8th International Conference on Higher Education Advances (HEAd'22)
Universitat Politècnica de València, València, 2022
DOI: http://dx.doi.org/10.4995/HEAd22.2022.14473

From project-based to problem-based learning in engineering disciplines: enhancing Cartography and Geomatics education

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Abstract
Engineering disciplines such as Cartography, Geomatics and Geodesy depend heavily on practical courses and "hands-on" education, both demand a strong "active" component of students and opportunities of systematic interaction loops between teachers and students. In this paper we discuss the enhancement of such classes through switching from a rather project-based learning focus on a problem-based learning mode. Experiences from several classes in this context, especially in the domain of Location-based Services, Cartography and Geomatics, are discussed and reasoning for further development of such a problem-based learning environment is given. The aim of "activating" students can be reached therefore.

Keywords: *Pedagogy, education in Geomatics and LBS; Problem-based Learning (PrBL); Bloom's taxonomy, learning experience; LBS2ITS Erasmus+ CBHE (Capoacity Bulding in Higher Education) project.*

1. Introduction

The usage of PrBL (Problem-based Learning) is currently not common in disciplines with a strong engineering focus. Especially in geomatics education, only a few examples can be found in the literature (Gabela et al. 2022). In GIScience, cartography and related disciplines, most of the courses are usually oriented towards a project-based education – referred to as project-based learning (PjBL) in the following – than to start with a real-world problem leading to a fully immersed PBL course work. Note, in this paper; the abbreviation PrBL is used for Problem-based Learning to better distinguish it from the Project-based Learning approach, which is abbreviated as PjBL here. However, in the literature, the abbreviation PBL is commonly used for Problem-based Learning.

In a project-based learning environment tasks, assignments and action steps are usually defined by the teacher. In contrast, PrBL is rather student-centered and provides self-paced learning modules for the students. Learners are gradually given more and more responsibility in order to become independent life-long learners. Unlike traditional pedagogy methods, which are teacher-centered and where teachers transfer knowledge directly to students, in PrBL, teachers are there to facilitate learning and educational materials to students. Furthermore, it is based on real world problems, sometimes research-oriented, that stimulate learning, integrating and organizing learned information to ensure recall and future application (Retscher et al., 2022).

In this paper, some results of a workshop on e-learning and PrBL pedagogy held in the Erasmus+ Capacity Building in Higher Education (CBHE) project LBS2ITS, short for 'Curricula Enrichment for Sri Lankan Universities Delivered Through the Application of Location-based Services to Intelligent Transport Systems', founded by the European Commission are presented.

2. PjBL versus PrBL Courses

Both PjBL and PrBL courses rely on a student-centered approach. However, PjBL courses assume that the teacher defines the problem and the action steps, while in PrBL courses, this responsibility shifts primarily to students (Cuzelis 2011, Hunt et al 2010). Figure 1 shows the differences and common elements of the two approaches. As can be seen, the major role of the teacher is to act like a guide and mentor, and the students are at the center in both approaches. In terms of real world connections, either the teacher in PjBL or the students in PrBL define and identify the action steps of the problem. To achieve the learning outcome in PjBL, the students usually create a product, such as an LBS application, or in PrBL, more solutions are created. This goes hand-in-hand with the steps of Bloom's taxonomy discussed in section 4 (compare Figure 2): Another important aspect of PrBL and PjBL is the assessment of the students' performance, whereby both approaches include a self and peer

assessment step. In regards to metacognition, which means thinking about thinking and is defined as awareness or analysis of one's learning or thinking process, PrBL is more advanced. Metacognition must be about a retrieved representation of the awareness. Assessment as learning is a process of developing and supporting metacognition for students.

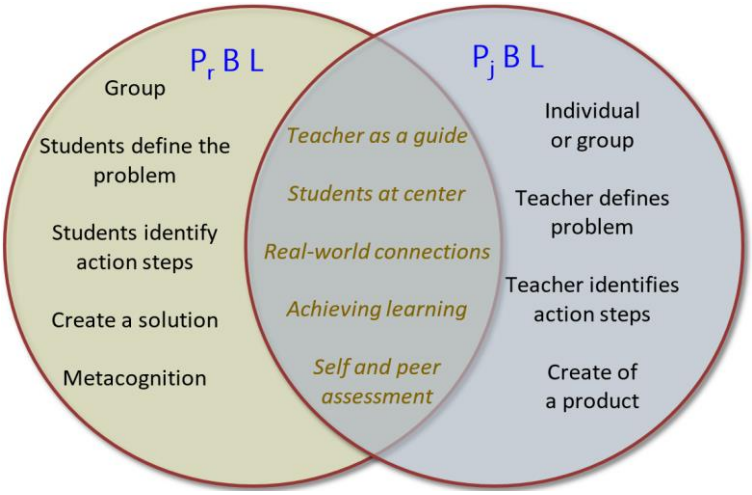

Figure1. Problem-Based Learning (PrBL) versus Project-Based Learning (PjBL).

