

# Different structures of projects in engineering: the perspective of freshmen students

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## Abstract

This article emphasizes the difference between a Project-Based Learning (PBL) interdisciplinary project developed in the Industrial Engineering and Management of University of Minho and a transversal course to all engineering programs called “Projeto FEUP” implemented in the Faculty of Engineering of the University of Porto (FEUP). It clarifies three different points of view, from three different freshmen students, about the importance of the implementation of projects as learning/teaching methodologies in universities and the impact that this would have in the reinforcement of the links with the professional world. In one hand, the Integrated Master Degree on Industrial Engineering and Management, from the Department of Production and Systems of University of Minho – Portugal, requires the development of a teamwork project in the first semester of the first year, which consists in the application of an active methodology of learning multidisciplinary contents of engineering courses of the semester using the PBL methodology. On the other hand, all engineering courses in the Faculty of Engineering of the University of Porto include a course designated “Project FEUP”, that was conceived to promote a complete integration of the newcomers; a familiarization with FEUP facilities and the services its students are allowed to use and to adapt more easily to the academic environment. This paper aims to highlight the differences of these two project approaches that are very different in contents, context and objectives from the point of view of the students involved that are three authors of this paper. At the same time, the paper authors discuss their opinion about the different project structures and the gains/advantages obtained with both. Main results of this discussion is the awareness for PBL methodology as a dynamic and revolutionary form of learning that empowers the students where they are able to develop not only technical, but also soft skills such as teamwork, among others.

**Keywords:** Active Learning; Engineering Education; Project-Based Learning; Soft skills; Interdisciplinary Project.

## 1 Introduction

The globalized market creates some challenges to Education, particularly, Engineering Education which educates professionals for the world and future decision-makers. This education continues demanding solid competences in technical or “hard” contents but, to face these challenges, it is also needed strong competences in transversal “soft” skills such as communication, creative and critical thinking, system-thinking, pro-active spirit, project management, among others. This means that learning approaches which promotes these kind of competences, better prepare the students for these real world challenges. Active learning methodologies have been discussed as approaches that have what is needed to promote these competences because involve the students in their own learning (Prince, 2004).

Projects approaches and, in particular, Project-Based Learning (PBL) methodology are considered active learning methodologies because they engage the students in the learning process (de Graaff & Kolmos, 2007). Implementing this kind of methodology is not an easy process and depends much on teachers will because it involves changing their normal practices, curricula and programs. This change is needed and even recommended by the High Level Group on the Modernization of Higher Education (2013) to introduce and promote cross-, trans- and interdisciplinary approaches to teaching and learning, in order to help students develop their breadth of understanding and entrepreneurial and innovative mind-sets.

Few universities are doing this, but, fortunately, in the University of Minho (UMinho) this effort has been made. In the particular case of Integrated Master of Industrial Engineering and Management (IEM) of Department of Production and Systems, PBL has been implemented since 2004\_2005 (Lima, Carvalho, Flores, & Van Hattum-Janssen, 2007; Alves, Moreira, Sousa, & Lima, 2009; Alves et al., 2012; Fernandes, Mesquita, Flores, & Lima, 2014). The PBL model implemented is the model of Powell & Weenk (2003) that was implemented by a group of IEM teachers after training workshops with Professor Powell promoted by the UMinho rector. This implementation has been a dynamic process as the teachers involved are always searching continuous improvement by researching in a continuous action-research cycle (Alves & Leão, 2015). After each semester, teachers organized a workshop to have feedback from students and teachers involved. This provided many important progresses in the PBL model (Alves et al., 2014) and an understanding of challenges and difficulties of teachers in this process that becomes a facilitator in a student-centered teaching (Alves et al., 2015; Alves et al., 2016).

To know better this PBL model and responding to a call of an IEM teacher and PAEE organizer, the authors of this paper, as students of different universities, wanted to compare the project implemented in IEM program of UMinho developed in the course Integrated Project of Industrial Engineering and Management in the first year, first semester (IPIEM1) and in the FEUP in the course "Projeto FEUP". So, it was proposed this paper to explain the differences between these two types of project approaches that are very different in purpose, content and objectives. This paper continues the effort of research in the PBL model implemented in IEM program launching a new perspective about this, the perspective of the main stakeholders, the students. In order to do this, the papers authors raises some important questions that were prepared in order to obtain the responses of the comparison.

