Journal of Modern Education Review, ISSN 2155-7993, USA
November 2020, Volume 10, No. 11, pp. 973–981
Doi: 10.15341/jmer(2155-7993)/11.10.2020/001
© Academic Star Publishing Company, 2020
http://www.academicstar.us

Team-Based Learning and Project-Based Learning: Innovative Assessment Methodologies Comparison

Cleginaldo Pereira de Carvalho[1], Eduarda Pinto Ferreira[2]

(1. Industrial Engineering Department, Faculty of Engineering of Guaratinguetá, University of the State of São Paulo, Brazil;

2. Instituto de Ensino Superior do Porto, ISEP-P. PORTO, ISRC - Interdisciplinary Studies Research Center, Porto, Portugal)

Abstract: Universities around the world are adopting innovative methodologies in applied science education. The conception takes into account that the students are the center of knowledge acquirement and are becoming a mandatory guide for the engineering courses. One innovation methodology is project-based learning (PBL) in which, the students learn the technical concepts through one multidisciplinary project which they conceive, design, implement, and operate one prototype. On the other hand, there is a methodology that stimulates the students to develop transversal skills through a teamwork conception called team-based learning (TBL). In this paper, a comparison between both methodologies is presented considering the assessment outcomes from each methodology, applied to a group of students from an industrial engineering course. The results obtained from the students' assessment under both methodologies application are treated statistically and the results are compared and discussed. Finally, the conclusion is shown as well as suggestions for further works are presented. The justification for this paper is based on the rare comparison of the performance results between the two innovative learning methodologies.

Key words: project-based learning, team-based learning, engineering education, assessment, innovative learning

1. Introduction

In today's world, there are several ways to describe team learning as collaborative learning, cooperative learning, and team-based learning as an integral part of high-level engineering education. "The universities started implementing methodologies to develop student's teamwork capabilities but asking professors to provide individual marks/grades". Learning in teams is very important for the development of the students, as Lejk, Wyvill, and Farrow *(*1996) and Li (2015) describe as being of high importance to evaluate team learning assessment. However, they lead to some problems (Hansen, 2006). When the teamwork assessment is evaluated, a range of implications takes place, since a team grade is, in some cases, not a fair reflection of an individual's work (Conway et al., 1993). The job of converting an individual's teamwork collaboration into a numeric grade is a difficult task (Johnston & Miles, 2004). It is important that the students feel confident that they will be fairly recognized for their contributions, and it is important to develop a proper functioning learning team that provides high qualified outcomes.

Cleginaldo Pereira de Carvalho, Post Ph.D., Industrial Engineering Department, Faculty of Engineering of Guaratinguetá, University of the State of São Paulo; research areas/interests: learning innovation, lean manufacturing, knowledge management and industry 4.0. E-mail: cleginaldopcarvalho@hotmail.com.

According to Lima et al. (2012), project-based learning (PBL) has been one of the main points of discussion about active learning, as well as the way to select the school's curriculum alternatives for innovative methodologies in engineering education. PBL is one strategy used for teaching and learning in the 21st century, which demands high student's and professor's commitment. It demands that the professors consider the changes in the new activities and develop him into becoming a learning coach rather than a simple educator, and the students, more responsible for their learning.

In this paper, both learning methodologies are presented and evaluated: Team-based learning (TBL) and Project-based learning (PBL). The research took place in a class in the course of industrial engineering. The lecturer was regarded as the manufacturing process and the class was divided into groups compounded in a maximum of six students each. The project was to develop the whole manufacturing process for one specific auto part. Firstly, the TBL was applied with the groups in the project development, which is that in fifteen days the professors conduct a checkpoint meeting. As the outcomes of this stage, a team assessment was conduct. In the second phase, the PBL was adopted as the learning methodology and the final assessment was performed and the outcomes were measured again. A statistical approach was used to compare the outcomes from the two learning methodologies considering the individual performance for each student. The results are presents and commented on. Finally, the conclusion for the research is presented with the recommendations for further works.

