Overview of the PBL in Geodesy, Geoinformatics and Transport Engineering Education

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Key words: Education, Geodesy, Geoinformatics, Problem Based Learning, Transport Engineering.

SUMMARY

In 2021, the three-year 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', started with the aim to introduce and/or update education at four partner universities in Sri Lanka in the LBS (Location-based Services) domain. The level of education in LBS in Sri Lanka is still in its infancy and cannot rapidly deliver the knowledge inputs required to change transport management decision-making in Intelligent Transport Systems (ITS). Modern education methods, such as e-learning and Problem-based learning (PBL), must play a central role in the newly developed courses and course modules. Thereby, syllabi and course contents are developed on the lesson level. The outcome will be a digital learning environment supporting synthetic and real-world learning experiences which encourage self-paced learning modules with digital resource kits for interaction with modern equipment, continuous assessment and two-way feedback. Webinars and virtual experiences will underpin real-world PBL scenarios. In this paper, the results of a workshop on e-learning and PBL pedagogy are presented. Examples for PBL courses in geodesy, geoinformatics and transport engineering from the literature and the seven participating project partners underpin the feasibility of the introduction of these new education methods.

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1. INTRODUCTION

Much of the available Problem Based Learning (PBL) literature is based on medical education due to PBLs beginnings in health sciences curricula modernisation in the 1970s (Burrows, 1996). It was first introduced at McMaster University in Canada where the first such class graduated in 1972 (Burrows, 1996). In the following two decades, the PBL spread to many other medical schools across North America and Europe and became an acceptable teaching method for health sciences (Savery, 2006). With the rising popularity and success of the PBL, the 1990s saw the expansion of the PBL into other disciplines such as engineering studies, chemical engineering, law schools, architecture, business administration, physics, science courses, economics (Hung et al., 2007). However, a lack of literature in PBL for geodesy, geoinformation and transport engineering has been observed by the authors.

In addition to overviewing the current literature on the adoption of PBL in geodesy, geoinformation and transport, this paper documents the level of PBL implementation in partner universities of the LBS2ITS Erasmus+ project.

LBS2ITS (Location-based Services to Intelligent Transport Systems) is an Erasmus+ Capacity Building in Higher Education funded project with the aim of curricula enrichment delivered through the application of LBS to ITS for four Sri Lankan partner universities (https://lbs2its.net/). It is based on the consortium of three European Union (EU) universities: Technische Universität Wien (TUW), Technische Universität Dresden (TUD) and National Technical University of Athens (NTUA); and four Sri Lankan universities: Sabaragamuwa University of Sri Lanka (SUSL), University of Moratuwa (UoM), University of Sri Jayewardenepura (USJ) and General Sir John Kotelawala Defence University (KDU). The project aims at, not only enriching the curriculum but also at providing fully immersive and integrated teaching and learning experiences. One way of doing this is by introducing PBL into the new modernised and enriched LBS courses that will be the result of the LBS2ITS project. Consequently, PBL as a pedagogic method was presented at an LBS2ITS virtual workshop in September 2021. The workshop aimed to introduce, define and describe PBL to all partner universities. The further aim of the workshop was for every partner to present their current courses and if they already use any facets of the PBL pedagogy. Consequently, all partners shared their experiences, some of which will make up the main content of this paper.

Some of the main questions that this paper aims to answer through the experiences of all seven partner universities are: What are the challenges of implementing PBL in geodesy, geoinformation and transport engineering education? At what level do students have to be in order to be successful in PBL? How do we determine a good problem that will stimulate and encourage learning that encompasses the desired learning outcomes? What are the challenges and constraints set up by the university bodies? Is a mix of traditional learning methods and PBL a good compromise where obstacles are presented?

The following section will provide the background on PBL and detail some of the main PBL characteristics. This will be followed by the analysis of the currently available literature on PBL in geodesy, geoinformation and transport. The fourth section will detail the experiences of all LBS2ITS partners, which will be followed by the summary and conclusion section.

2. ABOUT PBL

Barrows (1996) details some of the motivations behind implementing the PBL in medical education in the 1970s. One of the main motivations was students’ boredom and overload with information, which was deemed irrelevant for medical practice. Furthermore, the students were more excited about problem solving and working with patients, which led to the development of PBL at McMaster University in Canada, where the first such class graduated in 1972 (Burrows, 1996). Over the years, PBL has been implemented across many different disciplines, including engineering.

