Identification of optimal features of the knowledge base in project-based learning engineering education - Qualitative analysis of applications in engineering practicum

D. Purković

* University of Rijeka, Rijeka, Croatia
damir@uniri.hr

Abstract - Project-based learning (PjBL) is an important segment of today’s technology and engineering education. It is essential for the development of students' adaptation and anticipatory competencies, i.e., the acquisition of procedural knowledge, the development of tacit knowledge and metacognitive skills. Accordingly, the relevant knowledge base could be of an invaluable help to students in performing problem-solving tasks, which are one of the key elements of project-based learning. For this very reason, the aim of the research was to identify the basic elements and characteristics that the knowledge base in project-based teaching should exhibit, and that are important from the point of view of their cognitive effect. The paper therefore gives an overview of the qualitative analysis of the achievements in project-based engineering practicum, which is offered to students enrolled on the undergraduate study of Polytechnics, University of Rijeka. The observation analysis indicates the main features of the knowledge base that are important from the cognitive impacts in the project-based engineering education. In summary, main features and characteristics are as follows: simplified visualization, fundamental and/or simulated abstraction, segmented problem situations and tasks, user friendliness, the possibility of basic interactivity and collaboration, and clear students' expectations. Despite the role that knowledge base and knowledge management system can occupy in a project-based engineering education, their importance and use should not obstruct the main PjBL activities.

I. INTRODUCTION

A successful solving of the main problems of modern education, as well as technical (technology) and engineering education, can be explained to the efforts of educational institutions and systems for more effective development of the adaptation and anticipatory students' competencies [1], [2], [3]. Adaptation competencies include verifiable knowledge, skills and personal values that will help an individual to enter the labour market faster and become an integral part of the "real world" after they complete their formal education. The term "anticipatory competencies" is applied to the abilities to jointly analyze, evaluate and create rich "images" of the future that are pertinent to the issues of sustainability and the sustainability of the problem solving framework [1]. In fact, these competencies, which could be regarded as a qualitative upgrade of the adaptation competencies, mostly refer to the development of the individuals' mental mechanisms, i.e., their cognitive and metacognitive skills, which will enable them to faster managing in new and unfamiliar situations and circumstances. Nowadays, the need for the aforementioned competencies is strongly emphasized in different technical and technological branches and engineering. Such state of affairs highlights the necessity to encourage the development of these competencies at educational institutions.

A. Project and problem-based learning

Contemporary teaching and learning strategies, systems and models of technology and engineering education are seeking to respond to the challenges and demands of contemporary world in which current educational systems, which are mostly organized in a traditional manner, recognize an immense importance of project and problem-based learning and teaching. However, the differences in defining the models of problem-based and project-based teaching and learning suggest an overriding and constant need to draw a clear distinction between the aforementioned approaches and traditional teaching. Without going into different theoretical definitions, let us state that the so-called project-based learning (PjBL) should meet the following criteria: it should take a central place in the curriculum relating to a specific subject area; it should focus on issues or problematic tasks that that "drive" students to encounter and struggle with the central concepts and principles of a discipline; students should conduct applied, multidisciplinary and constructive investigations in which they need to invest a high level of autonomy and a great responsibility for project realization; and it should allow students to have a high level of autonomy and a great responsibility for project realization; and it should create a sense of authenticity, which links the education and the "real world", amongst students [4]. Despite the fact that problem-based teaching and learning (PBL) are defined and interpreted differently, PBL activities usually share some common features, which are as follows: an increased focus on students who work independently in small groups and under the guidance of teachers who perform the role of facilitators; the students are faced with authentic problems that represent tools for acquiring the necessary knowledge and skills required to solve the problem in question [5], [6]. The characteristics and
criteria of the project- and problem-based learning and teaching reveal many correlations that emphasize the importance of the learning context, as well as the features of contextual teaching [7]. Although in the field of technology and engineering education, project-based teaching and learning make a more acceptable option, or even a key component [8], it is clear that the some steps of PjBL represent a typical PBL, i.e. micro-steps of project-based teaching and learning. Therefore, in this research, student problem-solving activities, as part of the PBL, represent important micro-steps of PjBL whose purpose is to product development.