2. The PBL and TBL in Engineering Education

To promote the understanding of the two learning methodologies some definitions and considerations are described as following:

2.1 Project-Based Learning (PBL)

The engagement of the students was verified when they were commited to the PBL activities, as well as their transversal skills were improved mainly in terms of problem-solving (Mitchell & Rogers, 2019).

Vesikivi et al. (2019), had conducted experiments to justify the consequences of the application of PBL in the first-year retention and the implication on the pedagogical methods.

PBL is an active teaching method that aims to engage students in acquiring knowledge and skills through real-world and well-planned activities.

One of the first definitions for PBL was given by Adderley et al. (1975). For them, PBL:

> (1) involves the solution of a problem, often, though not necessarily, proposed by the student's; (2) involves the initiative of the student (or group of student's), and it requires a variety of educational activities; (3) usually results in a final product, such as a thesis, a report of a project or a computer program, among others; (4) involves projects, which in most cases are long and take a considerable period to be completed, and (5) leads teachers to engage in a consultant role, rather than an authoritative position, at all stages of a project (initiation, conduct, and conclusion).

Thomas (2016) seeking to answer the question: "What must a project have to be considered an example of PBL?" presents five core criteria for a successful approach:

> (1) Centralization: Projects are an integral part of the curriculum. They are not peripheral. They are part of the basic education strategy since students will learn the core concepts of the discipline through them; (2) Question triggering: Projects must be focused on questions or problems that lead students to find (and even, to face) the central foundations of a given discipline; (3) Constructive Research: The core project activities

> should involve the transformation and construction of knowledge by students; (4) Autonomy: The development project is the students' responsibility, without the typical supervision of traditional teaching and (5) Realism: Projects should be realistic, dealing with concrete, tangible problems. It should not be a mere academic activity. They should have characteristics that allow the student the feeling of authenticity.

According to Powell and Weenk (2003), PBL involves students working in teams to solve concrete problems by using the theory in practice. Furthermore, they must also learn to relate what they are learning to their future profession. Moreover, for them, PBL should place the student as the main actor in the teaching-learning process and relate content from various disciplines on a project.

Helle, Tynjala, and Olkinuora (2006) sought to define and distinguish PBL pedagogical or psychological reasons in this kind of pedagogical approach. For them, the most important feature of PBL is the fact of having direct oriented problems, which serve to conduct learning activities. Furthermore, they have proposed several additional reasons to justify the use of PBL:

> 1) the construction of a concrete artifact forces the student (or group of student's) to develop a series of learning activities during the stages of the construction process; 2) the control of the student in the learning process since it is the student's role to make decisions about the pace of work and its sequence; 3) the contextualization of learning is evident in projects carried out by student's; 4) the potential for the use and creation of various forms of representation since as in professional life most activities require the use of interdisciplinary knowledge and 5) the existence of motivating features for student's.

For Duch, Groh, and Allen (2001), PBL should lead students in search of open problem solving, as well as the acquisition of skills, such as problem-solving ability, oral communication, written communication, and teamwork, among others.

The labor market is demanding extraordinary professional skills and just knowledge is not enough. Thus, teaching through PBL provides many benefits for students, and improves their academic development. These authors emphasize, among others, the following benefits for students: they do not only gain knowledge, but they learn to do a project; they practice their skills and acquire others; they know how to behave in a group; they gain as practical activity, as it approaches those of their profession. Besides, the authors propose that: projects, whenever possible, should involve the university and the communities in surroundings; should evaluate students based on the reality that they will find in the labor market; should increase communication and unity within the classrooms.

Project-based Learning (PBL) has been proved to be one of the effective student-centered strategies in engineering education in many fields (Grant, 2002; Niewoehner, et al. 2011; Gavin, 2011; Neto et al., 2016). However, this concept has more applications in vocational education schools than in engineering universities in China.

Recently, several Conceiving – Designing – Implementing – Operating (CDIO) initiative collaborators in China have adopted their curricular planning to provide students with various levels of projects in the context of CDIO real-world systems and products (Crawley et al., 2014). For the non-CDIO members, the PBL practices are not systematic and only applied in some individual courses.

