Proceedings of the International Conference on Industrial Engineering and Operations Management
Toronto, Canada, October 23-25, 2019

A Project Based Learning Tool for Industry 4.0 Manufacturing Engineering Education

Kapil Gupta, Doctor Mukhawana, Madindwa Mashinini

Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
Johannesburg, South Africa
kgupta@uj.ac.za, mmukhawana@uj.ac.za, mmashinini@uj.ac.za

Abstract

Project based learning (PBL) is an educational technique where learners gain subject knowledge and learn by investigating and responding while busy doing a project or challenge. It implies learner's active involvement in a real world problem where s/he can apply, investigate, respond, and reapply the theoretical knowledge to find appropriate solutions. This paper presents some significant insights about a teaching innovation project conducted on project based learning for better understanding the manufacturing engineering module contents. First project based learning (PBL) is introduced which is followed by some review of past research work conducted on PBL, then formulation of a project problem for the students of manufacturing engineering is discussed and it ends with the analysis of the students response on the effectiveness of PBL for them to understand and learn the module contents. A majority of the students realized the effectiveness of PBL technique, and accepted better understanding of the manufacturing processes and learning enhancement. It is worth mentioning that the University of Johannesburg is a forerunner institution globally to implement, follow and encourage the fourth industrial revolution activities in teaching and research. As regards to that, it is hoped that this project would contribute to develop industry 4.0 ready engineers to cater the local and international needs.

Keywords

Education, Engineering, Industry 4.0, Learning, Manufacturing, Project

1. Introduction

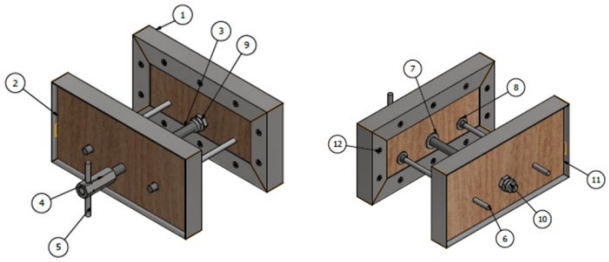
Project-based learning (PBL) is a student-centered pedagogical technique that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge through active exploration of real-world challenges and problems (Frank et al., 2003; Rios et al, 2010). In PBL, students learn about a topic/course/subject by working on a project or challenge, where they busy investigating and responding. Here, an advantage of digital tools and technologies can be taken to accomplish project requirements and further product development. PBL can also be recognized as an education tool where teaching and learning is done by engaging students in investigation. The three set of techniques, namely, problem based learning, project based learning, and CDIO (conceive, design, implement, and operate) have been identified as revolutionary techniques to develop problem solving and critical thinking skills for learner's success and better results in engineering education (Crawley et al., 2007; Perrenet et al., 2000; Rios et al., 2010). To conceive or formulate a project in project based learning is a major challenging task, as it must be feasible; fulfill the requirements of learning objectives; aligned to the skill development goals; along with fulfilling the course/subject contextual requirements. The important past attempts on PBL based education are discussed here as under.

Kanigolla et al. (2014) investigated the impact of PBL on the students learning in a lean and six sigma course. A survey based on twenty three questions (belong to learning, critical thinking and engagement) was conducted and it was found that the students found project very effective to understand and learn six sigma fundamentals. Frank et al. (2003) also reported the effectiveness of PBL for development of engineering thinking; information retrieval, problem solving and laboratory skills in the students. An important work reports the improvement in student's performance in the electrical control technology course after PBL interventions (Samaca and Ramirez, 2010). A recent study identifies PBL as an effective complimentary technique for the enhanced student learning in lean manufacturing module (Tortorella and Miguel, 2018). In case of many engineering subjects where laboratory work

is essential and major aspect, PBL is more or less similar to work-integrated learning (Agwa-Ejon and Pradhan, 2017; Mutereko and Wedekind, 2015).
Literature review concludes the significance and potential of PBL technique for better understanding and learning of the students. However, the acceptance and dissemination of project based learning approach in engineering education domain still require more sincere future attempts. The work reported in this paper is a part of a teaching innovation project conducted at University of Johannesburg where PBL approach has been used in manufacturing engineering education for better understanding of the course contents and skill development of the students. In this paper the details of the methodology adopted for PBL of manufacturing students and analysis of their feedback on the effectiveness of this approach is discussed.