PBL is a learner-centred pedagogy in which the students take responsibility for their education with teachers being there to facilitate the learning (Barrows, 1996) (Hung et al., 2007) (Savery, 2006). PBL process can be well described by syntagma “learning by doing” from Taboda et al. (2006). According to Perrenet et al. (2000), PBL addresses three education objectives: “acquisition of knowledge that can be retrieved and used in a professional setting; acquisition of skills to extend and improve knowledge; acquisition of professional problem-solving skills”. This is in line with the PBL aims, such as creating life-long learners, anchoring knowledge in context to easily be retained and retrieved, improving students' self-awareness, independence and problem-solving skills (Hung et al., 2007).

In PBL, the students take the active role and come up with a problem or are assigned with a problem, they identify what they need to know and then learn how to solve a problem. In this scenario, the teacher is a facilitator that supports the students in their self-directed learning. This active role of students and the passive role of teachers is in contrast to traditional teaching methods where the teacher transfers knowledge to students, students need to memorise the told knowledge, and then they have to reproduce it and solve a problem that illustrates the application of told knowledge (Hung et al., 2007).

PBL cycle is shown in Figure 1. The cycle consists of seven steps, which have been produced based on the review of literature in (Retscher et al., 2022). In the first phase, the students are presented with a problem or choose a real-world problem themselves. Subsequently, this problem is defined and clarified, then students can think about how they would solve a problem based on the knowledge they already have from their previous studies (i.e., *a priori* knowledge). In the third step, the students collect the *a priori* knowledge from all members of the group and analyse the problem. Definition of learning objectives is an important step in which the students have to define the knowledge they are missing in order to solve the problem. This is an important step in creating life-long learners because they have to be self-aware and demonstrate their critical thinking skills. Following the definition of the learning objectives, the students engage in a self-directed study where they gather materials from different sources. Students can use diverse materials from different disciplines such as books, videos, journal and conference articles, forums, online discussions and interviews with stakeholders and experts from multiple fields. Teachers are there for students across all these steps to moderate discussions, guide the students and facilitate learning. In the final steps of the PBL cycle, the students synthesise all the acquired knowledge to solve the problem, which they then present to everyone.

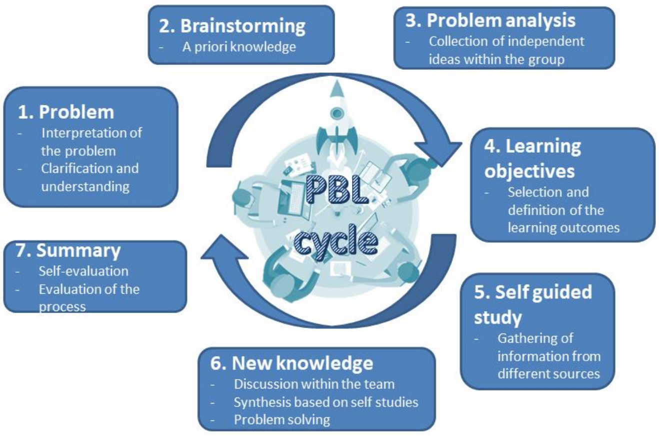

Figure 1. PBL cycle (from Retscher et al., 2022).

3. STATE-OF-THE-ART OF PBL IN GEODESY AND GEOINFORMATION AND TRANSPORT ENGINEERING

The literature on PBL implementation in geodesy, geoinformation and transport engineering education is limited. This section gives details of some available literature in these fields.

Božić et al. (2020) present their experience after a year of using PBL to teach Adjustment Calculation at the study program of Geodesy and Geoinformatics, University of Belgrade. Their paper was written for another Erasmus+ project called GEOBIZ (http://geobiz.eu/). One of the GEOBIZ project aims is to introduce PBL to their nine partner institutions. The course described in (Božić et al., 2020) is a first-year master's study course with 15 students in total. The students were divided into groups of seven and eight students. In order to implement PBL, they used the steps of the classic PBL cycle as described in the previous section (see Table 1). They first introduced students to the PBL principles, divided them into groups, presented the problem scenario and then held group sessions throughout the semester. When deciding on a problem text, they aimed for the problem to encompass a large portion of the course content, for the problem to be realistic and not too detailed. The problem text is given as follows: “It is necessary to set up a free geodetic network on a 2kmx3km area, for the construction and deformation monitoring of an engineering structure. Measures of accuracy and reliability in the geodetic network need to be in accordance with the known object deformation allowance.” The problem they gave the students is generic enough and presents something that they will probably have to do in their professional career if they work in the field of engineering geodesy. The problem will also lead students to self-learn things such as what is a free geodetic network, choosing good stable geodetic points, network planning for all stages of the object: planning, construction, testing and deformation monitoring, network optimisation, accuracy and reliability, network adjustment, quality requirements of the chosen object, etc. In traditional learning, the students would listen to lectures on this topic and they would have to reproduce what has been told to them by the teacher. In this case, the students have learned independently and have acquired important soft skills, as mentioned in the previous section. Following the self-assessment where students assessed themselves, other members and the PBL process, students thought that an optimal group size would have been three to five. The teachers noticed that the students were better motivated and engaged. Equally important, the teachers noticed that the students correlated theory and the problems better.