B. Knowledge base and knowledge management

Even though the use of a knowledge base (KB) and an appropriate knowledge management system (KMS) could constitute an important part of project-based technical and engineering educational context, their implementation depends on the necessary support in terms of management and organizational culture and structure [9]. The term KB is generally used to refer to as an organized repository of knowledge that comprises concepts, data, aims, requirements, rules and instructions 10. On the other hand, KMS are conceived of as tools aimed at supporting knowledge management processes (KM), i.e. knowledge creation, storage and retrieval, the transfer of knowledge, the application of knowledge, and the flows between these processes [11], [12]. Taking into account these definitions and the previously mentioned features of PjBL, it is not difficult to conclude that the process pertaining to the dynamic development of an appropriate KB and the implementation of the KM system in engineering and technology education is extremely complex. This complexity also calls for a high level of explicit knowledge, tacit knowledge which is rooted in action, experience and participation in the specific context [11, 13], as well as a high amount of embedded knowledge, which resides in a number of norms, rules, processes, products, specific ethics, etc. [13].

In the light of this review, it seems fair to conclude that any application of the KB and KMS in project-based teaching should take into account all of the above, as well as the systematic assessment of the direct impact of KB and KMS on the student’s overall achievements and competencies.

II. PROBLEM, AIMS AND RESEARCH CONTEXT

This research is concerned with the issues concerning the basic characteristics of the KB, but also the processes and KMS, important from the standpoint of cognitive impact and specificity with regard to the particularities of technology and engineering education. In the light of these issues, the present study poses the following research question: Which essential features knowledge base and an appropriate knowledge management system should have in order to achieve the optimal cognitive effect in project-based technical (technology) and engineering education? In other words, the aim of this research is to identify the basic elements and characteristics of the KB in project-based teaching, which are important from the point of view of their cognitive effect, namely to achieve the optimal level of student achievement.

In this respect, it is important to explain the context in which the research was conducted. The contexts of learning and teaching are particularly vital and they differ in terms of conditions, dispositional and experiential students’ knowledge, but also in terms of the level of education. The research reported in this paper was carried out during the implementation of a project-based approach to the teaching of the course in Practicum of the material processing, which in fact represents an introductory engineering practicum. The aim of this practicum was to enable students, future engineers, to apply theoretical engineering knowledge to the development of products, as well as to perform different activities and standardized manual material handling (Hands-on activities). For a long time, this practicum has been taught in a traditional way. This means that students were not encouraged to developing products. Rather, they were given practical exercises that stimulated them to implement standardized manual material handling procedures. By observing that the competencies developed in such a manner do not satisfy the needs of the contemporary society, four years ago the traditional approach was replaced which project-based teaching and learning aimed at stimulating students to come up with product ideas, create products, adapt to conditions, make decisions about materials and resources, make the product, document and present their own project and product. The preliminary research into this approach has shown that some of the effects of project-based learning are better then the impacts exerted by traditional exercises [14]:

- Students find project-based learning and teaching more interesting than traditional approaches;
- Students believe that the quality of their technical knowledge and competencies is higher and that the knowledge and skills that they have acquired are more useful;
- The analysis of the results of students’ activities shows a significantly higher level of product quality in their work;
- The analysis of the results shows a higher level of motivation, self-confidence, responsibility, and readiness for team work, especially in the final stages of project realization.

