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Students' Attitude Towards Problem-Based Learning: A Case Study*

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Current educational approaches in engineering education should provide students with attributes required in professional practice. Active learning, in the form of Problem-Based Learning (PBL) and Project-Based Learning (PjBL), as an educational approach, shows promise in engineering. The paper describes the attitudes of students towards the application of problem based learning element in the Mechanics of Machines course in a Bachelor of Mechanical Engineering programme. The Mechanics of Machines is a core course in Year 3 of Bachelor of Engineering programme in Mechanical Engineering. The PBL element of the course was an individual project on kinematics of planar linkages; a topic always challenging to students. The project was to help the students in visualizing the motion of mechanisms, to assist them with understanding the entire solution process, and to draw conclusions for relatively simple mechanism.

Two surveys were administered to students to assess their attitude towards the PBL element of the course; one before the commencement of the project, and the second just after they submission of the reports, but before marking. Out of 61 students registered for the course 54 responded to the first survey, and 50 to both. The aim was to observe the changes in students' response to the PBL element. The comparison between the results of the surveys shows improvement in students' attitude towards pedagogy. The students declare that the experience with PBL improved their ability in problem solving, critical reasoning, searching effectively for information and use technology as a learning tool. However, they were critical about their ability to negotiate a work load and to prepare and follow a schedule. Those did not improve while negotiating the project.

Keywords: engineering education; project-based learning; students' attitude; planar linkages

1. Introduction

Over the past few decades, several educational initiatives have been tried to drastically change the teaching and learning of science and engineering. The initiatives include secondary education [1–4] as well as post-secondary education [5–7]. Effective educational initiatives include the use of Problem-Based Learning (PBL) and Project-Based Learning (PjBL). Despite attempts at change, most of teaching and learning in engineering education is still based on traditional classroom and laboratory methods. The most common form of instruction is still lecture—tutorial—laboratory. There are many reasons for this, however, two major reasons appear feasible. The first is that a majority of engineering instructors may not have enough knowledge and experience in the theory and practice of effective instructional approaches. In addition, such approaches require special organization and management of the classroom and students, and special scheduling and management of teachers' and students' time, as well as slightly different assessment. The second reason is the claim that such active pedagogical approach is the most challenging and often not well-understood [8, 9].

Both, PBL and PjBL demand resources available for students to carry out particular work or project; those could be tools, materials, equipment, hardware and software [10]. Another resource is professional development, which may be required to provide instructors with the skills they need to implement the approach. Such resources require both funds as well as time.

Active learning approaches such as PBL and PjBL may be affected by the rigid curriculum in engineering programmes. In some cases, the syllabi for engineering courses are constructed with specific requirements on the number of continuous assessment elements, not leaving enough time for substantial problem-based or project-based work. In addition, for the pedagogy to be indeed effective, it should be done in teams, whereas the assessment may involve additional time and effort by the instructor [11–13].

2. Active learning

The benefits of active learning have been reported by educators, such as John Dewey, for over 100 years [10, 14] and experiential and hands-on learning has a long history in engineering education. 'Doing projects' is a long-standing tradition, especially in American education. Also, engineering

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curriculum has always been full of laboratory investigations and field trips, showing elements of active learning, which can significantly improve the integration of knowledge [15].

Problem-based (or inquiry-based) learning (PBL) and project-based learning (PjBL) have been developed together and there is a bit of confusion as to which one is broader. Some believe that project-based learning is problem-based learning by definition [16]. However, there those who say that since project-based learning incorporates methods from problem-based learning, cooperative learning, active learning and project management theory [15], it can be asserted that PBL is the subset of PjBL. If PjBL is implemented, PBL will be indirectly implemented as well [9].

At the moment, PBL, which may have double meaning of either project- or problem-based learning, is used as a 'key' word to cover an incredible diversity of educational practices, ranging from typical inquiry-based learning, through problem-oriented lectures to completely open experiential learning. According to Hong, the substantive difference between project-based learning (PjBL) and problem-based learning (PBL) is the emphasis; the development of students' skills, in the case of PjBL, and the development of students' knowledge, in the case of PBL [17]. Also, the motivation is slightly different, as the PBL approach is driven by the problem and focuses on research and inquiry, whereas the focus of PjBL is the end product [14].

Both PjBL and PBL are fundamentally student-centred pedagogy and share many other characteristics. In both methods, improvement in students' learning is achieved by connecting them with real world tasks as students work on open ended problems or projects. The role of the instructor is to act as a facilitator, guiding students instead of using detailed instruction. The expectation is that it will provide the students with an in-depth understanding of a topic [18], connect them to higher levels of thinking [19], and provide them with an auxiliary, flexible and stimulating environment [20]. It can be summarized that problem-based learning emphasizes knowledge gain, with the final outcome often considered secondary, and project-based learning emphasizes the application and integrating of knowledge, with focus on the final outcome or product.