2.2 Team-Based Learning (TBL)

Team work-based learning was justified as a way to improve communication and problem-solving skills, where the teaching process must use different methods (Rotgans et al., 2019).

With a globalized world, engineer students seek high paid jobs in the corporative world, which demands engineers with abilities in teamwork and teamwork processes. Multinationals strongly evaluate the engineers' teamwork skills (Lewis, Aldrige, & Swamidass, 1998; Nengsheng, Xiaohua, & Yueyun, 2016). In the universities team working is one methodology which stimulates the students to learn collaboratively to achieve results. Team working has been adopted by schools, to develop the students' abilities to solve engineering problems (Borrego et al., 2013), as well as the development of transversal skills (Conway et al., 1993).

In the last twenty years, psychologists have developed conceptual foundations, stages, models, and different approaches to team learning. Several theories explain team learning as motivational theories, social cohesion theories, cognitive theories, and dynamic systems (Li, 2015).

The preparation of the academic staff according to the PBL methodology is not rigorous in terms of training programs regarding learning and teaching teamwork (Palmer & Hall, 2011), usually following the educational psychologist's theoretical literature. Not just the theoretical aspects of team learning are important to define this subject as heterogeneous, confusing, and difficult to comprehend and implement in an engineering program (Zhou, 2012; Tio, 2016).

It is possible to confirm that most engineering academic staff does not have adequate resources available to implement team learning considering theoretical concepts and the methodology of teamwork is, often, included without adequate preparation to unlock the greatest improvements by the students (Powell, 2004).

Team learning subjects, training manuals, guidelines, and tools have been developed by the academic institution, such as Harvard University (Harvard University, 2016) and CDIO (CDIO, 2019; Crawley et al., 2007; Taru & Kontio, 2016), which base their foundations on the theoretical part considering how important teamwork is and how aligned it is with the constructivist theory education.

As a result, engineering academic staff prefers not to include teamwork in their subjects, even if they are asked by the school and academic directors to incorporate it into their subjects. They usually take the fewest obstacle paths and simply ask the students to complete a learning task or a team assessment (Nepal, 2012). They may also include teamwork if they believe it reduces grading workload, especially in large classes. Both practices do not help the adequate development of teamwork knowledge, skills, products, and experience and hinge the core teamwork-based learning outcomes (Gogfrey, Crick, & Huang, 2014).

Simply asking students to complete a task or team assessment is not the same as developing the foundation of teamwork. The team assessments without addressing core teamwork-based learning can generate significantly problematic outcomes (Lebeau et al., 2014). Research illustrates that placing students into teams without preparation, scaffolding or facilitation results in lower academic achievement and poor teamwork skill development and attainment, and can result in unclear goals, mismanagement, conflicts, and inequalities (Maturana et al., 2014).

Teamwork and associated skills and capabilities are neither acquired nor developed without scaffolding and facilitation (Killingsworth & Xue, 2015).

There is the acknowledgment that teamwork has long suffered as a result of inadequate epistemology, and those principles of "good practice" need to be identified and adhered to if effective team learning consequences are to be acquired (Parr, Michael, & Townsend, 2002; Brewer & Mendelson, 2003).

It is important to reinforce that both PBL and TBL are methodologies that integrate CDIO principles as an innovative educational framework that prepare the new generation of engineers, and in the case of this paper with the focus in the outcome-based assessment.

3. Research Question

This research study incites the following questions:

(1) What is the relationship between the innovative assessment methodology and the average of the student's outcomes?

(2) What is the assessment methodology in which the outcomes are the highest?

4. Methodology

4.1 Context

The methodology was introduced in the fifth semester of the Industrial Engineering Course, in the Manufacturing Processes course, in a Faculty located in São Paulo State, Brazil. The students had never taken classes under innovative learning methodology before. The course was taught at night and 76% of the total student's worked during the day. In the phase where the PBL methodology was applied, the groups should first establish the timetable of the project, considering each phase of the project, responsabilities, deadlines, how they should conduct the phase, and possible costs involved. With a frequency of two weeks, a checkpoint meeting was conducted between the teacher and each group. The groups worked in the project conceiving, design, implementation, and operation of the manufacturing process for one autopart. In terms of TBL methodology, the Peer Instruction methodology was adopted what means that the students had received the material of the lectures in advance, and in the class, they worked in a team to solve proposed exercises present by the teacher involved the concepts used in the project phases.