Despite the above-mentioned findings, the average level of students’ achievements in project-based teaching context is not strikingly different from the level of achievements in the environment which adopts traditional teaching approach [14]. In this research, standard tools for measuring were used in order to measure workpiece precision and the quality of the documentation produced, as well as to assess the practical skills of applying standardized material processing. However, the achievements of those students who were provided with the opportunity for self-realization were significantly higher than students’ achievements in those contexts which adopt traditional teaching approaches. Therefore, it ought to be emphasized that the value of PjBL lies in the possibilities of students’ self-realization and the development of anticipatory, communicative, collaborative and socialization competencies, which are
nowadays regarded as the key competencies of an individual.

By analyzing the previous students’ experience with technology as some kind of assumptions for successful PjBL, preliminary research [14] revealed a relatively low level of such experience. That can significantly influence the student’s final competencies, but also determine all the stages and end result of project-based learning. Based on a short overview of students’ previous experience (Table I), we can conclude that despite the fact that they have been attending various engineering courses for many years, most classes have a low level of real-world experience with technology. What remains an exception is a somewhat higher level of experience in the following areas: technical design and drawing, ICT experience, and experience in the e-learning environment. Such state of affairs seems to be the result of the educational system in the Republic of Croatia, where technical competencies are developed at a minimum level or are not developed at all in primary and secondary education. In such a context, which is still demanding and intensive, it is necessary to conform to students’ expectations. Moreover, facilitating, moderating and encouraging should be more intensive.

<table>
<thead>
<tr>
<th>Areas of student experience</th>
<th>Approximate level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience with technology and technological equipment</td>
<td>LOW</td>
</tr>
<tr>
<td>Mechanical engineering experience</td>
<td>LOW</td>
</tr>
<tr>
<td>Technology design and drawing experience</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>Experience in the field of applied sciences and mathematics</td>
<td>LOW</td>
</tr>
<tr>
<td>Electrical engineering experience</td>
<td>LOW</td>
</tr>
<tr>
<td>Programming and program languages experience</td>
<td>LOW</td>
</tr>
<tr>
<td>ICT and e-learning environments experience</td>
<td>MEDIUM</td>
</tr>
</tbody>
</table>

Apart from the above, it should be emphasized that the research was conducted within a typical Croatian educational context whose characteristics are as follows: relatively limited resources and technical support, no qualified staff, fairly limited opportunities to find external partners for project cooperation and the difficulty of harmonizing such learning with the traditional teaching approaches. Taking into account the fact that there is no systematic strategic and organizational support for the integration of the relevant knowledge bases into a complete KMS, it is not difficult to conclude that teachers carry the burden of incorporating project-based teaching in the curriculum, and they have the obligation to cover necessary expenses.

Despite such circumstances, it is possible to organize and implement project-based teaching, whose results, guidelines and developed systems and mechanisms could be a good roadmap for the future implementation and the wider use of appropriate KB, KM and KMS in technology and engineering education.

III. RESEARCH METHODOLOGY AND SAMPLE

A. Procedure-KMS development

For the purposes of the research, different and already available LMS and CMS systems and tools for the storage and dissemination of materials, as well as the ones for cooperation, communication and content exchange were used. The system was developed as a series of handheld mechanisms that provided content, problem tasks, and performed activities in various ways and with different dynamics. Therefore, no separate or specific software has been developed, but a dynamic mechanism that simulates KB and KMS, without elements of corporative strategy and policy. Due to the peculiarities of project-based technology and engineering education, which are characterized by the fact that in these areas of study the explicit and tacit knowledge is demonstrated and assessed through application and practice [17], the KM mechanism was based on a general theoretical framework. In this framework, which is considered to be a certain hybrid between the matrix of knowledge types and approaches proposed by Gamble and Blackwell [13] and the process model of knowledge management quoted by Botha et al. [15], individual activities have priority over technology. Technically, it is a platform of related and integrated data that is based on a model of the connected data architecture [16], and consists of the core of basic knowledge component, knowledge acquisition component, a set of meaningful links, a problem-solving component, and a component relating to communication and information exchange. More specifically, general knowledge consists of information on the structure of technical creations, products, materials, tools and machinery, processing methods, standards and technical equipment. The problem-solving component comprises: technical requirements for the realization and design of the mechanical construction, the selection of materials, procedures and equipment for the realization of the products, the selection and realization of the electrical and electronic circuits, and the realization of the program support and the circuit management codes. The knowledge acquisition component includes the contents and materials produced by the students, as well as students’ segmented problem solutions. The validity of these contents and materials was verified by students during project implementation, with intensive use of the communication and information exchange component. Everything mentioned so far was related to a set of meaningful links, i.e. a separate component which was a link between the components, but also the links with external sources.