3. Problem-based and project-based learning

The primary reason for application of active learning in engineering is a need to adapt to a changing world [21]. The argument is that students should thrive in an environment centred on learning instead of on teaching. Both, PBL and PjBL are attempts to create a student-centred environment in which students' tasks are based on challenging questions or problems that involve design and problem-solving.

The problem-based learning approach allows the students to look closely at a particular problem/ topic over an extensive period of time, and not compress the topic into a 2–3 hour lecture and tutorial, or even assignment. The more the task reflects reality, the more the students feel motivated. The PBL intends to cultivate students' ability to learn actively, to think critically, and to solve problems through an instructional process that focuses on practical problems and encourages students to conduct group discussions. PBL offers an attractive alternative to traditional education by shifting the focus of education from what teachers teach to what students learn. By engaging students in real-life projects and involving them in active inquiry, the learning process is intensified and improved. The emphasis moves from the result, to the process, and the teacher transforms from the classroom main actor and a dictator, to an advisor; colourfully described as a shift from a 'sage on the stage to a guide on the side' [22].

The project-based students' activity is directed at achieving the end product whereas in problem-based learning, which can also involve project, the emphasis is on the process of applying existing and acquiring new knowledge.

Learning is normally defined as the process of acquiring new or modifying existing knowledge, behaviours, skills, values, or preferences [23]. That definition can be extended to describing learning as an active process of investigation based on the learner's interest, curiosity and experience, and resulting in expanded insights, knowledge and skills [11]. In applying PBL, the main motivation for learning creates a learning environment characterized by [24]:

- Learner-centred approach—students are required to take more responsibility for learning.
- Constructivist approach—students construct own version of reality rather than version presented by the instructor.
- Team-based cooperative learning outside class—active learning, primarily self- directed.
- There are many examples of successful problem-based and project-based learning in engineering education. The common features of such approach include the following.
- Project/problem work is normally supported by traditional teaching in the beginning of the course/topic.
- Learners control the learning process, and the instructor remains an advisor, typically not constantly present during the learning process.

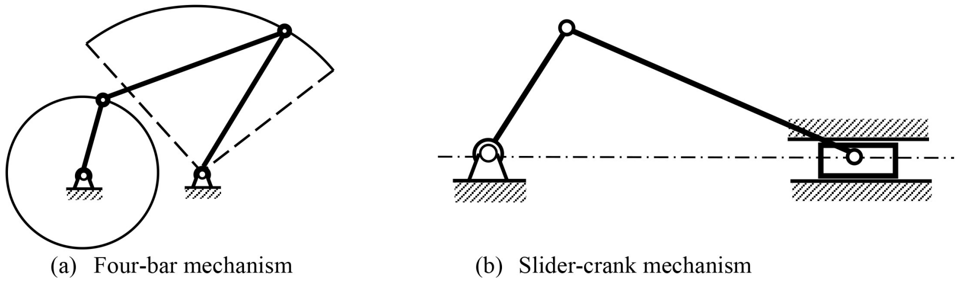

Fig. 1. Mechanisms considered in the project.

- Students learn the content as they try to address a problem/project, and the solution is partly dependent on the acquisition and comprehension of facts, but also based on the ability to think critically.
- Students typically work in teams.

4. Application of problem-based learning

The University of Botswana (UB) has been using the PBL approach for several years, and has chosen PBL as a pedagogical method to introduce students to a specific topic of kinematic analysis of linkages. The topic is one of many covered in the Mechanics of Machines core course in Year 3 of a 5-year BEng programme in Mechanical Engineering. The course is 3 credits, and is covered in a 15-week semester with 2.5 hours of lecture, 1 hour of tutorial and 1 hour of lab each week. The course follows a general Dynamics course in Year 2, which is taken by all engineering students.

The Mechanics of Machines course covers a number of topics such as balancing (both rotating and reciprocating masses), turning moment diagrams and flywheels, epicyclic gears, gyroscopic motion, general equation of motion for the machine and vibrations. The analysis of planar linkages, which is one of the topics in the syllabus of the course, has always been a challenge for students. The syllabus prescribes the traditional velocity and acceleration diagrams. The elements of relative motion, including simple velocity diagrams, are covered in the Dynamics course in Year 2, however, even simple velocity diagrams must be repeated in the Mechanics of Machines course. The students have difficulty visualizing the motion of mechanisms, completing a solution and draw conclusions, even for relatively simple mechanism. The lab portion of the course is designed to complement the lecture with specific emphasis on understanding the subject matter. However, even complementing the theory with practical did not bring the expected results despite offering a specific lab on simple linkages analysis.

The project approach in learning kinematic analysis of planar linkages entailed asking the students to perform the analysis using three methods, then compare them for a specified position of the mechanism as determined by the crank angle. Those tasks were packaged as a 2-month project, with a report submitted at the end. The type of mechanism was limited to a four-bar linkage and a slider-crank mechanism, although each student was issued with different data (Fig. 1). The students were to use the following methods:

- Velocity and acceleration diagrams.
- Analytical method based on the closed loop equation.
- Software (FOURBAR and SLIDER) provided with the Norton textbook [25].