4.2 Participants

The class was composed of 145 students, divided into groups of six people at most.

4.3 Design

During one semester, the same class was submitted to two learning methodologies: TBL and PBL. The outcomes were statistically analyzed.

4.4 Instruments

For the TBL evaluation, one team assessment was conducted using descriptive conception, while the PBL was evaluated through a project and a paper presentation (Cinar & Bilgin, 2011).

4.5 Procedure

To evaluate the TBL outcomes one team assessment was conducted, in the middle of the semester, where the group, with six people maximum, was evaluated being different exam content for the individual student. For TBL evaluation the content of the examination was the theoretical concepts regarded to different manufacturing processes commonly used in the auto parts enterprise. In the PBL case, each group should present, at the end of the semester, a project of the whole manufacturing processes for one entire automobile component, including process flows and quality control plans and a scientific paper about the project.

4.6 Data Analysis

The data obtained from the two evaluations from the two methodologies were treated with descriptive statistical analysis.

5. Results

Two evaluations were performed with the different learning methodologies (PBL and TBL) considering a sample of 145 students. A preliminary statistical analysis for each data sample could be seen in Figures 1 and 2.

In both Figures, the horizontal axis shows the direct grade with a scale of 0.5 points and the vertical axis represents the frequency of each grade in the number of students.

The scale's length is not in the same range of scale to emphasize the difference of the results in terms of the region the grades were concentrated in it and how no Gaussian distribution was each one outcome result.