The paper is divided in five sections. After this first introduction where the objectives are presented, the second section presents the research methodology. The third section introduces and describes the study context. The fourth section presents the main part of the paper: the comparison between the projects structures. The conclusions are shown in the fifth section.

## 2 Research methodology

To achieve the objective proposed for this paper, some questions were raised by the paper authors in order to be answered and to have the results of the comparison of the project structures. It was intended to know how different these projects are, difficulties felt in each, learning and competences acquired. As so, the main research questions were:

- What differences exist between IPIEM11 and FEUP project?
- What difficulties and/or challenges were felt in each?
- What were the personal and professional gains?
- What competences do you considered that were developed in each project? Are they improved?
- Are these projects structures benefit the students which learning level and attention are reduced?
- Is it possible to apply the PBL model to all programs?
- What are the differences felt during the transition from a project semester to a traditional classes semester? How this change was reflected in the learning?
- Do you liked the experience of being integrated in a project approach?

To answer these questions, the papers' authors consult the documents provided by teachers such as "project guide" in the case of IPIEM11, the reports and presentations produced during the project and the experience acquired in the project. Also, in the case of "Projeto FEUP" (PFEUP), the base for the information was the experience of the realization of the project, associated with the report and the presentation. It is important to notice that three authors of this paper are the students who were involved in the projects developed and they are from both universities (two from IEM of UMinho and one from Mechanical Engineering of FEUP) so they were reporting their experiences, perceptions and feelings. So, they defined the questions according to their need in explaining the differences between IPIEM1 and PFEUP they experienced and only for a particular year as they were not involved in different years.

### 3 Study context

The PBL in IEM program is operationalized in Integrated Project of Industrial Engineering and Management I (IPIEM1) course of the first year, first semester (IEM11\_PBL). In this integrated project, students are exposed to an introduction to engineering, concepts of industry and management strategies. Accordingly to these peculiar characteristics, the courses integrated in the project (IPIEM1) are Linear Algebra (Alg.), General Chemistry (GQ), Calculus (CC), Introduction (Topics) to Industrial Engineering and Management (IEM) and Algorithms and Programming (AP) (Figure 1a). These courses are from different schools and departments (Figure 1b).

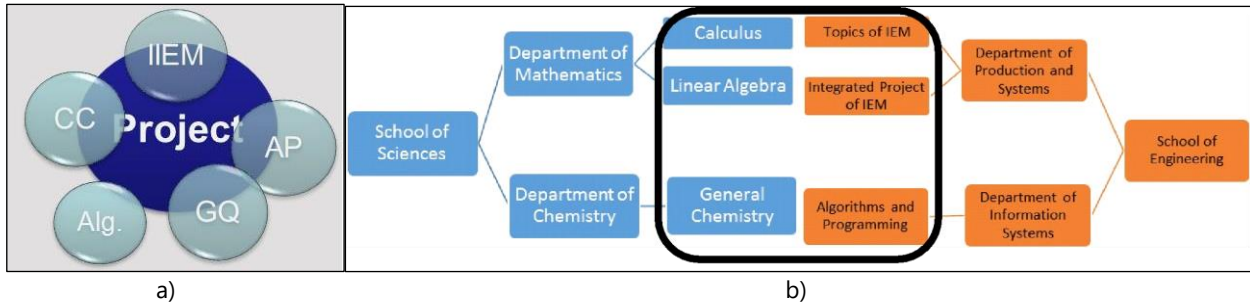


Figure 1. a) PBL model of IEM11 (IEM11\_PBL); b) Schools and departments involved in the IPIEM1 (Alves & Leão, 2015).

This semester is developed with a close approach to the project and it includes the effort from teachers and students (teams with nine elements), and the cooperation between both. IPIEM1 is a course with an active methodology of learning in IEM being an independent course that lasts the entire semester (from September to January). As it is considered an important course, with its strong practical component, IPIEM1 has the same amount of European Credit Transfer System (ECTS) of other curricular units like Algebra or Programming.

In the beginning of the semester, teachers provide useful tools (e.g. documents, bibliography and workshops) for teamwork learning. Teachers prepare a PBL guide that explains the project theme, the specific objectives, the learning outcomes for each course, the assessment methodology of each course, the milestones and resources students can use (teachers' contacts, communication tools, among others). Examples of contents of workshops are: teamwork tools and solve-problems tools, Powerpoint use and to make presentations, to prepare Word documents, how to make references and use reference systems.