There were no formal lecture(s) on the topic of kinematic analysis delivered to the students. However, there was an introduction to the project providing basic information of methods of analysis, explaining expectations and also available resources.

The students were asked to perform full kinematic analysis, determining the position angles, velocity and acceleration of all joints and links, and an arbitrary (although clearly specified) point on the coupler. The velocity and acceleration diagrams were to be drawn to scale, but only for one position of the crank. Additionally, students were requested to calculate and comment on the velocity ratios. For the same position, kinematic values were to be determined by analytical method with derivation of equations for the velocities and accelerations, both linear and angular. The software accompanying Norton textbook (FOURBAR and SLIDER) was chosen as the most convenient for use by the students, providing visualisation of the motions and contrasting its application with other methods. The software is a flexible and easy to use program to analyse and animate simple planar mechanisms. The results obtained using the software were to be exported into a spreadsheet which was to be used to plot the results. Finally, the professional report, to be submitted via Blackboard, was to be prepared as a single electronic document with all text, figures, graphs, and calculations included. The most important part of the report was to compare and comment on the results obtained using three methods of analysis.

For project-based learning to be an efficient way of learning, it can be combined with problem-based learning to make it also an effective method to acquire new knowledge. The students must research, investigate, collect data, explore and adept information in order to present a possible solution to the problem. It does require students to utilize their skills, both already acquired and possible new ones, both technical and professional, to answer project problems and to report on it. Such approach should help them in proper understanding and remembering new information as students tend to remember things they have experienced or had to research on their own. The inquiry they perform answers their own question, not just one presented during class [26]. However, are the students aware of the methodology? Do they want to learn the course topics in such way?

To determine the results of the PBL approach, students registered for the course were asked to, voluntarily, answer two surveys related to their experiences. The main purpose of the investigation was to see the change in the students' attitude towards PBL. Hence, the first questionnaire was administered just before the commencement of the project, and the second just after students' submissions, but before they received marks for their work. Out of 61 students registered for the course 54 responded to the first survey, and 50 to both, giving the response rate of 82%. Both questionnaires, created using Likert-scale items, consisted of similar questions asking their opinion on the problem-based learning approach applied in the course. There was only one open-ended question seeking general comments at the end of the questionnaire, and administered after the project.

5. Results

The results of the survey indicate that 50% of the students were not sure whether they had ever participated in the PBL activities before (Fig. 2). They were also not sure about their previous knowledge of such learning approach (30%), with the majority (39%) stating no previous knowledge of PBL (Fig. 3).

Before the commencement of the project, the students were quite positive about instructors' best interest when introducing the project, with 64% positive answers and 20% negative. That view improved after project implementation as the percentage of positive answers increased to 74% (Fig. 4), and negative dropped to 0%. Strangely, the percentage of 'not sure' answers increased from 17% to 26%. Unfortunately, the students did not comment on the open-ended question of the survey as to why they were unsure.

Students' opinion on the value of the activity was positive before project; 63% positive answers, with 35% not sure and only 2% negative. That assessment increased to 88% positive, 0% negative and 12% not sure answers after completing the project (Fig. 5).

Similarly, the number of students seeing the time used for the activity as beneficial increased from 70% to 90%, with number of 'not sure' dropping from 30% to 8% (see Fig. 6). On the contrary, the students who enjoyed the activity (96% positive answers), but were not certain after the actual activity took place, as the number of positive answers dropped to 72%, with not sure growing from 4% to 24% (Fig. 7). This may be attributed to the demand on time the students had to spend on performing the project, and was stated by students in the open-ended question:

- It was a good experience, but it added a lot of work load to an already demanding course.
- The project was very challenging, but time consuming.
- The project was time consuming, as we had to spend a lot of time to find the relevant information needed for the project.

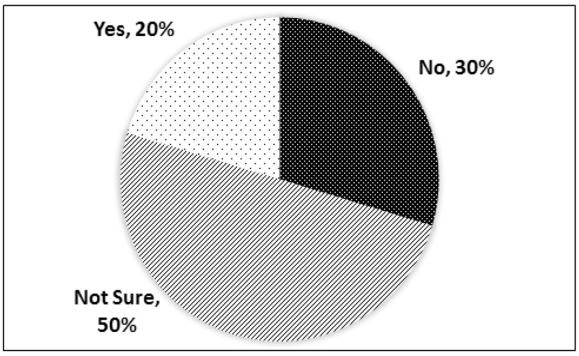

Fig. 2. Participation in activities related to PBL.

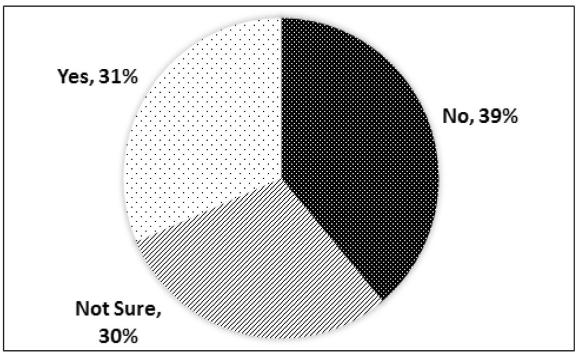

Fig. 3. Knowledge of PBL.

