definitely the most suitable method. This is because video communication is the only method of virtual communication that is close to face-to-face communication [38, 39].

Based on the nature and scope of the project (e.g. search for opportunities for new product development, a medium-sized company, a co-located team, common ICT), it was not necessary to use complex collaborative techniques, such as Internet-based collaborative design environment, which would allow the integration and interoperability of heterogeneous software and hardware as is the case e.g. with multinational corporations, strategic alliances or merged enterprises.

Because of the vital importance of searching for various types of data and extraction of information for successful implementation of the SETL method, the data-mining process (especially text and Web mining) and computer support of the process show great promise. This technology was not used in the project because there were no resources for its implementation at the time. Due to its high complexity (for example, most flexible tools are enterprise-wide applications and setting up a consistent framework across different functional units may require significant upfront investment of time, effort and cost [40], plus the tools are highly complex), focus on large enterprises, the newness and high price of the tools, there is currently little chance of it being accessible to manufacturing SMEs. In addition, for now SMEs tend not to build their own databases (e.g. regarding customer feedback reports, customer e-mails etc.), which would enable the extraction of various concepts, trends, patterns etc.

An even more complex and potentially highly useful process is audio mining of e.g. potential/existing user interviews and internal discussions. We have to bear in mind that minutes of discussions are merely interpretations of the minutes writer, and that some valuable data may be filtered out during transcriptions.

In spite of the use of mature ICT, the team managed to find opportunities for new product development relatively quickly and the company included them in its developmental plans. Applied ICT was not as sophisticated as data-mining tools, but it was much more accessible (because of its wide availability and low price). Due to the previous experience of team members (especially students), it only required short training on search strategies.

9. CONCLUSIONS

Collaboration between the University and industry in the area of product development (i.e. search for opportunities for new product development) and project based learning is presented through descriptions of the SETL method and its implementation in the company. The SETL method offers a prescriptive approach to increase the probability of discovering and economically exploiting high-value opportunities. The method is systematic and as such it is also transferable (i.e. teachable).

Certain tasks which could have been done by individuals, such as searching for data and information, were intentionally assigned to two people, i.e. a student and a company employee. The students were unconstrained by the company's characteristics, while the company members contributed their pragmatism and experience from practice. In addition to more comprehensive and reliable collecting of data and information, the students' ideas were thus placed within a feasible framework, while on the other hand the company team members were induced to invest more effort and not rely on the well-known excuse 'This is not possible'. It was also easier to implement idea generation methods, such as e.g. brainstorming and brainwriting, which the company employees were not accustomed to, while the students had used them regularly during the course of their studies. The company employees were thus forced to adjust, as they wanted to become equal to the students in terms of methodological knowledge. On the other hand, the company employees had a large advantage of knowing how to do economic calculations for individual opportunities, and this also proved highly beneficial to the students, since financial calculations are constantly done in the company, while the students only had some basic knowledge about them.

Another important result which should not be overlooked was the recruitment of the students by the company. Through this project, the company had the opportunity to get to know the students and the students got to know their potential future employer. From the financial standpoint, it is important to note that the costs of the whole process of discovery of opportunities for new product development and education of students/industrial engineers were lower than they would have been had these three processes (i.e. discovery of opportunities, education of industrial engineers and education of students) been executed separately. It is true, however, that the price/performance ratio was not quantified due to the many complexities mentioned above.

The achieved project outcomes comprise the inclusion of identified opportunities in the company's developmental plan, contribution to the validation of the method, and positive responses of the project participants. The key factor for the progress of this project (as well as any future similar projects) is having the support of the company management and ensuring its continual participation in the project.

However, it was not possible to conduct an in-depth analysis of the effects of project-based learning on the development of various competencies of the participating students and industrial engineers/managers on the basis of just one project and one mixed team, so for the time being its potential effects (e.g. steeper learning curve, competence development) are supported by the positive evidence of various other studies of learning curves, project-based learning etc.

One of the key problems related to the use of this approach in regular education of students is certainly the availability of appropriate projects. They would need to be performed at the right time and in adequate numbers, their content would have to be harmonised with the students' competence level, and the companies would need to agree with the team composition. The availability and increased workload of faculty members in performing project-based learning is also problematic and such education is much more costly than traditional curriculums.

The presented insight into the above-mentioned approach might suggest that SME management and academia should initiate and perform similar projects, benefit from their educational and industrial content and outcomes, and perform in-depth analyses of its potential. Successful projects could also prompt relevant government institutions to financially support such an approach in order to facilitate (university and corporate) education and the success of new product development within SMEs.

Acknowledgments—A part of the project is co-funded by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia (Contract No. P2-0256), and the authors appreciate its support.

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