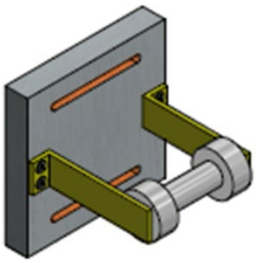
2. Methodology

As discussed, formulation of a project is the most important task in PBL based education. In this work, a project work where production of two different engineered parts with the help of different manufacturing processes was finalized. It was decided to engage students to start the project from processing of the raw materials received in the form of bars, sheets, and sub-assemblies to finally making an assembly by following various stages of manufacturing. The subject aligned with this project is mechanical manufacturing engineering where in the classroom practice, students were lectured for many types of manufacturing processes such as fitting; carpentry; welding and joining; and cutting or machining such as turning, milling, reaming, tapping and drilling. Along with the theoretical knowledge, the students were given practical exposure where they had to apply that knowledge to complete the project with the accomplishments of various tasks. The envisaged outcomes are as follows-
Enhanced learning and In-depth understanding of the manufacturing processes linked with this project;
Student professional training in scare/critical skill area i.e. ‘advanced manufacturing’;
Competency building and accomplishment of graduate attributes;
Understanding Industry 4.0 concept via online design, modelling, and automated manufacturing involved in this project.
The project work is based on fabrication of a Roller Host and a Clamp or Bench Vice using various manufacturing processes which they also studied in the class lectures under the subject Mechanical Manufacturing Engg to understand theoretical fundamentals. In other words, these two projects have been conceptualized in such a way that while developing them the students should be exposed to the implementation and application of important manufacturing processes which they are studying in their theory subject. It would help them to understand the nature, application, and characteristics of important manufacturing techniques in a much better way, when exposed practically. Figure 1 presents the drawing of the project parts and the list of the associated manufacturing processes to be used and studied. Both parts were produced within one hundred and twenty hours allocated time.



Welding
Tapping
Fitting
Carpentry
Drilling

Clamp



Turning
Riveting
Fitting

Roller host

Fig. 1 Mechanical parts for PBL and the associated manufacturing processes

Designing these project models also involved their modelling in a dedicated 3D Modelling CAD Software. It helped the students to get aware of cyber technologies being used these days in industries where Industry 4.0 concept has been adopted. It is known that the subject manufacturing engineering is one of the basic subjects and belong to the manufacturing field of mechanical engineering. After graduation, students may encounter and assign jobs in manufacturing department in the industries where they work. Therefore, it is essential for them to have knowledge, exposure, and appropriate skills in manufacturing beforehand. Welding, machining, and hands-on skills etc. are some of the very basic manufacturing processes. Having skills in these make them capable to design and develop (build) parts, components, and products either individually or in a team.
In the current project of manufacturing of roller host and clamp, under the supervision of instructors and technicians, the students were instructed and exposed to the advancements in these manufacturing techniques being used while developing their project models. Certainly, a basic knowledge on hands on skills, material science, and lab safety etc. was given them to make a strong foundation. A total of ninety students were engaged in this project based learning task. All students successfully completed the development of both mechanical parts with the allocated time of one hundred and twenty hours time that could approximately stretched for three and half months following the routine time table. This experiential learning project was also very essential to complete the course credit requirement and competency building to achieve graduate attributes mainly problem solving, application of scientific knowledge, investigation, and team and multidisciplinary working etc.
The feedback of the students on project based learning and its analysis is presented in the next section.