In the field of Geomatics, most courses are PjBL oriented courses. A typical example was the "Location-based Services" (LBS) course at TU Wien, Austria. It is a compulsory course offered for master students of the Master programme on Geodesy and Geoinformation and to the International Master Programme "Cartography" annually. The course includes a number of theoretical inputs and group assignments on a topic from a list of topics defined by the teachers. Such topics can include aspects of positioning, modelling or mobile cartography. Students work in groups of up to 2-4 members, under the supervision of an academic staff member for a continual period of at least two months. Teachers identify action steps while students combine and exercise their knowledge and develop practical and analytical skills to finish the project technically and methodologically and present it accordingly. The assessment based on teacher-evaluation and an assessment of the students themselves reflects their performance based on multi-criteria list, including the project deliverables, a written exam and the project presentation. Based on several student's evaluation results and feedback rounds the setting of the class was changed into a PrBL mode. While theoretical input was still given as a starter to the topics from the lecturers the students then define the problems themselves, analyse literature and propose a methodological concept and work together on developing solutions. When presenting results a critical evaluation of their approaches is given amongst the students as well as from the lecturers. Anonymous student evaluation results of this class demonstrate the acceptance of this PrBL approach.

A typical example of student-centered courses displaying both PrBL and PjBL elements in the programme at TU Wien refers to "Project Map Creation" courses. These are selective courses offered in the Master programme on Geodesy and Geoinformation and to the International Master Programme "Cartography", that engage students to work individually and to come up with a solution to a real-world problem of producing a professional map ready for print, using their creativity and the knowledge acquired in the previous years of study. The students attending this course combine their knowledge and skills in a multitude of topics, including data acquisition, data modelling, geoinformation analysis, cartographic modelling, map design, layout and pre-press techniques, to produce a complete/self-contained map product. The role of the instructors is mainly of an advisory character, while students share full responsibility for refining and pursuing specific goals and presenting final results. Student assessment is exercised throughout the semester, reflecting their achievements in individual consultations and through presenting final results to the fellow students and instructors. The aim of this course is to allow students to use and apply their learned skills and competences for a problem of their choice, in this case a map production. The students determine the different steps that are required towards the final design of the map. During these steps, the students may face or define particular problems for which they need to find solutions. In this sense they apply elements of PrBL. To produce a map, several questions need to be answered. Students have to define these questions and utilize the relevant background knowledge they have acquired during the study programme to answer them. This procedure is a characteristic of PrBL. The final result, which is the design and assessment of map, is an element of PjBL. The results of this particular course are usually displayed in several public spaces of TU Wien and sent to International Cartographic Exhibitions. Several resulting maps have won international map awards, proving the success of the approach.

The different approach in applying PBL in these two examples stems mainly from the students' level of a priori knowledge the students possess to solve complex problems.

3. The LBS2ITS Project

The Erasmus+ CBHE project LBS2ITS deals with the modernization of curricula modules and courses in the field of Location-based Services (LBS) and intelligent transportation systems (ITS) in the partner country Sri Lanka. For further LBS development and to stimulate collective efforts in the partner country, modern curricula in the geomatics and transportation sector need highly qualified graduates. In addition, transportation systems need to be changed in the partner country to enable safer and greener sustainable mobility (Retscher et al., 2021).

LBS deliver information depending on the location of a mobile device, and the user plays a key role in this mobile information era. Huang et al. (2018) have identified a list of 'key

research challenges' that have to be addressed to bring LBS to a higher level to benefit our human society and environment better. These research challenges can be classified into seven broad areas: (1) positioning; (2) modelling; (3) communication; (4) evaluation; (5) applications; (6) analysis of LBS-generated data; and (7) social and behavioural implications of LBS. Smart transportation is an ideal LBS application since it is based on locating people (e.g. using smartphones) and objects (e.g. cars, trains, etc.). Transport researchers in the consortium of the LBS2ITS project directly support in evaluating user needs in the transport domain. Therefore, LBS applications have a great potential for supporting the work of transport planners and engineers in municipalities, higher-level administrations, private consultancies, academic and further institutions in the field of Intelligent Transport Systems (ITS). Based on the analysis of these various users' needs and in direct collaboration with the transport community, tailor-made LBS services/applications are developed that fully meet users' needs. In the direct collaboration of providers / developers and (potential) users of LBS services, the project spans the whole research cycle: (1) users' needs are investigated as the basis for developing new LBS services; (2) the uptake of these services is evaluated; (3) the results feed into their advancement in the next round of the research cycle.

LBS2ITS aims at a fully immersive and integrated teaching and learning experience in the field of ITS and LBS. The outcome is a digital learning environment supporting synthetic and real-world learning experiences encouraging self-paced learning modules for both teacher and students containing digital resource kits for interaction with modern equipment, continuous assessment and two-way feedback. Webinars and virtual experiences enable real-world PrBL scenarios. Furthermore, new pilot LBS courses will be developed from the project partners by analysing and using experiences from existing courses (Retscher et al., 2021).