Normally, the teachers organize six teams of nine elements each and a tutor is allocated to each team. The teams also have a room project with a space for the teamwork that they can use whenever they need (they have a key of the room). Each year the project is different but teachers select a theme that felt will attract and motivate the teams and, at the same time, deal with a contemporary issue always related with sustainability (Colombo, Alves, Hattum-Janssen, & Moreira, 2014; Colombo, Moreira, & Alves, 2015; Moreira, Mesquita, & van Hattum-Janssen, 2011). The main objective of the project is to allow students to contact, right after the beginning of their university life, with the harsh reality of the world of work that is governed by the resolution of problems that require multidisciplinary knowledge applicable in different situations.

In the FEUP project, the students are organized in groups of three or four elements of each program, randomly, and must develop a theoretical thesis whose theme is defined by the tutor teacher. The main objective of the project is to make the students work as a team while sharing ideas, debating and making decisions as a whole, the same way they will be doing once they enter the labor market. By the end of the project, students should have a report on the given theme, a presentation and a poster on the same subject. This course has the duration of six weeks and is divided in two phases: the first one consists on a week of intensive formation, with presentations related to: public speaking; documentation copyright and the process of making a public presentation. After this first week, the second phase is more practical since it is related to the report preparation. During this phase, students attend a class weekly with the tutor teacher and two monitor students whose help is to aid and advise the students during the report preparation.

The theme is related to the program of students of the groups and in some courses it is integrated in the introductory course of the program. The main objective of the integration of the project in the introductory

course is to incite the interest and the motivation of the students on the tasks of the project since these are related to themes of their interest.

## 4 Comparison of the projects

This section presents the IPIEM1 vs FEUP project comparing the two structures, which is centered in the following topics: objective, model of execution, importance, ECTS, infrastructures, team dimension, skills developed, duration and courses integrated. After this comparison, a discussion is followed.

### 4.1 IPIEM1 vs FEUP Project

Both curricular units have the designation of project, although the term is the same, the way the word is interpreted is different, starting by the objective of each curricular unit. While IPIEM1 objective is to integrate contents of the courses of first year, first semester in a project, coordinate and monitor the development of the reports and to assess the application of the theoretical topics in the context of the project; the objective of FEUP Project is to provide students with the ability to make public presentations, inform the alumnus of the educational services available at FEUP and create awareness of the importance of copyright and trustworthy sources of information.

Another major difference between the two courses sites on the number of ECTS associated to each project: - IPIEM1 has the value 6 ECTS and FEUP Project has the value of 1,5 ECTS. This difference can be related to the importance of each course has in the program and that is evident in the difference between durations of both unit, being that IPIEM1, just like the other courses of the program, lasts an entire semester, while Project FEUP only lasts 6 weeks, because FEUP Project is an introductory course whose objective is to promote the integration of the students in an independent way from the other courses, whereas IPIEM1 project is the result of a multidisciplinary work, which complements the assessment of each unit has. The importance of the IPIEM1 in the program of IEM is also portrayed in the fact that each team had its own working space, where the team gathered and developed the project. On the other hand, at FEUP students had no space attributed for their meetings. Table 1 synthetizes the main characteristics of each project.

Table 1. Characterization of IPIEM1 vs FEUP Project

| Characteristics             | IPIEM1   | FEUP Project                 |
|-----------------------------|--|------------------------------|
| ECTS                        | 6  | 1,5                          |
| Duration                    | One semester (Sept.-Jan.)  | 6 weeks                      |
| Integrated Curricular Units | 5  | 1                            |
| Competences to apply        | Technical and transversal (soft)   | Transversal                  |
| Milestones                  | 6  | 4                            |
| Team dimension              | 9  | 4/5                          |
| Tutor role                  | Monitoring, guiding and reporting to teachers team progress of the teams | Monitoring                   |
| Infrastructure              | Project meeting room   | No associated infrastructure |

The skills developed during the elaboration of the project is the point where both curricular units are closer since both aim to develop soft skills, simulate real life challenges while promoting the creation of bonds inside teams.