3. Discussion

After evaluating the quality of the project parts, where they all have passed, a questionnaire based survey was conducted to understand and analyze their learning, development of skills, and engagement. A total of 62 students out of ninety one participated in this survey. The questionnaire distributed to the students consisted of twelve questions. The Likert scale rating responses i.e. strongly agree (5), agree (4), disagree (3), strongly disagree (2), and not applicable (1) were used by the students to respond the questions asked. Figure 2 is the graphical presentation of the feedback results on PBL. The results are shown in Table 1 where the number and percentage of students are tabulated in case of each question. It is analyzed that over 90% students were either agree or strongly agree that mechanical parts assembly drawings given to them ere understandable and most of the manufacturing processes they studied during lecture were covered o involved in building project parts given. All (100 %) students agreed with the fact that they understood and learnt mechanisms and principles of manufacturing processes in a much better way through these projects. Only one out of sixty two students was shown disagreement on the question of learning enhancement after doing these projects. Approximately 7-11 % students were found in disagreement on building skills in advanced manufacturing, and competencies to fulfill graduate attribute's requirements. However, a major percentage of the students accepted the fact that PBL activities helped to develop conceptual understanding and was in favour of using PBL type technique for other modules as well.
While developing project assemblies, I understood and learnt mechanisms and principles of manufacturing processes in a much better way.
Some anonymous qualitative responses provided by the students are quoted as follows-

- "Well organized time schedules should be provided for each group".
- "The labs were conducted very well and we as students understood the manufacturing processes and principles. Therefore, all was well as we cooperated with the assistant tutors and lab technician as well".
- "The labs were conducted in a good manner. They improved my hand skills and applying the theory".
- "From the projects that we did in the workshop, I learned how to operate basic mechanical engineering machines. I also learned how it is like in the mechanical engineering environment".
- "It was a very wonderful, challenging module and equipped us with the necessary knowledge of the engineering work place. I am grateful for this module".
- "Only if we could be given the flexibility to temper with the design it would be better".
- "Everything was conducted thoroughly".