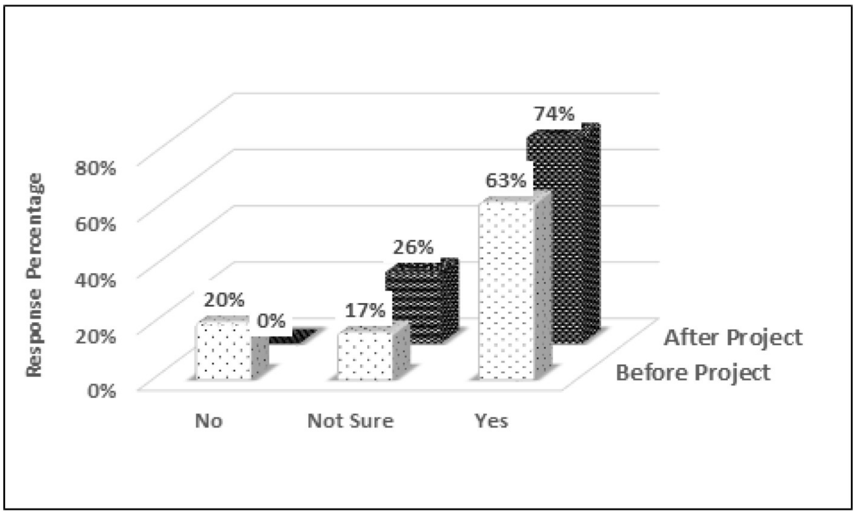

Fig. 4. Instructor had the best interest in mind.

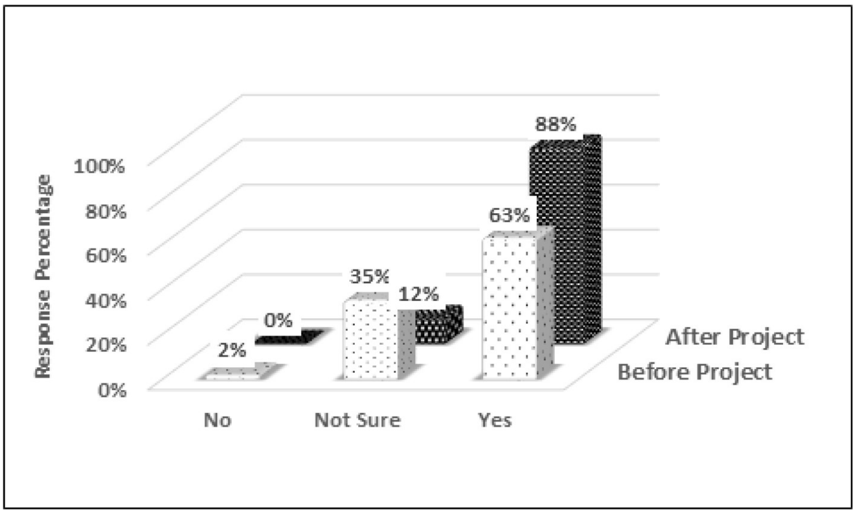

Fig. 5. Value of the activity by students.

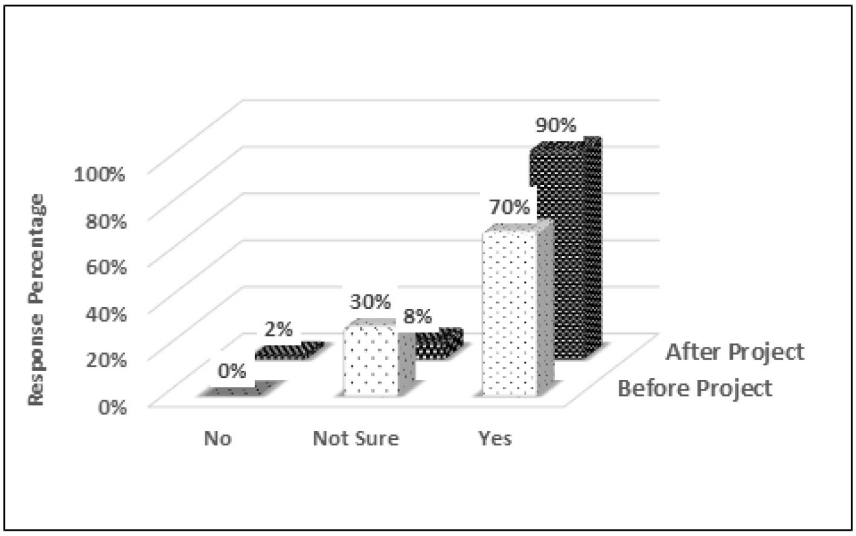

Fig. 6. Time used for the activity is beneficial.