KB and KMS that were structured according to the above-mentioned procedure were used to facilitate students’ project activities, research, decision-making, communication, content sharing, and problem-solving at the key stages of PjBL (Figure 1). Using KB and KMS, students designed the product, solved segmented problem tasks, produced documents, and valorised their own solutions during product realization. In practice, they
implemented their solutions, refined them, or revised them.

Consequently, they expanded their knowledge, developed new skills, and a knowledge acquisition component. In the end, they presented the acquired knowledge, the developed product, project documentation, experience and contributions to their colleagues.

B. Sample

The sample (N = 56) comprised undergraduate students of Polytechnics, University of Rijeka and the research was conducted during three academic years. The participants were the students enrolled in the 5th semester, who already had some background theoretical knowledge of sciences and the field of technical design, mechanical engineering, electrical engineering, computing and energy. Participants were not randomly selected. As a matter of fact, all students enrolled in a particular academic year participated in the study. During each academic year, students were engaged in designing, constructing and building prototypes, i.e. functional CNC milling machines and robotic arms. Project topics were chosen by students themselves, while the limitations were imposed by the teacher or the community. Limitations were related to the use of products, as well as the use of discarded materials, assemblies and parts (recycling), and the use of widely available and inexpensive microcontrollers and other development platforms. Activities were conducted in teams consisting of 7 to 10 students, and the teams were formed by the students themselves.

C. Instrument

In order to monitor the cognitive effect of the described mechanism and the progression of students, participative observation was applied, as a method of observing student behavior / response during the teaching activities. For this purpose, a semi-structured instrument was developed. In this instrument, students’ achievements, which are relevant in terms the KB and KM, were thoroughly commented upon. The instrument consisted of predefined categories with descriptive observations / performance indicators. Performance indicators, which were carefully monitored and evaluated during the research by using the above instrument, were as follows:

- Students’ engagement, orientation, as well as the level and intensity of teacher’s intervention in the solving of partial problem tasks;
- Using sources, contents and other materials to sort out problems and providing feedback on partial problem solutions;
- The quality of produced documents and materials, as well as the overall impact on the achievements;
- The quality of communication, collaboration, and student materials shared by KMS;
- The quality of solution implementation, and the individual and collective presentation of their own activities.

According to this structure, predominantly collective observations were conducted, but also individual if they differed significantly from the group. With this structure of the instrument, the aim was to keep as much observations as possible within the ones that should primarily be the product of using the KB and KMS.

D. Data collection

The previously described instrument was used to note down observations from direct teaching during the 12 weeks of PjBL implementation. Even though the course in question is a one-semester course lasting 15 weeks, the first three weeks were dedicated to the performance of pre-tasks aimed at familiarizing and adjusting students with the conditions, means and the rules regarding the safe use of the equipment. Observations were written by the teacher, who is also the author of this article, after each week of classes, but also during the communication with students, by examining solutions that are shared through KMS and the evaluation of students’ presentations. Observations were made continuously and especially after each modification of the KB. Through the modifications of the KB, we directly manipulated different levels and ways of adjusting content, events and segments of problem tasks, as well as ways of content dissemination during project realization. The modifications of the manipulated KB components are shown in Table II.