Table 1. Sessions as shown in (Božić et al., 2020).

Session	Activity	Time
1	Introduction to PBL. Group formation. Expression definition.	Day 0
2	Problem definition and clarification of different assignment requirements.	Day 7
3	Analysis of the previous knowledge relevant to the problem at hand.	Day 7
4	Defining new knowledge necessary for solving the problem Hypothesis definition.	Day 15
5	Learning outcome definition.	Day 15
6	The realisation of the set goals and learning outcomes. Learning. Information gathering. Individual and group learning. Literature review.	Day 31
7	Discussion and knowledge synthesis. The final presentation and/or report.	Day 59
8	Result presentation.	Day 92

Implementation of PBL in GIS and Cartography at the University of Leon, Spain, for the degree in Surveying Engineering was discussed by Taboada et al. (2006). The implementation is discussed for the GIS (Geographic Information System) course in the second semester of the undergraduate degree (i.e., first year) and the Cartography course in the fourth semester of the undergraduate degree (i.e., second year). Due to the lack of cartographic knowledge of students in the GIS course held in the first year, the students had to have tasks such as “Can you read spatial information?” in addition to the six practical tasks that teach them about GIS software. A task like this would not necessarily be given to the students in a course that fully implements PBL. However, to solve problems given in a PBL course, students have to have sufficient *a priori* knowledge, including the general knowledge of the field. Therefore, unlike Božić et al.

(2020), Taboada et al. (2006) could not fully implement the PBL method. They combined the traditional teaching method in the form of theoretical lectures, smaller tasks and the PBL method. Lecturing made up 30% of the course and active learning (including the smaller tasks) made up the rest. After the initial tasks students got a topic for self-learning: “Introduction to GIS: definition and applications”. The goal was for them to learn about GIS and its main applications. They were guided to learn using resources like books and journals and to discuss and brainstorm within the group. Cartography course students got a project: “Mapping reference and thematic maps”. In groups of two students, they had to produce a map with the justification regarding the legend, layout, scale, format, etc. To learn more about theory, the students had to work on a shorter three-week task on the topic of “History of Cartography”. In the case of the Cartography course, even less of the course was based on traditional lecturing - 10% and the rest was based on active learning (PBL and learning based on researching). Although Taboada et al. (2006) do not demonstrate implementation of a PBL course, they indicate difficulties implementing PBL in basic courses like GIS and Cartography that introduce students to the field. Nevertheless, to stimulate self-learning and all the associated soft skills, they have shown how some theoretical knowledge can be self-taught through shorter tasks.

4. PBL IN THE LBS2ITS PROJECT

This section details the current state of the PBL implementation in teaching for all seven partner universities of the LBS2ITS project. Five partners out of seven partner universities, have already implemented PBL in some form. Two universities are in a process of introducing such courses through the LBS2ITS project. All newly developed courses as part of the LBS2ITS project will be based on the PBL.

4.1 Vienna University of Technology (TUW)

The International Master Programme “Cartography M.Sc.” is an Erasmus Mundus Programme of four universities in München, Wien, Dresden and Twente. It focuses on a broad education in cartography and geoinformatics. The four partner sites represent centres of excellence in the field of cartography, recognised at the European and global levels.

The programme takes place at all four cooperating universities. Students stay together as a group during the whole time and have to spend their first semester at the Technical University of Munich (TUM) in Germany. Then they have to study the second semester at the Technical University of Vienna (TUW) in Austria. The third semester is held at TU Dresden (TUD) in Germany. During the first and third semesters, online modules from the University of Twente are integrated into the curriculum. In the 4th semester, students prepare their Master’s thesis at one of the four participating universities.