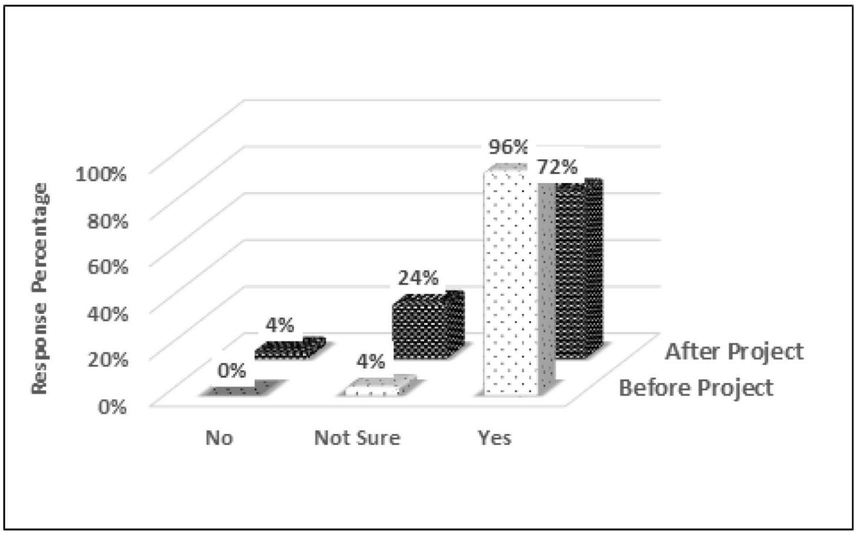

Fig. 7. Enjoying the activity.

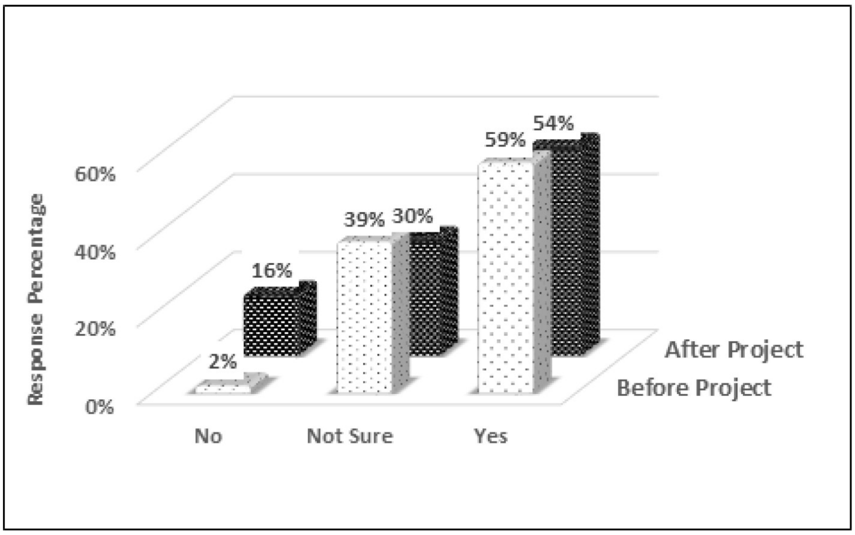

Fig. 8. Learning the content of the course during the project better than during normal classes.

More than half of the students indicated that learning the content of the course was better using PBL than using traditional lecturers (Fig. 8). However, that percentage dropped slightly; 59% before and 54% after the project, respectively. There were also many students who were not sure (39% before, and 30% after the project), with negative answers increasing from 2% before the project, to 16% after. Once again, an explanation can be found in some of the comments, in which several of students opted for '*combining the project with traditional teaching by lectures with at least half of the material and questions done in the classes*'.

Students commented that learning the details during the projects was better despite the content not covered in lectures (Fig. 9). That positive feeling improved noticeably after the project, with percentages changing substantially. Positive answers increasing from 46% to 72%, and not sure and negative answers dropping, from 33% to 18% and from 20% to 10%, respectively.

A separate section of the survey dealt with students' opinion on the change in their abilities. The results are presented in Figs. 10–12. Students were very positive about their abilities, even before the project, which may not be a reflection of real life. Therefore, it is better to look at the differences between students' assessment of different skills before and after project.

The figures show big improvements in students' opinion on their ability to:

- Think logically about a question or problem—improvement by 22%.