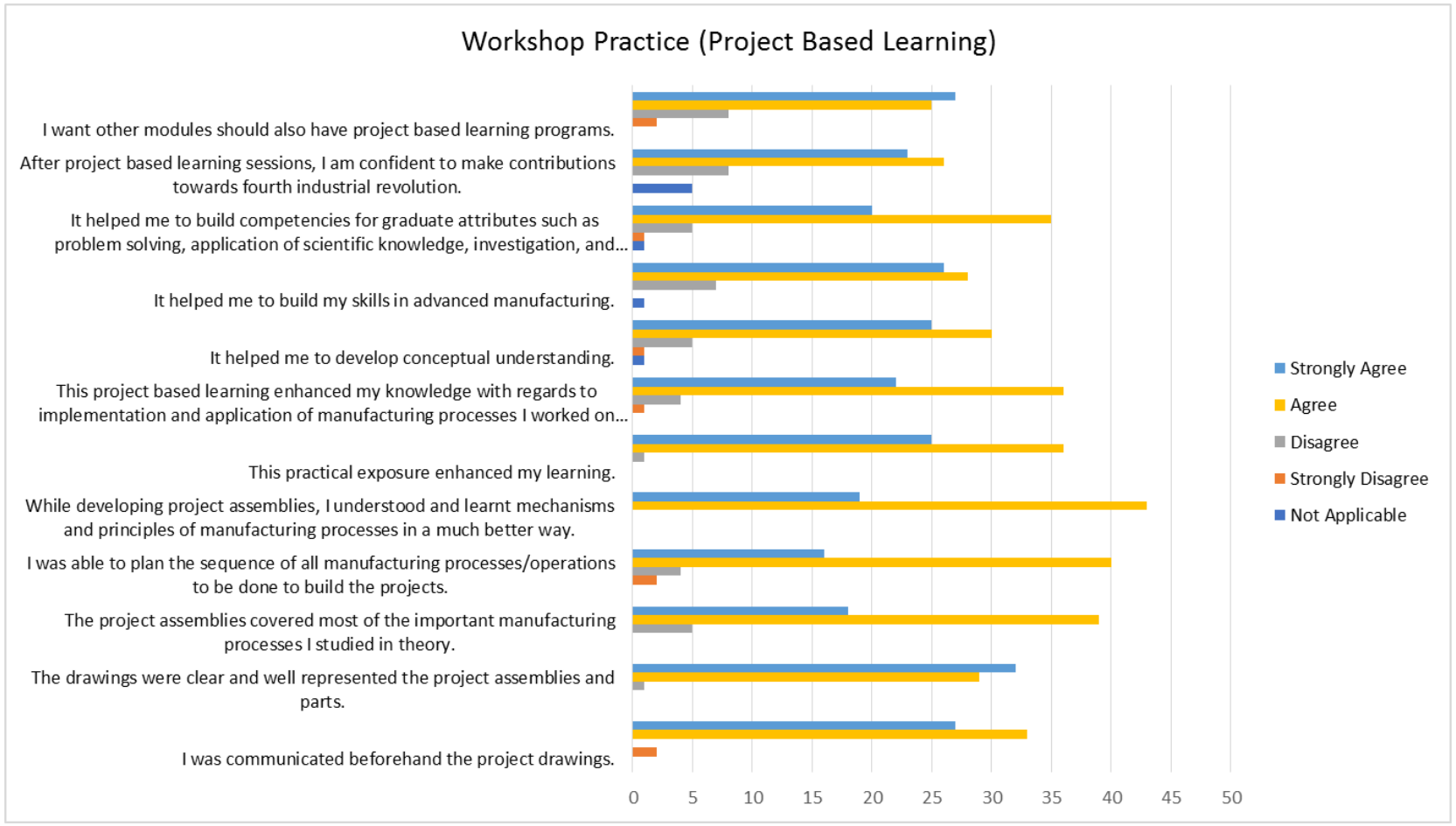


Fig. 2 Graphical representation of feedback of the students on PBL

Table 1 Question statements and corresponding number and percentage of student's responses

QUESTION STATEMENTS	Not applicable	%	Strongly disagree	%	Disagree	%	Agree	%	Strongly agree	%
	N	1	N	2	N	3	N	4	N	5
1. I was communicated beforehand the project drawings.		0	2	3,23	0	0,00	33	53,23	27	43,55
2. The drawings were clear and well represented the project assemblies and parts.		0	0	0,00	1	1,61	29	46,77	32	51,61
3. The project assemblies covered most of the important manufacturing processes I studied in theory.		0	0	0,00	5	8,06	39	62,90	18	29,03
4. I was able to plan the sequence of all manufacturing processes/operations to be done to build the projects.		0	2	3,23	4	6,45	40	64,52	16	25,81
5. While developing project assemblies, I understood and learnt mechanisms and principles of manufacturing processes in a much better way.		0,00	0	0,00	0	0,00	43	69,35	19	30,65
6. This practical exposure enhanced my learning.		0,00	0	0,00	1	1,61	36	58,06	25	40,32
7. This project based learning enhanced my knowledge with regards to implementation and application of manufacturing processes I worked on and studied in theory.		0,00	1	1,61	4	6,45	36	58,06	22	35,48
8. It helped me to develop conceptual understanding.	1	1,61	1	1,61	5	8,06	30	48,39	25	40,32
9. It helped me to build my skills in advanced manufacturing.	1	1,61	0	0,00	7	11,29	28	45,16	26	41,94
10. It helped me to build competencies for graduate attributes such as problem solving, application of scientific knowledge, investigation, and team and multidisciplinary working etc.	1	1,61	1	1,61	5	8,06	35	56,45	20	32,26
11. After project based learning sessions, I am confident to make contributions towards fourth industrial revolution.	5	8,06	0	0,00	8	12,90	26	41,94	23	37,10
12. I want other modules should also have project based learning programs.		0,00	2	3,23	8	12,90	25	40,32	27	43,55

4. Summary

In this paper, implementation of problem based learning (PBL) technique in manufacturing engineering course and its impact on the understanding, learning, and skill development of the students are discussed. The following conclusion can be drawn from this work-

- Mechanical parts under the PBL were developed by each student successfully.
- Students accepted that it helped them to understand the manufacturing course contents i.e. various manufacturing processes in a better way.
- All students confirmed to achieve the applicable graduate attributes.
- Recommendations and qualitative feedback from the students have been noted for further improvements.
- Future work avenues include analysis of the impact of PBL via group interviews, focused PBL mini-project individually for each chapter, extension of PBL techniques to other engineering branches and subjects.

Acknowledgements

- This work is supported by DHET University Capacity Development Grant (UCDG) 2019 and Teaching Innovation Fund 2019, University of Johannesburg.

References

Rios, I.G.L., Cazorla, A., Diaz-Puente, J.M., Yague, J.L., Project–based learning in engineering higher education: two decades of teaching competences in real environments, Procedia - Social and Behavioral Sciences, vol. 2, no. 2, pp. 1368-1378, 2010.