Nevertheless, IPIEM1, by the team dimension, period involved and the project challenges, allows the development of essential skills for the practice of good engineering, time and conflict management, teamwork, argumentation, efficient communication (written and oral), decision making and, at the same time, builds a spirit of creativity and initiative in the students, which is essential in a world marked by fast shifts and accelerated rhythm of the industry. It has a strong practical component, because it forces students to use their learning from the traditional way to create a product and its productive system. Therefore, students have one common mission: pursuit knowledge, scientific rigor, and determination in order to demonstrate the

acquisition of scientific or technical skills enhanced in the course units, to produce solid and eminently practical products / production systems solutions.

To exemplify, this year's project theme was a solar oven. Students had to create the mission, objectives, final products, strategies to maintain the motivation to create a concise and strong basis between team members. After, the team was assessed in several oral presentations and various reports (ones were specifying the structure of the production system and other were related with which curricular unit). Thus, it should be highlighted the proximity created between students and their future as Industrial and Management Engineers. It is important to refer that students attended a class weekly, with teachers from other courses, in order to solve problems about that specific discipline. To exemplify: it was suggested, from the Programming teacher, that students should develop a code to create a program to the non-real solar oven enterprise. If students had doubts on succeeding in this challenge, this class provided the information and explained the doubts students had. So, students took challenges and difficulties, not as a barrier, but as an opportunity to learn more.

Briefly, IPIEM1 consists on a methodology that emphasizes teamwork, solves interdisciplinary problems, articulates theory / practice environments. The realization of this project culminates with the presentation of a solution to a real situation related to professional practice (an efficient productive system, in this case). Therefore, the success of the project is dependent on the quality, management, motivation, dedication and dynamic attitude from students, as the reinforcement and consolidation given by teachers.

## 4.2 Discussion

This section presents a discussion divided by the main research questions referred in section three. This discussion is based on the experience of the papers authors for the academic year (2015\_2016) they were involved and developed the project. At the same time, IEM students and authors of this paper also experienced the second semester without project, allowing them to compare the two semesters.

### 4.2.1 Advantages and disadvantages of project implementations against traditional teaching method

The advantages of the implementation of the PBL model in every university are based on the introduction of a learning that is meaningful in students, meaning that they only contact with subjects that have importance and practical use, used to resolve the problems and challenges that mark today's world. It has significant effects on the learner, being that it makes classes more enjoyable and satisfying, encouraging greater understanding and creating lifelong skills, and this increases class attendance, promotes interdisciplinary and encourages students to study more by their own. For the institution, the PBL implementation shows that student learning is a priority, decrease student retention and establishes its role in society as an institution that values knowledge and teaching.

In terms of disadvantages, the implementation of this methodology of learning implies some risks for the university and the teachers. Since from the start of school the learning model is listening the teacher speak, memorize the subjects taught, and do an exam, students do not have sufficient preparation in terms of learning experiences to do a PBL. It also requires a lot of time and takes away study time from another courses possibly compromising the success of students in the course and it creates anxiety, because the learning process is messier. For teachers, it requires a lot of preparation and extra work to do a good PBL for students, and it raises a lot of problems in what to assess and how. In terms of the institution, PBL creates a need in staff development and support, it takes more instructors and it requires a big change in educational philosophy for universities who mostly lecture.

### 4.2.2 Differences experienced in the transition between project period and traditional classes period

This question does not apply to FEUP project, since the project does not involve other courses. Although, in IPIEM1 after the end of the project, a feeling of relief and peace "starts to run through our body", because of the workload ended, all the presentations, all the weekly tasks that students had to accomplish and reports that had to deliver, all the meetings to discuss ideas, students get a feeling of emptiness when they go to the "traditional" class in the second semester.

The transition from a period with a project, when students have a sense of purpose in going to class, objectives, and goals to reach for, to a period without project is really a 180 degrees change in every aspect of

a student life. They feel like the motivation vanished, and it is much more difficult to learn certain topics because it is lacking the bridge between theory and reality, something that was accomplished when worked in the project. The learning is no longer a fun process, and it does not excite the students in general anymore, being that there is no longer a seek for knowledge, there is no longer the spirit of search for more and deeper ways to resolve problems, and there is no longer a true interaction between science and practice.