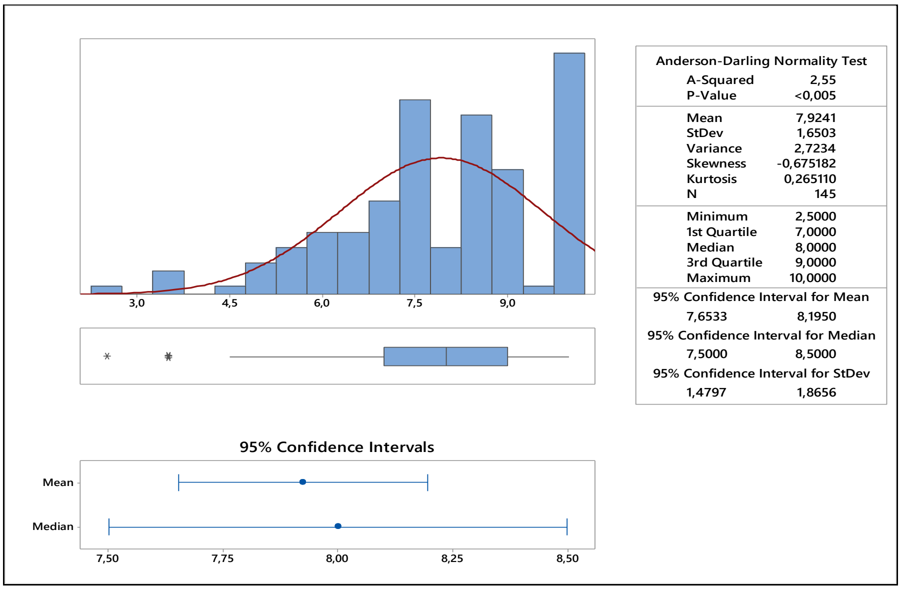

Figure 1 Preliminary Statistical Analysis for PBL Evaluation

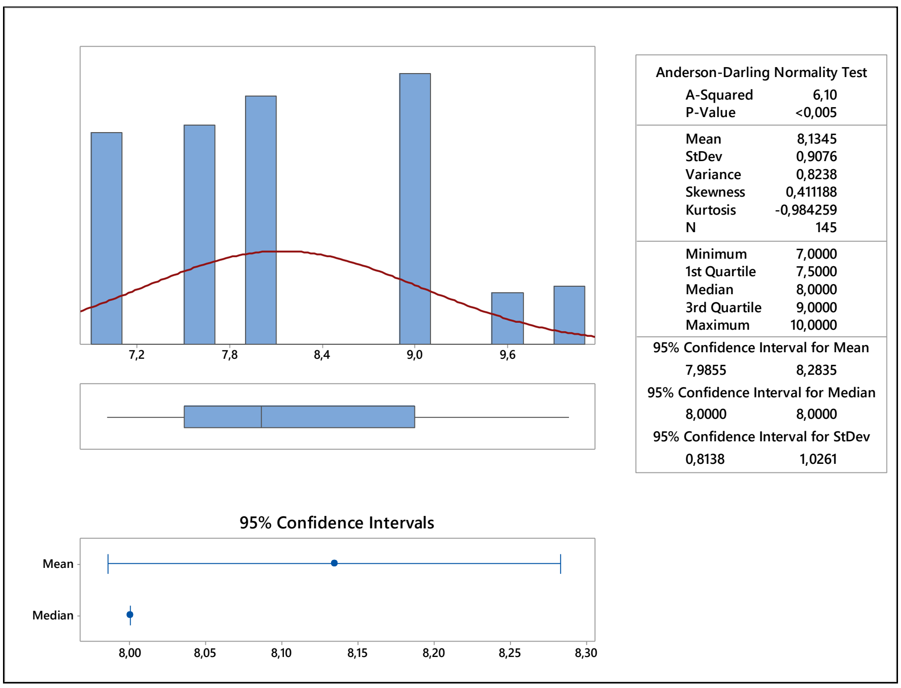

Figure 2 Preliminary Statistical Analysis for TBL

As can be observed in Figures 1 and 2, the data does not follow the Gaussian distribution, a fact that can be justified by the means of the grading system attribution which could not allow one significant variation that forces a non-continuous distribution of the data. It is, also, important to reinforce that the difference of variability between the two assessment methodologies can be justified by the fact that the PBL gives the same grade to one group of students, generating a significant impact on the data variability.

There is no difference between the performances of the students for the two applied methodologies assessment. This result can be considered as evidence that the methodology applied has a small impact on the student's performance compared to other factors, such as the professor's performance, student's commitment, time of the dedication of the student's, etc. As a consequence, it is very important to increase the range of the studies with other students from different universities, other courses, and different disciplines to conclude that the degree of confidence level is higher over the influence of the applied method.

During the development of this work, the researchers had observed that PBL and TBL, as innovative engineering learning, improve the performance of the student's in terms of learning absorption. It was observed that the commitment of the students was higher than the traditional learning methodology.

It is mandatory that this study collects more data and makes the conclusion more robust, including the identification with more precision, which includes other factors already mentioned in this paper, which can have an equal or larger impact than the innovative learning methodologies applied.

6. Conclusion

This research work aimed to present the innovative learning methodologies TBL and PBL and based on the results discussed above, it reached its goal. The work also answered the research questions as discussed.

In the student's population, where the research was performed, the impact caused by the application of active learning methodology is equivalent to the PBL as to the TBL. Then it confirms that the work also answered the research questions as discussed in the presentation of the result.

More data is necessary to make the research more robust, but the main conclusion is that the student is the main agent of the knowledge acquiring and it does not depend on the time the student dedicates his time to study since the majority of them work during the day.

One important point of this research regards the statistical analysis, which had been applied to evaluate the variation of the final results between the two learning methodologies. It permitted one more accurate evaluation of the results and supports the conclusion of this work.

References

Adderley K. et al. (1975). *Project Methods in Higher Education*, SRHE working party on teaching methods: Techniques group. Guildford, Surrey: Society for research into higher education.

Borrego M., Karlin J., McNair L. D. and Beddoes K. (2013). "Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review", *Journal of Engineering Education (JEE)*, Vol. 102, No. 4, pp. 472–512.