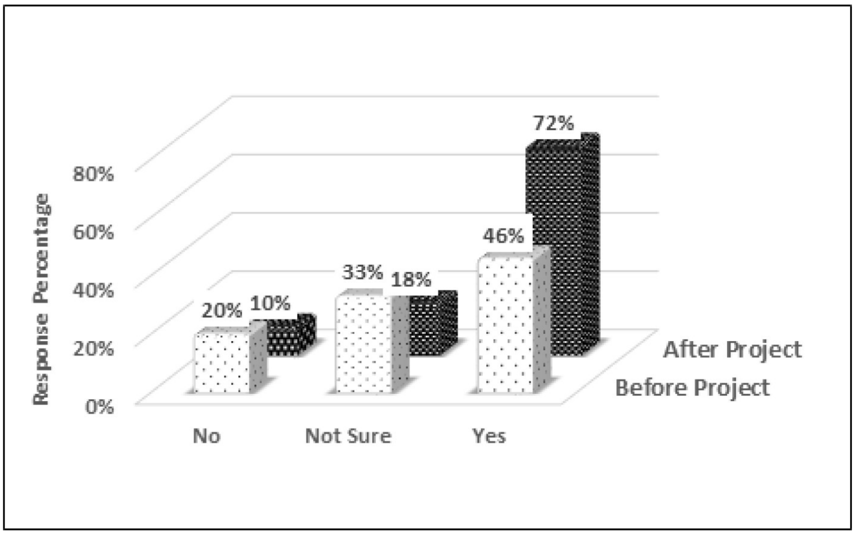

Fig. 9. Learning the details during the projects better despite the content not covered in lectures.

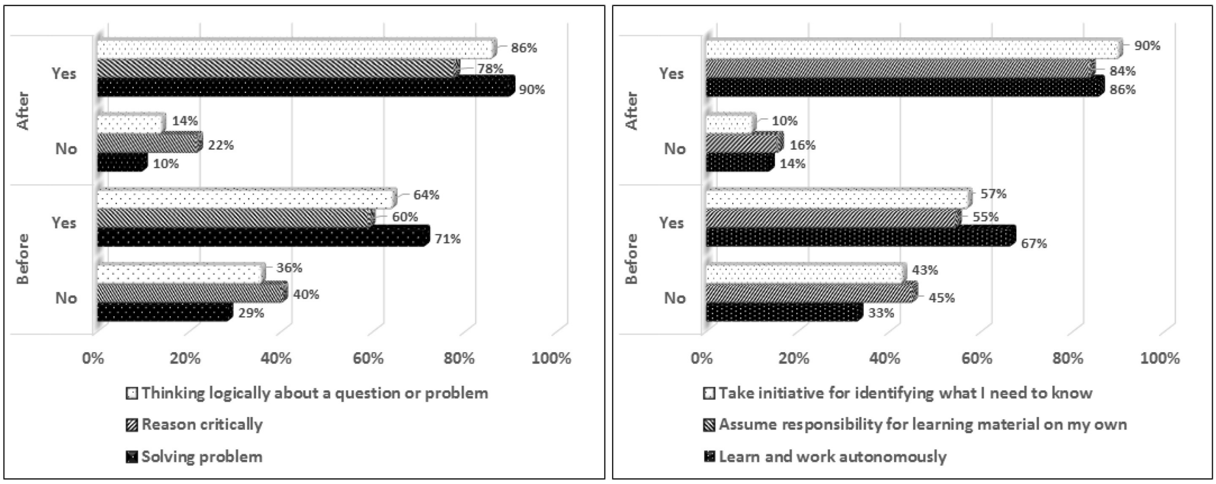

Fig. 10. Students' ability to solving problem, reason critically, thinking logically about a question or problem, and to learn and work autonomously, assume responsibility for learning material, take initiative for identifying learning scope

- Reason critically—improvement by 18%.
- Problem solve—improvement by 21%.
- Take initiative for identifying what to learn—improvement by 33%.
- Assume responsibility for learning—improvement by 29%.
- Learn and working autonomously—improvement by 19%.
- Search effectively for information—improvement by 37%.
- Scope a problem—improvement by 38%.
- Break problems into solvable components—improvement by 52%.
- Use technology as a tool for learning—improvement by 11%.
- Use technology to analyse information—improvement by 37%.
- Use technology for self-instruction—improvement by 12%.

However, there was almost no improvement in students' opinion on their ability to:

- Negotiate work load—improvement by 6%.
- Keep track of work on extended tasks/assignments—improvement by 9%.

There was a negative opinion on '*preparing and following a schedule*', showing a drop by 22%. Students were given ample time to complete the project and were advised at the start to plan their time and actions carefully, and to follow their plan. However, it became quite obvious before the deadline that a majority of the students left most of the work until the last moment. Some students were