It is also evident that even the professor feels less motivated to teach, because they, like the students, don't have the need to seek for more, for new ways of teaching, and they are not challenged by the students anymore. Where as in the period of the project the teachers learned new ways of teaching, in order to make students realized how they can introduce the theory in the project, in traditional class they stick with a static and standard model of class, where the student is just an exam taker and the teacher is the one who takes the active role in learning.

If teachers maintain traditional notions of students as information recipients, teaching and learning become a pointless game where, instead of connection and engagement, the main challenge for students is to read the teacher's mind while producing a product in which they don't feel invested.

#### **4.2.3 Difficulties and challenges felt during the project**

In FEUP project, there were some challenges during the elaboration of the project, that needed to be overcome and that required the dedication and continuous dialog by the group. The main challenge was the time management due to the tight schedules, requiring the ability to work under pressure constantly in a continuous work of improvement. Another aspect that represented a challenge was the debate of ideas that was permanent; the good relationship between the group members was essential to maintain the motivation levels high and constant dedication. In terms of difficulty, the level of the project was adequate to the capabilities of the students despite their inexperience with such type of evaluation.

The IPIEM1 produces a feeling of desire to learn more and to find different and simple ways to resolve the problems that appear, so it creates an entire new environment of learning, creating highly motivated students who seeks more from the teachers, seeking the practical application of the science taught in the classroom.

Paper authors can point out, as disadvantages of the project, the big teams formed with nine elements which creates big challenges in terms of division of work: 1) there are always some team members that work more than others; 2) make ideas clear for everyone, make decisions and communication in meetings to discuss the direction of work; 3) the fact that because there are a lot of members in the team, sometimes it's formed a spirit of "parasitism" in some team members that live from the work of others and do not produce value to the project; 4) the ambiguous model of individual assessment of the students, meaning that there is not established a real and rock-solid structure to evaluate the individual performance of each person in the team because the teachers can only see the work that the team accomplished in periodic discussion sessions, in presentations, reports and with conversation to the students but has never the knowledge of who did what and if the work load was equally divided through the team members; 5) lack of support from some teachers in the execution of some technical tasks; some of the units integrated in the project were not the most appropriate to allow the creation of a viable project that could possibly turn into reality.

#### **4.2.4 Gains in personal and professional terms: competences developed**

The impact of having a project like the one in FEUP is quite significant in terms of adaption since the process of integration in a new environment is eased. The fact of having a group of students with similar interests developing a project related to the area they appreciate leads to the creation of social connection with peers. In terms of professional aspects, having this project incites the development of several soft skills such as: time management, due to the tight schedules that are stipulated; team work and dialog, since several opinions have to be considered; and presentation experience since all the reports had to be presented to a jury at the end of the project. Some hard skills were also developed during the elaboration of the reports such as the ability of working with document editing on the cloud, and recognizing and applying the structure of a scientific report.

In IPIEM1, throughout the project, there were many obstacles which when beaten allowed the development and growth of all the people involved, either professionally, with the knowledge acquired from the different



courses integrated in the project but also with the creation of a new perception of the how science can be integrated in a practical term; either personally with the development of skills indispensable to the practice of Engineering like time management, once everything had to be coordinated. At the same, students had exams and assignments for other courses; conflict management with the conflicts that come to surface with divergence between ways of thinking and the feeling of lack of dedication from team colleagues; efficient communication of ideas because teams only have ten minutes to present everything that had worked in, so they must be concise and direct without compromising the content of the presentation; decision making, because teams must have to make decisions every week that could jeopardize the future direction of the team; and, finally, team-work, once integrated a team of nine members with different personalities and totally different work rhythms, which taught to understand everyone's limitations and to use each person skills in the creation of a viable and innovative project.

#### **4.2.5 Variations in the teacher's position on the student learning**

This question does not apply to FEUP project since it is not considered a PBL model, therefore, there is no difference in the teaching method. Project-based learning transforms the roles of students and teachers in ways that benefit all. In the IPIEM1, the teacher is the passive piece in the process of learning, giving the students the tools to achieve knowledge, making the learner the one that is active, the one has the responsibility for their own learning by identifying their learning issues and needs.

Throughout the entire project, students were the ones who looked for the information, and asked the questions to the teachers that worked as guides, giving us tools to structure the knowledge acquired from researches made, but there was not a right direction, being that the students had to be the ones that took command of everything they were doing in the project.