Crawley, E.F., Malmqvist, J., Ostlund, S., Brodeur, D.T., Rethinking Engineering Education- The CDIO Approach, 2007, Springer.

Perrenet, J.C., Bouhuijs, P.A.J., Smiths, J.G.M.M., The Suitability of Problem-based Learning for Engineering Education: theory and practice, Teaching in Higher Education, vol. 5, no. 3, pp. 345-358, 2000.

Kanigolla, D, Cudney, EA, Corns, SM, Samaranayake, VA, Enhancing engineering education using project-based learning for Lean and Six Sigma. International Journal of Lean Six Sigma, 5 (1), 45-61, 2014. https://doi.org/10.1108/IJLSS-02-2013-0008

Frank, M, Lavy, I, Elata, D, Implementing the Project-Based Learning Approach in an Academic Engineering Course. International Journal of Technology and Design Education 13, 273–288, 2003.

Samaca, LF, Ramirez, JM, An approach to applying Project-Based Learning in engineering courses. IEEE ANDESCON, 2010. 10.1109/ANDESCON.2010.5630007.

Tortorella, G, Miguel, PC, Combining traditional teaching methods and PBL for teaching and learning of lean manufacturing. IFAC PapersOnLine 51-11, 915–920, 2018.

Agwa-Ejon, JF, Pradhan, A, The Impact of Work Integrated Learning on Engineering Education. IEEE Global Engineering Education Conference (EDUCON). 1258-1265, 2017. 10.1109/EDUCON.2017.7943009.

Mutereko, S, Wedekind, V, Work integrated learning for engineering qualifications: a spanner in the works. Journal of Education and Work, 29 (8), 902-921, 2016.

Biographies

Kapil Gupta is working as Associate Professor in the Dept. of Mechanical and Industrial Engineering Technology at the University of Johannesburg. He obtained Ph.D. in mechanical engineering with specialization in Advanced Manufacturing from Indian Institute of Technology Indore, India in 2014. Advanced machining processes, sustainable manufacturing, green machining, precision engineering and gear technology are the areas of his interest. He has authored several SCI/ISI Journal and International Conference articles. He also authored and edited 10 international books on hybrid machining, advanced gear manufacturing, micro and precision manufacturing, and sustainable manufacturing with the renowned international publishers. He has also successfully guest edited special issues of a Scopus indexed journals and he is currently editing a series of handbooks on Advanced Manufacturing as a series editor. He is a recognized reviewer of many international journals and in the advisor/technical committees of international conferences. He has also delivered invited speeches in international conferences and symposiums, and seminar talks at international universities. Kapil Gupta is a NRF [National Research Foundation] rated Researcher in South Africa. Currently, he is supervising 8 Masters and 4 Doctorate students who are busy conducting research in

advanced manufacturing and industrial engineering fields. He is also conducting research in teaching & learning in higher education (HE) scenario along with doing his PG Diploma in higher education. He is working on implementation of innovative teaching techniques for the enhanced learning of engineering students. Recently, he also developed a manufacturing engineering virtual lab.

Madindwa Mashinini is a Senior Lecturer in the Dept. of Mechanical and Industrial Engineering Technology at the University of Johannesburg. He holds a post of head of the department currently. He obtained PhD in welding technology and conducting research in advanced manufacturing. He has published many papers in international journals and conference proceedings of repute. He is supervising postgraduate students in mechanical engineering. Madindwa is a member of many professional societies and serving as a member of advisory committees of conferences. He is also busy doing research projects and publications in teaching and learning.

Doctor Mukhawana is a Lecturer in the Dept. of Mechanical and Industrial Engineering Technology at the University of Johannesburg. He holds a Master degree with specialization in manufacturing engineering. Doctor is a member of various committees of research and teaching and learning. He is pursuing PhD in manufacturing engineering. He has published many conference articles. Doctor is doing research projects in manufacturing engineering and teaching and learning. Project-based learning, virtual reality-based education, game-based education, and engineering education 4.0 are the areas of his interest. He is busy implementing innovative techniques for the improved teaching and enhanced learning of the students. Recently, he has developed a virtual lab for manufacturing engineering students.