The research was carried out during the period of the three academic years and it included different student groups. The modifications were introduced in the same manner in all three groups. The default level of KB was used during the first 4 weeks, the first modification during the other 4 weeks, and the second modification during the last 4 weeks of PjBL. Since it was not possible to equalize the groups of students, only those observations that were common to all groups were taken into account. As the research was concerned with the characteristics of the knowledge base, it sought to keep the focus on those observations that were assumed to be the result of the KB and KMS used. All the observations were categorized according to the indicators and their percentage share in overall observations pertaining to each individual component and modification was determined.
Only observations with a high percentage share in the overall observations relating to each modification (> 50%) were retained and descriptively modified in order to be comprehensible. The most significant findings, emerging from all the observations, were then grouped into complex categories and an appropriate interpretation of the observations was given. Based on the results, the main characteristics of the knowledge base and the knowledge management mechanism were identified. These characteristics could produce an optimal cognitive effect in the project-based teaching and learning which takes place in the context of technology and engineering education.

IV. RESULTS

Upon carrying out the research, a total of 963 observations have been extracted from extensive records, produced materials, documents, project work results, and student presentations. In reference to the default, first and second modification, there were 248, 392 and 323 observations respectively. By creating logical links between observation categories and manipulated components, the most common observations pertaining to each manipulated component were identified (Table III). On the basis of such a linkage, the effect of these modifications on the project activities of students was determined.

In regard to the default (initial) level relative to "The core of basic knowledge" component, a high degree of disorientation of students (95%), a low level of understanding and the use of the proposed sources (64%) was observed. Furthermore, it should be pointed out that the impact of such sources on the achievements in project-based teaching was not entirely clear (55%). Although the understanding of the problem tasks (75%) was observed in reference to the "problem-solving" component, there was also a high intensity of teacher interventions (92%) and a low percentage of appropriate partial problem-solving (78%). As far as the "meaningful links" component is concerned, it ought to be emphasized that students were well-oriented (63%), but there was a low level of comprehension of the content they were studying (73%) and inappropriate adjustments to problem solving solutions emerging from the proposed sources (92%). In relation to the default level of the "Communication and cooperation" component, it was noticed that students communicated with the teacher only in order to fulfill their formal requirements (75%). Furthermore, a low level of the use of system for student communication and content exchange (62%) was identified, as well as a low level of production and a poor quality of materials exchanged by students through the system (54%).

The introduction of the first modification to "The core of basic knowledge" component resulted in a higher level of student orientation (69%), and stimulated further research and project activities (57%). Furthermore, it contributed to a high level of comprehension of the contents in the majority of students (75%), a faster development dynamics (73%) and the use of examples and materials to solve problems (89%). In relation to "The problem solving" component, an acceptable level of comprehension of problem tasks (82%), an acceptable level of student engagement (64%), and an acceptable level of satisfactory solutions to partial problem tasks (58%) were observed. Nonetheless, the findings relating to this component indicate a high degree of teacher’s engagement in problem solving (56%) and student disorientation in using resources (51%). When it comes to the fist modification of "The meaningful links" component, an acceptable level of student orientation (78%) and a low degree of student engagement (67%) were detected. At the same time, there was a low level of understanding of the content needed to solve the problem (53%). Furthermore, students did not use resources which would help them solve partial problem tasks (57%). Students intensively tried to use the links for inappropriate adaptation of solutions to complete their own problem tasks (81%). In regard to the first modification of the "Communication and cooperation" component, a low level of communication with the teacher (52%) and an increased use of communication and content exchange system tools (71%) were noted. Moreover, it was observed that the level of production of the materials that students shared through the system was low, but of acceptable quality (52%).