#### **4.2.6 Benefits for students whose degree of learning and attention in class is reduced**

This question does not apply to FEUP project since it is not considered a PBL model, therefore, there is no significant change in the way students attend classes.

In IPIEM1, when the papers authors start to compare the differences between the period with the project and the period without it, it is evident the modification in students behavior, and it is even more evident the changes that occur in students with a lower level of learning. With the project, because they are inserted in a team of nine elements, being that everyone has different levels of knowledge they have, besides the teacher, other eight members can resort to when they have doubts in a certain topic. Another important fact that must be taken to count, when the differences are analyzed, is the environment, being that the environment, has one of the most important roles in human behavior. In the project, the entire team has one goal, that it is accomplish all tasks presented by the teachers, make good reports and presentations, and finish that project with a good grade, so they have to work together, put each other in the same stage of knowledge and comprehension because the teachers asked everyone periodically questions about each discipline and about the development of the project. So the students with low level of learning were forced, by the environment to learn, to understand, and also to share knowledge with the other team members.

#### **4.2.7 Application of the PBL model to all courses**

The challenge with the implementation of the PBL model is that it requires a lot of resources to be put into practice, such as, more work hours and dedication from the teachers, the modification of the way and structure they teach the topics, because they have to mirror the theory into the real world so that the students can apply their knowledge the resolution of the problems in the project; and a lot of bureaucracy to go through to establish a project in just one course of the university.

Although there are a lot of challenges in applying the model of PBL in courses, the gains that the teachers, the university, and the world of work can collect from it are far more great than the risks and difficulties allied with it, so the paper authors strongly believe that the direction of education should be the application of this model not only in university level but also in high school, because it is the best way to prepare students for the resolution of real problems in real life, something that is certain to happen when they start working.

#### 4.2.8 Did you like the experience?

The experience of having a course like FEUP project was a very enriching since it was essential in the adaptation to the academic environment, since it allowed the students to integrate more easily by establishing social relations with new people, to know better the place where they studied and the resources students have available to use in their daily academic routine. On the other hand, learning how to search for information whose reliability is assured and guaranteeing the copyright of the information, was very useful for students since it was a whole new aspect to take in consideration. In conclusion, students considered the experience very useful since it helped to integrate and to acquire more motivation for the rest of the semester.

The Integrated Project of Industrial Engineering and Management of University of Minho, integrated in the first year of the program was an incredible experience once allowed to understand what would be the role of an Industrial and Management Engineer in the world of work, something that cannot be achieved with traditional classes where students are not more than mere exams takers without realizing how our knowledge can be truly applied. Thus, the paper authors believe that the project introduces in the course the “reality” component that is lacking in many universities, reducing the gap between the world of work and the theory that learned throughout the course. In conclusion, papers authors would like to highlight how enriching this experience was, and how much believe that it will help to succeed in the future as engineers.

## 5 Conclusion

The practice of engineering is in constant need of updates, due to the rapid changing needs of the market and society. In this way, education in engineering strongly needs an update and a transformation in teaching methodology, in order to adapt to the fast shifting world that constantly creates new necessities, new problems where different and ingenious solutions are required.

Even though there are many similarities between Project FEUP and IPIEM1, the paper authors cannot consider the first one as a PBL approach. PBL is an active method of construction of learning based on the model “Learning to Learn”, making the learner the active part of the learning process- being the one that seeks for the best ways to learn subjects -, and the professor no more than an advisor that guides the student through the road of learning and shortens the distance between the student and knowledge. There is a distance that separates the two models marked by the no integration of the courses from the program in the project – that is the basis of the PBL -, by the technical nature that dominates the entire project, (the process of learning is more focused in technical aspects than in the development of soft skills). Therefore, there is not a real interaction in Project FEUP between the learner and the environment of the course and does not exists a real contact with day life problems, being only a way to give students soft skills.

To sum up, the paper authors experienced two types of project in the university context and agree that the benefits of having such an experience are unquestionable, because these type of project put students in a position very similar to that they will face in the labor market and it is a preparation that no other unit provides. However, they also agree that the IPIEM1 type of project is the one that is more advantageous to students, since it enables a complete interaction with the course units enabling a broader perspective on the functional way the units are structured. The main characteristic of IPIEM1 is the symbiotic and synergetic relation with all courses, which separates it from the traditional way of learning.

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