4. LBS Education

In this section, the LBS education at TU Wien is briefly reviewed, leading to the newly developed courses for the four Sri Lankan partner Universities in the LBS2ITS project.

PrBL is used and applied throughout the whole programmes of the International Master Programme 'Cartography M.Sc.' as well as 'Geodesy and Geoinformation' of TU Wien, especially in all classes related to programming and applied aspects. For example, in the class on LBS, the focus is on the competences of knowledge acquisition and the development of other skills such as enhanced group collaboration and communication. After theoretical input on all elements of LBS in 8 lectures, students choose a topic based on the real-world research-oriented problem. They work in groups with a size of 2 to 4 students. Starting with a literature review, they present the project aims and scope to the entire group in a mid-term presentation, starting with a literature review. After receiving feedback, the students then adapt the

methodology and they follow a detailed project work plan as a team in order to solve a problem. Teachers are monitoring the process, supporting, helping with problems and steering the students in the right overall direction. At the end of the semester, the groups present their results, and a report must be submitted, which forms part of the course assessment and grading. Over the last ten years, PrBL-based group work within the class of LBS has seen more then 80 projects. The approach of these projects, which incorporate diverse aspects of LBS, have proven to be a successful method for students and teachers, both in achieving the main goal and scope of the course and in the applicability of gained skills (Gabela et al., 2022).

The successful work in the courses at TU Wien builds the foundation for the developing meant of the pilot courses to be taught in the third year of the LBS2ITS project at each of the four Sri Lankan partner universities.

5. Application of Bloom's Taxonomy in the Project

Benjamin S. Blooms together with a group of psychologists developed a taxonomy of learning objectives back in 1956, which can be seen as a major step towards PrBL education (Bloom, 1956). Figure 2 illustrates the verbiage and elements of the revised Bloom's taxonomy. The six levels of the taxonomy are (see e.g. Overbaugh, 2014):

- L1: remembering – can the student recall or remember the information?
- L2: understanding – can the student explain ideas or concepts?
- L3: applying – can the student use information in a new way?
- L4: analyzing – can the student distinguish between the different parts?
- L5: evaluating – can the student justify a stand or decision?
- L6: creating – can the student create a new product or point of view?

Bloom's taxonomy has been applied to variety of situations and is helpful when a teacher desires to move a group of students through a learning process utilizing an organized framework. In the LBS2ITS project it is applied to structure the PrBL courses to be developed. The project provides the opportunity to test PrBL to a wider extent for its further development enhancing educational outcomes not only in Sri Lanka but also at European Universities and worldwide. QA practices focus on creating the right kinds of assessments and associated rubrics to ensure that all levels of Bloom's taxonomy are integrated into the assessments. Especially those relevant verbs associated with active learning and thinking are used. Thus, teaching with an emphasis on learning outcomes is a central theme in the project's approach (Retscher et al., 2022).

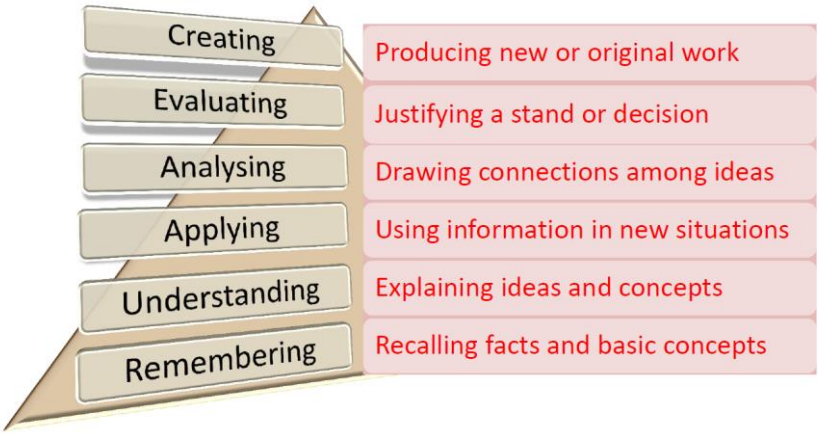

Figure 2. Bloom's taxonomy's verbiage and elements.

6. Concluding Remarks and Outlook

Education has become a very challenging and changing field of concern. Teachers and students are exposed and confronted with additional and innovative ways on how to be exposed to information, technologies, social trends and personal preferences. This leads to a variety of individual solutions, while systematic experiences which are analyzed and assessed are missing still. In this paper some experiences of shifting from a rather project-based learning approach to a more problem-based learning approach in the domains of cartography, geomatics and geodesy are discussed and experiences and results shared. Ultimately the aims is, to enhance the potential in engineering education for motivating and enhancing student learning, which can be achieved through "activation" of students, as shown with some PrBL-approaches applied in engineering courses at TU Wien and NTU Athens.

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