The second modification relative to the "Core of basic knowledge" component resulted in good student orientation (89%) and their high motivation for project activities (78%). Regardless of that, there was a low level of content understanding (91%), a low level of use of sources which would facilitate problem solving (83%) and a basic level of achievement (76%). At the same time, this component did not have a clear impact on the dynamics of student development in project-based learning (89%). In relation to the second modification of the "Problem solving" component, an acceptable level of understanding of problem tasks (76%) and student engagement (65%) was observed. There was also a noticeably lower degree of teacher intervention in problem solving (84%), an acceptable use of prepared resources and materials (88%)
and a high quality of partial problem solving (73%). The "Meaningful links" component showed the acceptable orientation (79%) and engagement of students (93%) and an acceptable level of understanding of the content needed to solve partial problem tasks (87%).

**TABLE III. MOST FREQUENT OBSERVATIONS FOR EACH MODIFICATION AND MANIPULATED COMPONENT**

<table>
<thead>
<tr>
<th>Manipulated component</th>
<th>Observations and percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>The core of basic knowledge</td>
<td>- A low level of understanding of the content (64%); - Only excellent and experienced students understand the content (64%); - Sources of solving problems are not used (92%); - Without a clear impact on achievement (87%).</td>
</tr>
<tr>
<td>The problem solving</td>
<td>- An acceptable level of understanding of problem tasks (75%); - A low level of student engagement (67%); - A high degree of teacher intervention in solving partial problems (92%); - High disorientation in using available resources (84%); - A low level of performance and appropriate solutions to partial problem tasks (78%).</td>
</tr>
<tr>
<td>The meaningful link</td>
<td>- An acceptable level of understanding of student orientation (63%); - A low level of student engagement (87%); - A low level of the understanding of the content needed to solve the problem (73%); - Intensive attempts at inappropriate adjustment of completed solutions (92%); - Without a clear impact on achievements in project-based learning (67%).</td>
</tr>
<tr>
<td>Communication and cooperation</td>
<td>- Communicating with the teacher only for the purpose of meeting formal requirements (75%); - A low level of the use of communication and content exchange systems (62%); - Low production and quality of contents being shared and exchanged (54%).</td>
</tr>
<tr>
<td>Observations</td>
<td>- A high level of orientation (89%); - Stimulates further research and project activities (57%); - A high level of understanding of content in most students (75%); - Examples are used to solve the problem (89%); - Noticeably higher level of achievement, better performance and development dynamics (73%).</td>
</tr>
</tbody>
</table>