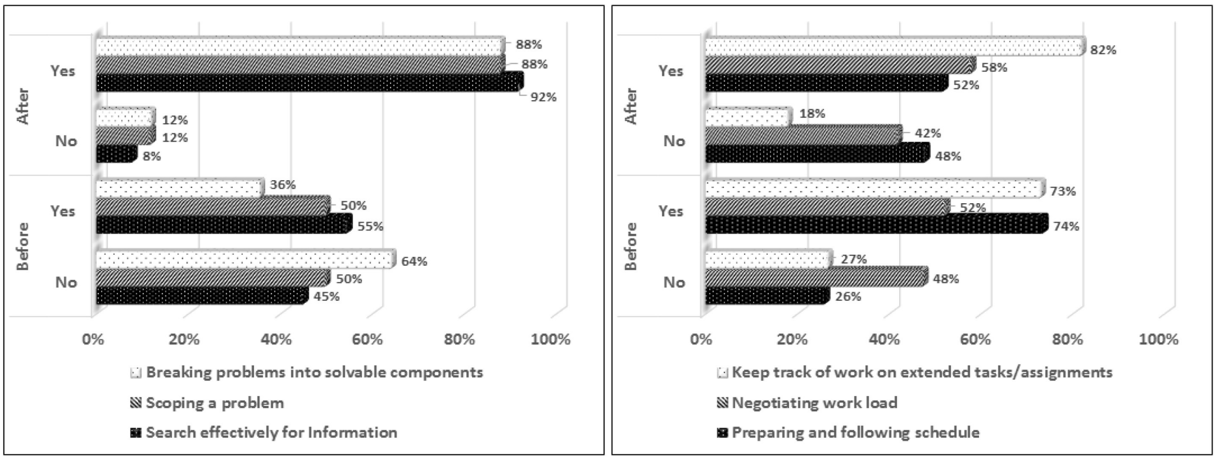

Fig. 11. Students' ability to search effectively for information, scoping a problem, breaking problems into solvable components, and follow a schedule, negotiating work load, keeping track of work on extended tasks/assignments.

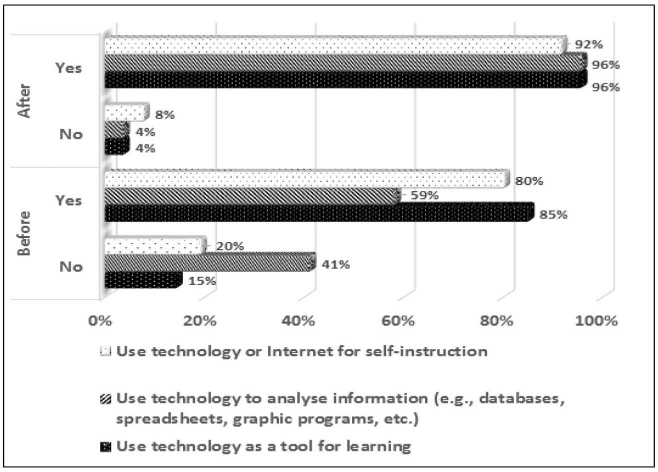

Fig. 12. Students' ability to use technology: as a tool for learning, to analyse information, for self-instruction.

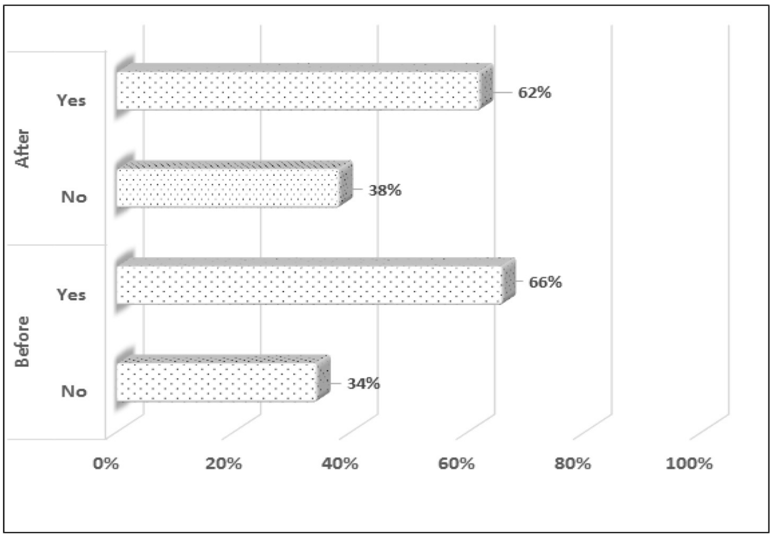

Fig. 13. Students' ability to communicate effectively by writing a project report.

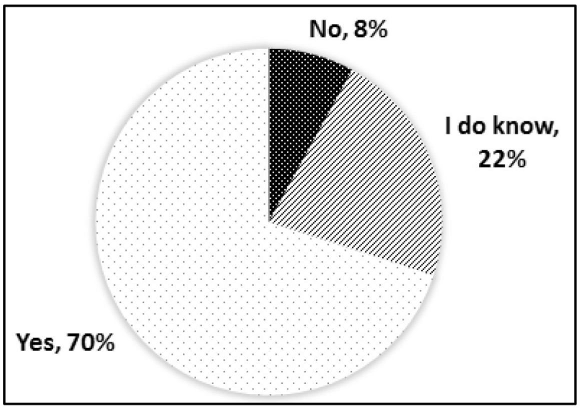

Fig. 14. Students' opinion on whether their PBL experience was better than traditional education.

frustrated, complaining that '*too much time given to it*'. It is a hope that the students learned a lesson, and they seriously reflected on the issue of time and activity planning.

Surprisingly, students' opinion on their ability to communicate effectively by writing a project report dropped, although slightly by 4%. It should be noted that it was not related to marks received for the report, as the survey after the project was administered before marking of work. This may have been the students' own reaction on their submissions.

The final question in the survey after the PBL activity was to ask students whether their PBL experience was better than traditional education. The students were enthusiastic about their active learning experience with great majority being positive about PBL (70%) in comparison to the traditional classroom teaching (Fig. 14).