Students have to pass four mandatory modules during the second semester at the TUW - Cartographic Theories and Applications, LBS and Multimedia Cartography, Cartography Publishing and Applied Cartographic Research and Development. Via the elective courses, students can set individual specialisations in geodata management, software application and programming, visualisation and LBS. The intended learning outcomes include gaining skills and competencies in using but also editing and developing modern cartographic applications, such as LBS.

PBL is used and applied heavily throughout the whole programme. For example, in the class on LBS, the focus is on the competencies 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 are encouraged to choose a group project topic based on a real-world problem. In groups of 2 to 4 students follow the PBL cycle steps and they:

- analyse literature and propose the methodology concept,
- present the project aims and scope to the entire group,
- adapt the methodology after receiving feedback, and
- follow a detailed project work plan as a team to solve a problem.

Different roles within the groups are welcomed. Supervisors are monitoring the process, supporting, helping with problems and steering the students in the right overall direction in the spirit of PBL.

Over the last ten years PBL-based group projects within the class of LBS at TUW, offered to both the International MSc Cartography students as well as to the local geodesy and geoinformation students, have seen more than 80 successful finished projects. These projects deal with all kinds of aspects of LBS, including positioning, modelling, communication and application areas such as ITS. For positioning, for instance, indoor localisation with different technologies and sensors were central topics. In this context, students performed real data acquisition with smartphones and/or other equipment followed by data analyses using different techniques. For data acquisition, applications for Android devices were also developed, and new routines as well as mathematical algorithms for evaluation. Further examples for former student group projects at TU Wien are:

1. Analysis of tourist’s terms of interest on social media based on Flickr photos.
2. Monitoring behaviour pattern changes due to COVID-19 via Twitter data.
3. Real-time traffic map using floating car data.
4. Tracking road conditions with smartphones on bicycles.
5. Analysing and visualising OpenStreetMap community activity data.

The PBL-based approach has proven to be a successful method for both the students and the teachers. This is confirmed by the results of various quality management methods, including student questionnaires and lecturer evaluations. Based on explicit inquiries on the concept, method, support and outcome the results validate that the main aim and scope of the class can be reached as well as the applicability of the gained skills and competencies are ensured. The latter can be seen as an indicator for the success of PBL in educating students in LBS.

4.2 National Technical University of Athens (NTUA)

Geomatics education is currently in transition at the NTUA. The School of Rural and Surveying Engineering (Çelik et al, 2006) has just been renamed to School of Rural, Surveying and Geoinformatics Engineering (SRSE) to reflect the opening up in the subject field and the rapid changes in the profession in recent years. In this regard, specific actions have been put into place to adjust and improve the teaching modes and pedagogical methods to advance student-centred learning. Most of the courses in the program include a term project and other components (e.g., exercises, assignments, fieldwork) aiming at enhancing student synergies and promoting experiential learning.

A typical example of the student-centred, PBL approach integrated into the SRSE program refers to project theme courses. These are elective courses offered in the 9th semester (5th year) that engage students to work collectively and to come up with a solution to a real-world problem using their creativity and the knowledge acquired in the previous years of study. Such a popular project theme course is the “Study, Design and Operation of Road Works”. This course is offered to students who have selected the direction of Transportation Engineering at the end of the third year. The number of students ranges from 7 to about 23. The students attending this course combine their knowledge and skills in a multitude of topics, including surveying engineering, photogrammetry, mapping, geometric road design, transportation engineering, economic aspects of road design, structural engineering and hydraulics to produce a complete/self-contained road design study. The role of the instructors is mainly advisory, while students share full responsibility for refining and pursuing specific goals and presenting final results in small groups. Student assessment is exercised throughout the academic semester reflecting their achievements in individual tasks, and through presenting final results to an audience and exam panel.

The students aim to connect two areas by road. The main, generic “aim-problem” is set at the beginning of the course by the teacher. The students should determine the different steps that are required towards the final design of the road. During these steps, the students may face or define particular problems, for which they would need to provide solutions. To build a road several questions need to be answered. Students have to define these questions and utilise the relevant background knowledge they have acquired during the SRSE program to answer them. This procedure is a characteristic of PBL. By solving the problem, students learn to (1) determine the road use and the potential users; (2) determine the geometric features of the road; (3) define the supplementary works that need to be designed to cater for the efficient operation of the road; (4) decide whether a bus line should also be designed and (5) assess the design and operation of the road.