**Notes:**
- The second modification was observed mostly hidden from the teacher (87%).
- V. DISCUSSION

Based on the observations pertinent to each modification of the KB, which indicate an acceptable or very acceptable effect on performance indicators, and by making a comparison between the features of each modification, it is possible to identify the main features each component needs to meet. For the component "The core of basic knowledge", the most optimal effect on the observed indicators was observed in the first modification. This indicator points out that the core of basic knowledge, which is appropriate for engineering PjBL, should be characterized by appropriate and simplified visualization, schematic representations, static images, simple interactive simulations and various explanations. These explanations should also refer to highly specialized sources and databases. As far as the "problem solving" component is concerned, the optimal effect on students' achievements was observed in reference to the second modification. This indicator shows that the problem-solving component should contain clear problem-based tasks, individual and group, as well as clear student expectations, accompanied by inventive problem-solving sources. The sources in this component are segmented examples of solutions to the problem tasks, which logically guide students to more effectively find solutions for solving their own partial problem tasks. In doing so, students adopt and apply the underlying logic, which is clear from the above examples and which leads them to the solution of the problem. It is extremely important not to give the students solutions to their problems, but only segmented solutions to similar problems. Namely, completed solutions will trigger the action in PjBL, but will not stimulate the student's mental effort that is essential for a successful learning process. With regard to the "The meaningful links" component, the best effect is expressed also in the second modification. Given the differences in modifications, it is obvious that linking to similar examples to problem-solving makes the main difference in comparison to other changes. It is therefore clear that the links should include those that will show the student partial solutions to similar problems and thus lead to success. When it comes to the "Communication and cooperation" component, the optimum effect is observed in the second modification. This means that the knowledge base and knowledge management system should allow students a free choice of tools and ways of communications, collaboration and sharing their own contents. Such a way of communication and cooperation, though largely beyond the control of teachers, probably provides the students most effective work environment.
Among the findings outside the context of the processed results, one should also consider some more important observations. When it comes to expert sources (manuals, standards, literature, material bases, tool specifications, etc.) without which it is not possible to develop a product or technology, it should be observed that students are intensively using them only during the preparation of the final documentation and project presentation. Until then, they mostly make use of various types of scripts, internet sources (often unreliable) and prepared (simplified) materials that are part of the core of basic knowledge. Therefore, sources relating to this component are used only if their level of adjustment is in the "cognitive range" of the student. For this reason, it is extremely important to form the core of basic knowledge that it is tailored to the cognitive level of students and comprises only available and highly specialized resources that will gradually become understandable and applicable in the final stage of project-based learning. When it comes to single project-based teaching phases, the research has shown that most of students' time is spent on developing and realizing mechanical prototype design, despite the fact that they have mastered most of the engineering subjects. Thus, the seemingly trivial problems of mechanical construction, in actual realization, become a major obstacle for students. Another major problem arises when connecting the knowledge from programming with the knowledge of electronic and computer hardware, in spite of high level of knowledge in programming, as well as the knowledge of computers, electrical assemblies, interfaces, actuators, sensors, etc. However, linking these knowledges into the meaningful logical concepts for the computer managing of developed prototype is a bigger problem for students. Resolving these two issues, unfortunately, does not facilitated by many examples of the ready-made solutions, but only with segmentation of each problem into smaller, logically related and cognitively appropriate examples.

Although the features of KM and appropriate KMS are apparent from the observations of the effects of each modification, the possible limitations of the research results should be highlighted. Namely, here are not controlled variables of possible external influences on the observed indicators. At the same time, the observed groups were groups of students whose characteristics were not uniform before the research was conducted. Also, it was not possible to distinguish the possible impact of maturation of students during classes, which is not a negligible factor. All this points to the necessity of further research in which these limitations will be controlled, but in which the actual impact of KB and KM on the students' achievements will be determined more precisely.

VI. Conclusion

The essential features of the KB and KMS, which are important from the point of view of the optimal cognitive effect they exert in project-based technology and engineering education, were identified based on the results emerging from participant observation. In this way, an answer to the research question was provided, even though this answer will surely require additional scientific confirmation. On the basis of the above-mentioned features, the following conclusions were drawn: a) the core of basic knowledge should be characterized by simplified visual representations, schematic views, static images, simple interactive simulations (appropriate abstractions) and distinct clarifications; b) the problem solving component should include clear individual and collective tasks, clear student expectations, and segmented and logically related examples of similar problem solving, rather than complete solutions; c) meaningful links should necessarily contain more (but not too much) links to the solutions of similar partial problems, which will logically lead students to their own solutions; and d) communication, collaboration and content exchange should be tailored for students, i.e. the system should enable free choice of the use of known and available communication systems and tools (i.e. teachers do not exert full control). In order for project-based learning to exert optimum cognitive effect, what is extremely important is students' practical valuation of their own solutions directly in the teaching process. Another aspect that should not be neglected is the importance of the students' presentation of the project's final result (product), in which the preparation of appropriate KB and KMS can play an important role. During practical valuation and the preparation for the results' presentation, students improve their own knowledge, but also the component of knowledge acquisition without which KB and KMS are incomplete.

Finally, computer knowledge base and KMS in project-based technology and engineering education should facilitate project work for students in terms of decision making, problem solving, cooperating and content exchange, rather than becoming self-sufficient. It should not be forgotten that the development of tacit knowledge, which can be gained and valorised only through practice, is the main goal of the project-based teaching which takes place in technology and engineering education. However, tacit knowledge is not the focus of this research.

LITERATURE