Brewer W. and Mendelson M. I. (2003). "Methodology and metrics for assessing team effectiveness", *International Journal of Engineering Education*, Vol. 19, No. 6, pp. 777–787.

Cinar Y. and Bilgin A. (2011). "Peer assessment for undergraduate teamwork projects in petroleum engineering", *International Journal of Engineering Education*, Vol. 27, No. 2, pp. 310–322.

Conway R., Kember D., Sivan A. and Wu M. (1993). "Peer assessment of an individual's contribution to a group project", *Assessment & Evaluation in Higher Education*, Vol. 18, No. 1, pp. 45–56.

CDIO (2019). "The CDIO Standards V.2.0", accessed on 12 August 2019, available online at: http://www.cdio.org.

CDIO (2019). "CDIO Syllabus 2.0, Interpersonal skills: Teamwork and communication", accessed on 12 August 2019, available online at: http://www.cdio.org/benefits-cdio/cdio-syllabus/cdio-syllabus-topical-form.

Crawley E. F., Malmqvist J., Oestlund S. and Brodeur D. R. (2007). *Rethinking Engineering Education: The CDIO Approach*, New York: Springer.

Crawley E. F., Malmqvist J., Oestlund S., Brodeur D. R. and Edström K. (2014). *Rethinking Engineering Education: The CDIO Approach*, Cham: Springer International Publishing: Cham, pp. 5–18.

Duch B. J., Groh S. E. and Allen D. E. (2001). "Why problem-based learning? A case study of institutional change in undergraduate education", in: Duch B. J., Groh S. E. & Allen D. E., *The Power of Problem-Based Learning*, Virginia: Stylus.

Gavin K. (2011). "Case study of a project-based learning course in civil engineering design", *European Journal of Engineering Education*, Vol. 36, No. 6, pp. 547–558.

Gogfrey P., Crick R. D. and Huang S. (2014). "Systems thinking, systems design, and learning power in engineering education", *Journal of Engineering Education*, Vol. 30, No. 1, pp. 112–127.

Grant M. M. (2002). "Getting a grip on project-based learning Theory, cases, and recommendations", *Meridian: A Middle School Computer Technologies Journal*, a service of NC State University, Raleigh, p. 5.

Hansen R. S. (2006). "Benefits and problems with student teams: Suggestions for improving team projects", *Journal of Education for Business*, Vol. 82, No. 1, pp. 11–19.

Harvard University (2016). "Group learning", accessed on 15 November 2016, available online at: http://www.gse.harvard.edu/course/fall-2015/t402-group-learning-fall-2015.

Helle L., Tynjala P. and Olkinuora E. (2006). "Project-based learning in post-secondary education — Theory, practice, and rubber slingshots", *Higher Education*, Vol. 51, No. 2, pp. 287–314.

Johnston L. and Miles L. (2004). "Assessing contributions to group assignments", *Assessment & Evaluation in Higher Education*, Vol. 29, pp. 751–768.

Killingsworth B. L. and Xue Y. (2015). "Investigating factors influencing student's learning in a team-teaching setting", *International Journal of Cognitive Research in Science, Engineering, and Education*, Vol. 3, No. 2.

Lebeau J., Trevisan M., McCormack J., Beyerlein S., Davis D., Leiffer P., Thompson P., Davis H., Howe S., Brackin P., Gerlick R. and Khan M. J. (2014). "Alumni perspective on professional skills gained through integrated assessment and learning", *Journal of Engineering Education*, Vol. 30, No. 1, pp. 48–59.

Lejk M., Wyvill M. and Farrow S. (1996). "A survey of methods of deriving individual grades from group assessments", *Assessment & Evaluation in Higher Education*, Vol. 21, No. 3, pp. 267–280.

Lewis P., Aldrige D. and Swamidass P. M. (1988). "Assessing teaming skills acquisition on undergraduate project teams", *Journal of Engineering Education*, Vol. 87, No. 2, pp. 149–155.