Following feedback from students considering course assessment, their main comments are that the course is very interesting, while at the same time quite demanding. It allows them to experience the challenges that engineers face, be creative and produce a final solution utilising and combining knowledge and techniques from several different domains.

4.3 Dresden University of Technology (TUD)

TUD implements PBL pedagogy in the “Urban Street Design” course held in the 4th year for the diploma degree in transport engineering. This course runs over two semesters (7th and 8th) and is almost completely implemented using the PBL pedagogy. There are only three lectures at the beginning of the course that summarise the main content of the course and provide materials to the students. The goal of these lectures is to get all students to the same level of *a priori* knowledge. One of the lectures is given by a practitioner from a consultancy, where they present one real case study from their work. This is useful for the beginning of the students' PBL process as they are introduced to the relevant real-world problem they may encounter when they enter the workforce.

In the first semester, students analyse transport supply and demand, relevant framework conditions such as expected changes in population and political strategies and visions for a selected city area, they identify strengths and weaknesses, and based on this empirical research they define their real-world problem. When choosing the problems, students are given a choice of city areas that have been chosen in consultation with colleagues from the city of Dresden administration. These study areas are often problematic areas of the city that have been identified by the municipality and where major projects/interventions are planned. This offers an additional layer of realness to the chosen problems students are trying to solve, as they are working to improve an actual area in their city. In the second semester, students develop concepts for mitigating the problem (i.e., methodology). This often involves re-designing urban street space in the study area, parking management, transport management or any combination of the different strategies. The students solve their chosen problem in groups of five. Each group has an assigned supervisor (i.e., teacher) with whom they have regular consultations. Relevant information and material is often shared and provided on an e-learning platform. Students ask questions or chat there, which provides an additional opportunity to get in touch with the teaching team.

Students present their work after the first semester (analysis of transport supply and demand, strengths and weaknesses) and the second semester (planning concepts, re-designs of streets including their assessment). In addition, at the end of the second semester, there is a written exam where students need to demonstrate their comprehensive knowledge on all relevant aspects, and each student answers on their own.

4.4 University of Moratuwa (UoM)

“Site Planning Project” course/module was offered in 2021 during the Covid-19 lockdown period for the first semester of level four (final year) undergraduate students as the core curriculum in the Department of Town and Country Planning Degree Program at the UoM. Ten students participated in the course and they were working as a group on redesigning a town centre for the Padukka area, Colombo District, Sri Lanka. In line with PBL, the site selection was done by the students considering the learning outcomes and the complexity of the planning of the area. The students had to analyse planning issues and provide a redesign plan for the site area. When doing so, they had to take into account the context covering aspects such as socio-cultural aspects, services, physical context, environmental considerations and stakeholder considerations. Considering the design and planning skills, students were asked to provide a new design covering land uses, plot coverages, floor area ratios, building heights and street lines as required in the Urban Development Authority (UDA Act, 1986) planning and building regulations. Students also had to consider the locations of open spaces, landmarks, vistas, street hierarchy, building typologies, colours and roof styles. In their analysis, students used published data, related reports, satellite images, online surveys, stakeholder consultations and they also visited the local areas during the context analysis stage. Due to the pandemic, all lectures and supervision were done online. University Moodle e-Learning platform, Zoom and documentary management system were used to introduce course materials, tasks, outcomes, group discussions, group presentations, marking and feedback.

Two teachers were working with the students and their role was to encourage deep thinking, innovative thinking, visual thinking for problems, build confidence, encourage collaboration and inclusiveness within the group. Teachers also held a few theoretical lectures and provided necessary materials on existing plans and regulations for students to review and refer to. Teachers also guided and encouraged students to come up with alternative solutions and challenged students' concepts in terms of planning and how the proposed design addresses the identified issues. In implementing the PBL task, compromises were done compared to traditional learning methods. It took more time for students to provide design solutions and teachers spent more time with students as students required more instructors/mentoring support. Students had frequent questions during the design process as the end direction and site plan design concept had to be proposed by them. Staff also spent more time on the project administration matters such as preparing the background papers, project task and outcomes, information on regulations, detailed assessment methods and criteria and handling group dynamic issues. The students were overall happy with the process of PBL and grateful for the teachers' mentorship. However, they experienced some difficulties that need to be considered. The students experienced stress due to having to decide on their own what to do next in the project but found frequent progress reviews helpful in managing the workload and identifying future steps. Another issue that was identified was the difficulty of ensuring equal contribution in the group work. Feedback comments of the students indicated many positive and encouraging aspects of the PBL strategy. Students (most) were satisfied (90%) at the end as they felt they learned something new on their own and thus built a high level of confidence.