6. Discussion

The PBL approach was used to introduce students to a specific topic of kinematic analysis of linkages in the Mechanics of Machines course. It was the first intentional attempt to use such methodology with this group of students, hence the students' awareness of the educational approach was very low. The majority were either not sure or denied both participation in such activity (89%) and knowledge of the method (69%). The students viewed the approach positively, both before as well as after actually working on the project. They valued the activity, and had no doubt that by applying it, the instructor had the best interest of students in mind. The students' positive opinions improved from 63% to 88% and from 63% to 74%, respectively. Similarly, the number of students seeing the benefit of the activity increased from 70% to 90%. A majority of students enjoyed the activity, although they were more enthusiastic before the project (96%) than after completing it (72%). As indicated in the open-ended questions in the survey, the main reason for such drop were time and effort devoted on the project.

In terms of PBL as a method for learning the material in the course, more than half of the students were of the opinion that learning the content of the course was better than when using traditional methods. However, they were more positive about learning details, with 72% positive answers after the project, indicating the effectiveness of the PBL in learning specifics. This was confirmed by the student comments:

- With gathering information on my own for the project, this helped to understand much better some concepts I did not understand in class.
- I have learned a lot of details, which I am sure I would have missed during normal lecture.

Students were very positive in their ability in problem solving, critical thinking, learning and working autonomously, and assume responsibility for learning material. Similarly, students were positive about their ability to search and collect information, and using technology as a tool for learning, analyses and self-instruction were seen to improve. Students commented:

- It was great exposure and experience in problem solving.
- The project was a good exercise, which led a student to thinking analytically and logical, when solving engineering problems.
- PBL enriched my ability to learn, and increase my potential in critical thinking.
- It was a great project, and it enhanced our skills in problem solving and using technology to do our work.

The above trend was not as positive in respect to managing the time and work. Although, still positive about their ability, the improvement in terms of negotiating work load and keeping track of work, were very low (6% and 9%, respectively). The ability to prepare and follow the schedule was reflected on by students very negatively, as their assessment before and after the project, dropped by 22%. Despite disappointment with such result, it had a positive connotation, that students realized the problem, which gave optimism for improvement.

Unexpectedly, the students' assessment of their ability to communicate effectively, by report writing, dropped during the project, although only by 4%. That was not a reaction to project report marking, as the survey was administered before students received the assessment. Once again, it may be a sign of students' own realization of their skills in report writing, and leaves room for improvement.

Overall, the students showed a very positive attitude towards their first experience with PBL. The project itself was used as a 'vehicle' for students learning, and the ultimate goal was not finding the best answer to a question, but rather acquisition of knowledge and training students to learn through the process of problem solving, i.e. thinking steps, research topics, development plans, etc. However, it was also the development of certain abilities, and management of time and tasks. The project was done by each student individually, but there was a serious, though informal, collaboration and discussion regarding the solutions. The actual pedagogical approach can be summarized as blending of both project- and problem-based learning.

A good summary of the goal of the introduction of the project, is indicated by students own voices:

- It was an eye opener on how teaching can be different to a normal class.
- It gave the opportunity to find information completely on my own, and were necessary discuss with friends.
- The project was a great exercise, which showed me that working on my own could be both more enjoyable, and more effective.
- We were forced to search for information, learn it and apply. Tough but really real.

The study presented had a few limitations and mainly related to its case study character. The population of students was limited to only 54 students participating in the survey before the project and 50 after the project. The study was also limited to only one course, out of many more available in the programme curriculum. However, there is also limitation related to the way the project was introduced to the students; it was an individual project with every students having a different set of data. Though discussions among the peers were encouraged, and indeed took place, typical team work was missing.

7. Conclusions

In order to prepare students for their professional careers, university courses should be designed to assist students to acquire problem solving and life-long learning skills, rather than simply spoon feeding them to memorise prescribed content and design methods. One of the most effective ways to change, is to apply active teaching methods, which shift teaching to learning. Of the active methods, both problem- and project-based learning seems to be the most promising in engineering education.

The study showed improvement in students' attitude towards problem-based learning. From a group of students that was unaware and unsure about the educational approach, with a majority not sure whether they had participated in such pedagogy in the past, the students declared a positive opinion about its benefits in many areas. The students confirmed that the experience with PBL improved their ability in problem solving, critical reasoning, searching effectively for information, and using technology as a learning tool. However, they were critical about their ability to negotiate a work load and to prepare and follow a schedule.

The comparison of students' attitude before and after the project suggest that, despite declared demand on time, students improved their opinion on the benefit and value of such activity, and that the instructor had their best interest in mind. Although their predicted enjoyment in completing the project was not fulfilled, they did indicate that they learned details better.

The experimental results presented showed clearly a positive influence of the PBL on students' ability in different crucial areas as well as on their attitude towards active learning. Although the students were originally not aware of the new methodology, the PBL activity was considered better than traditional educational approach. Therefore, PBL can be considered an effective method of delivery in engineering.

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