Li L. (2015). "Project-based learning in electronic technology: A case study", *European Journal of Engineering Education*, Vol. 40, No. 5, pp. 499–505.

Lima R. M., Silva J. M., Janssen N., Monteiro S. B. S. and Souza J. C. F. (2012). "Project-based learning course design: A service design approach", *International Journal of Services and Operations Management*, Vol. 11, No. 3, pp. 293-313.

Maturana J., Gonzalo A., Serandour G. and Luco R. (2014). "Developing teamwork skills in first and second year engineering students", *Journal of Engineering Education*, Vol. 30, No. 5, pp. 1225–1233.

Mitchell J. E. and Rogers L. (2019). "Staff perceptions of implementing project-based learning in engineering education", *European Journal of Engineering Education*, Vol. 45, No. 3, pp. 349–362, doi: https://doi.org/10.1080/03043797.2019.1641471.

Nengsheng B., Xiaohua L. and Yueyun C. (2016). "Assessment and analysis of engineering practical abilities learning outcomes of undergraduates through university — Enterprise cooperation", in: *Proceedings of the 12th International CDIO Conference*, Turku University of Applied Sciences, Turku, Finland, June 12–16, pp. 48–62.

Nepal K. (2012). "A comparative evaluation of analytical methods to allocate individual marks from a team mark", *European Journal of Engineering Education*, Vol. 37, No. 4, pp. 397–404.

Neto O. M., Lima R. M., Mesquita D., Ciciliano M. M. and Losovoi G. (2016). "The perceptions of faculty engaged in a curricular change to project-based learning in an engineering school in Brazil", in: *Proceedings of 8th International Symposium on Project Approaches in Engineering Education*, Guimarães, Portugal, July 06-08, pp. 221–228.

Niewoehner R., Crawley E., Koster J. and Simpson T. (2011). "A learning science foundation for project-based learning in engineering", in: *Proceedings of the 7th International CDIO Conference*, Copenhagen, Denmark, June, pp. 20–23.

Palmer S. and Hall W. (2011). "An evaluation of a project-based learning initiative in engineering education", *European Journal of Engineering Education*, Vol. 36, No. 4, pp. 357–365.

Parr J. M., Michael A. R. and Townsend M. A. R. (2002). "Environments, processes, and mechanisms in peer learning", *International Journal of Educational Research*, Vol. 37, pp. 403–423.

Powell P. C. and Weenk W. (2003). *Project-led Engineering Education*, Utrecht: Lemma Publishers.

Powell P. C. (2004). "Assessment of team-based projects in project-led education", *European Journal of Engineering Education*, Vol. 29, No. 2, pp. 221–230.

Rotgans J. I., Rajalingam P., Ferenczi M. A. and Low-Beer N. (2019). "A students' model of team-based learning", *Health Professions Education*, Vol. 5, No. 4, pp. 294–302, doi: https://doi.org/10.1016/j.hpe.2018.10.003.

Taru P. and Kontio J. (2016). "Integrating innovation pedagogy and the CDIO approach — Towards better engineering education", in: *Proceedings of the 12th International CDIO Conference,* Turku University of Applied Sciences, Turku, Finland, June 12-16, pp. 949–961.

Tio F. (2016). "Industry — Inspired experimental learning and assessment of teamwork", in: *Proceedings of the 12th International CDIO Conference*, Turku University of Applied Sciences, Turku, Finland, June 12–16, pp. 469–478.

Thomas J. W. (2016). "A review of research on project-based learning", accessed on 8 November 2016, available online at: http://www.bie.org/images/uploads/general/9d06758fd346969cb63653d00dca55c0.pdf.

Vesikivi P., Lakkala M., Holvikivi J. and Muukkonen H. (2019). "The impact of project-based learning curriculum on first-year retention, study, experience, and knowledge work competence", *Research Papers in Education*, doi: https://doi.org/10.1080/02671522.2019.1677755.

Zhou C. (2012). "Integrating creativity training into problem and project-based learning curriculum in engineering education", *European Journal of Engineering Education,* Vol. 37, No. 5, pp. 488–499.