4.5 General Sir John Kotelawala Defence University (KDU)

KDU utilises PBL pedagogy in the course concerning GIS for undergraduate students in the second semester of their last year of Information Technology or Information System degree programmes. In line with the PBL process, the students had to define the problem themselves. Among other things, students were encouraged to use the access to the wide research community available through ResearchGate. This meant that the students are involved in the community discussions with the research community and in communication with individual scientists. To facilitate GIS software learning, only the guidelines are provided to the third year computing undergraduates. Having defined their problem, the students can start developing a solution/concept. The developed concept is discussed in class and challenged by the teacher, based on how the students can adapt their methodology. As the next step, students presented their outcomes in the discussion. Students are encouraged to challenge the lecturer's comments. This approach makes the class more interactive, and students learn how to conceptualise solutions to practical problems. The class is limited to 20 students, and every day, each student's problem is discussed and guided to develop a GIS project. The GIS projects are individual projects where the final report and presentation are used to assess the student (70% of the grade). In addition, the students have to take a written exam (30% of the grade) on the fundamental issues and concepts and practical solutions the student has learned about. This is done due to the university requirement for the written exam. The result of student feedback indicated that the teaching method is acceptable. Students are more active to solve a real-world problem and they suggest continuing the PBL method for the GIS module. Furthermore, based on university recommendations, initial lectures were given to students on: "Spatial concepts related to IT", and "data and cartography".

The following list provides examples of some of the problems defined by students:

1. Cost evaluation of widening the roads in the city of Ampara: A GIS analysis.
2. GIS analysis to select a suitable location for an eco-friendly hotel in the Negombo area.
3. GIS analysis for finding the best place to plant a communication tower in Sooriyawewa.
4. Finding a suitable location for a railway station in the Sooriyawewa area.
5. Economically and environmentally friendly holiday home site identification using GIS: A case study of selecting suitable land to build a holiday resort in the Hikkaduwa area.
6. GPS based safe location guiding Android systems in case of a tsunami.

4.6 Sabaragamuwa University of Sri Lanka (SUSL)

Faculty of Geomatics, Sabaragamuwa University focuses on implementing new course modules to both the Bachelor and Master of Surveying Science degree programmes in addition to the modernisation of some of the related existing modules through the LBS2ITS project. Both degree programmes provide an intensive study of the technical, analytical and professional aspects of modern and advanced surveying, geodesy, geoinformatics, cartography, management, and environmental subjects. The SUSL university does not fully implement the PBL method in one of its classes. This pedagogy modernisation will be realised by implementing new courses developed during the LBS2ITS project. This section will present an example of the course where traditional teaching methods are applied overall with elements of PBL at a smaller scale.

GNSS for Surveyors is one of the course modules of the Master of Surveying Science degree program, which aims to provide the intermediate and advanced concepts of GNSS technology to implement in related professional work. The whole course is delivered by adopting mixed teaching methods. The theoretical components of the course are delivered in a traditional way of teaching. At the end of each theoretical section, students are given class assessments. One of them is to study a GNSS application where students have to understand a problem related to the selected application, analyse the problem, self-study and collect knowledge to generate a final report and a presentation explaining the use of GNSS technology. The 15 hours field program of the course is designed to adopt the PBL at a smaller scale and conducted as a group task with a maximum of five students per group. This course is offered in the last semester of the two-year degree program, where the students are assigned to conduct a small scale project, by developing a methodology and procedure incorporating GNSS and other technologies such as drone survey. However, synthesising a real-world problem/project to a smaller scale learning task including the design, implementation and competition within 15 hours is a challenge. As a solution for this, the project is designed by all the groups as one task and each group has a separate activity to conduct to complete the project. At the end of this group project, students are asked to generate a report and present their project, including the methods, challenges they have faced and how they managed to accomplish the work.

The written examinations are not mandatory within the Master of Surveying Science degree program. Therefore, this course module is assessed based only on the assignments, reports and presentations. The student feedback reflects the adopted mixed teaching method is well recognised by the students. The GNSS field project has shown to be very interesting to students due to its highly practical PBL approach that requires their independence.

4.7 University of Sri Jayewardenepura (USJ)

The Faculty of Technology was established in 2016 and currently comprises five departments. The Department of Civil and Environmental Technology and Department of Biosystems Technology are involved in the project LBS2ITS. Environmental Impact Assessments and Sustainable Planning, Air Pollution Control Technology, Precision Agriculture Technology, and Greenhouse Gas Accounting are the significant modules selected for the curricular enrichment via the LBS2ITS project. So far, the modules' teaching was based on traditional teaching, which is delivering the knowledge to students and assigning the project to solve at the end. However, experience and knowledge gained from the LBS2ITS project about PBL compelled the USJ team to remodify the above modules using PBL concepts. The process of adapting the PBL will be started by the end of 2022. Out of several modules, incorporating PBL concepts in the Air Pollution Control Technology module is explained.

Air Pollution Control Technology is a third-year course module usually involving about 30 students. The approach that will be adopted as well as the example of the problem is given in Figure 2. Students will be divided into groups of five or six members and they will be then given some current problems, that are based on ongoing issues related to the course topic, to solve. In line with the PBL cycle, they will then be guided to identify the required knowledge after which the students will receive support during their self-study process necessary to solve the problem at hand. Finally, students will be evaluated individually and as a group through presentations and reports. In addition to this evaluation, there will be a compulsory written exam. The lecturer's role will be to guide the brainstorming sessions, monitor progress, support finding necessary reading materials, and assess the quality of the work.

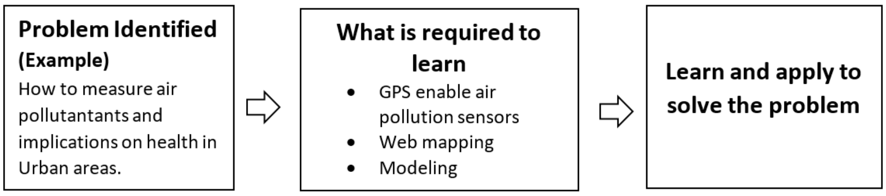

Figure 2: The planned approach to adopt PBL in Air Pollution Control Technology

5. CONCLUSION

Perrenet et al. (2000) analysed the suitability of PBL for engineering on the example of mechanical and biomedical engineering. At the end of their analysis, they concluded that there are benefits to applying PBL in engineering programmes such as cognitive and motivational reasons, application and the integration of theoretical and practical knowledge. However, they thought that separate direct instructions and supervised practice are necessary for engineering in addition to PBL. Due to the hierarchical knowledge structure in engineering, any missing concepts could increase the probability of PBL failure and contribute to students’ stress.

This need for traditionally delivered lectures is also clear from the course examples given by the LBS2ITS project partners in geodesy, geoinformatics and transport engineering. All presented courses required a combination of PBL and lectures to account for different levels of *a priori* knowledge of students and to introduce students to certain theoretical concepts related to each of the engineering disciplines. The ratio between the PBL and traditional lectures depended on the maturity of the students. For example, the master’s level students required fewer lectures than the undergraduate students. Across all disciplines, the PBL was implemented in a similar way and by closely following the PBL cycle steps. However, the most significant diversity in cases originated from the way a problem is chosen at the beginning of the PBL cycle. In some cases, the students were finding the problems themselves, and in other cases, the students were given real-world problems. Nevertheless, all LBS2ITS partners and their students had positive experiences implementing PBL in engineering education. The curricula enrichment and modernisation will continue during and after the LBS2ITS project when new pilot courses are introduced to Sri Lankan partners.

The results and conclusions of this research into the implementation of PBL in geodesy, geoinformation and transport engineering education will be utilised when designing the pilot courses that will be introduced during the last year of the LBS2ITS project at the Sri Lankan partner universities. Newly developed courses will be based on PBL and will, as required by the engineering education, contain come theoretical lectures depending on the *a priori* knowledge of the students. Furthermore, based on the conclusions of this paper and (Retscher et al., 2022), TUW will introduce a new PBL based course – *Positioning in indoor and GNSS challenged environments*. The course will be held in the winter semester starting from this year, and it will be offered to students in the second year of their master’s degree. To account for a different level of knowledge of students, online tutorials and lectures on topics such as GNSS basics, GNSS data processing, alternative PNT, sensor fusion, will be offered to students.

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