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## Changes in teaching and learning practice in an undergraduate logistics and transportation course using problem-based learning

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## Changes in teaching and learning practice in an undergraduate logistics and transportation course using problem-based learning

### Abstract

This research paper presents the outcomes of a change in the teaching and learning practices from a traditional lecture-based method to a Problem Based Learning (PBL) curriculum in the undergraduate Logistics & Transportation (L&T) course at the Federal University of Itajubá (UNIFEI), Brazil. Detailed PBL practices adoption and the perception by the students of the PBL process are explored in survey research using a mixed-methods approach. The data was collected in two subsequent semesters of the L&T course, with different PBL scenarios and students, gathering quantitative and qualitative data. It was demonstrated that aligned with the theory on PBL, the majority of the students, over 91%, appreciated the benefits of the PBL-based practices in all course dimensions, with a strong perception of L&T teaching and learning improvements. Researchers and faculty involved in university teaching and learning can use PBL detailed practices, including problem scenarios and theoretical framework to design their own PBL classes to improve student learning and can also use the questionnaire structure and statistical tests for adoption in future implementations. The study is one of the few to provide a change in teaching and learning practices, associated with a valid and reliable two-stage survey covering the course concepts and learning objectives modelled by Factor Analysis, and, going beyond to provide PBL process impact and adaptations due to COVID-19 pandemic.

### Keywords

Teaching & Learning Practices, Problem-Based Learning, Survey, curriculum change, Logistics & Transportation, University Education, Engineering.

According to Tynjälä (1999), Problem-Based Learning (PBL), as it is known worldwide, is a teaching-learning method characterised by the application of real-life problems. PBL instigates problem-solving skills and the acquisition of fundamental concepts in the area of knowledge in question, in addition to the development of critical thinking. Along with other educational techniques based on constructivism, PBL seeks to respond to various dilemmas inserted in contemporary professional education, such as the gradual increase in the volume of scientific and technological information that must be transmitted to students during undergraduate or graduate courses and their rapid obsolescence brought about by the same evolution. Survey research method can address student's perception of traditional lectures compared to the problem-based approach (Tick, 2007). Other approaches from literature aimed to catch the level of difficulties and challenges that students perceive when using PBL, like issues in the team communication, lack of formal instructions, development of a strategy for project completion, and searching for necessary information, including knowledge from other courses (Koromyslova & Garry, 2016).

Seman et al. (2018) collected the perceptions of undergraduate Electrical Engineering students regarding the knowledge formation process in a PBL implementation. Among other conclusions, the authors pointed out that PBL was considered very bureaucratic. It could be improved by several actions by the instructors, especially adding more simplification of the whole process, promotion of more student involvement, clear upfront explanations of the process practices, and more awareness of the group. Silva Filho and Calado (2013) discussed the use of PBL for student learning in an undergraduate Supply Chain Management course using the Lean Manufacturing A3 process. The A3 process is a simple way of getting problem analysis and a corrective action plan written down on a single sheet of large paper, often with the use of graphics. Many manufacturers use it as a powerful lean management tool. The results showed that PBL encouraged students to develop professional skills and attitudes. Besides that, the study conclusively showed that the PBL approach was very close to PDCA (Plan, Do, Check, Act) cycle, giving the similarity with the steps for solving problems. Rodrigues Da Silva et al. (2012) collected students' feedback in an undergraduate Civil Engineering course and the results indicated very positive perceptions, with over ninety percent finding the learning process "Good" or "Very good".

Even with the extra efforts, the PBL theory and practices indicated several cases where the students appreciated the teaching and learning practices' approach as the methodology. Nevertheless, the evaluation of PBL practices in the university context, targeting the Industrial Engineering Education and L&T field, grounded in adequate statistical analysis, are not widely deployed in the literature. This opportunity motivated the authors to pursue a relevant literature contribution that would add to the existing knowledge in teaching and learning practices at the university level, by exploring the students' perception of a change from lecture-based to PBL-based practices. The results aim to help other researchers, faculty, and institutions set up new PBL implementations in their courses. To achieve this goal, the authors proposed and implemented a set of PBL teaching and learning practices, then designed surveys in two subsequent semesters that addressed and confirmed the student's perception of these practices. The survey focused on the main concepts and learning objectives of the course.

Objectively, this research aimed to respond to the following Research Questions (RQs): 1) What are the PBL-based teaching and learning practices that can be implemented in an undergraduate L&T course? 2) Can a positive students' perception of the PBL-based teaching and learning practices be demonstrated statistically, using surveys that adequately cover the learning objectives and expected

outcomes with different sets of PBL scenarios and students? 3) What is the student's perception of learning improvements at the end of the course and in what aspects of PBL?

The paper is organized as follows: Next to this Section 1 - Introduction, Section 2 provides the Literature Review focusing on the PBL applications to the Logistics & Transportation branch of knowledge. Then, Section 3 brings the Research Methodology, followed by Section 4 with the Results, Section 5 with the Discussion, and Section 6 with the Conclusions and Recommendations.

## **Literature review**

PBL theory is not new. According to Boud and Feletti (1997), PBL had its origin and evolved from innovative health sciences curricula introduced in North America around 1970. Savery (2006) defined PBL as a learner-centred approach that gives learners more control over the research they are conducting to develop a viable solution to a defined problem. PBL can integrate theory, practice, knowledge, and skills, allowing the students to find a viable solution to a problem situation. Hmelo-silver (2004) described PBL as a method based on students that learn through the resolution of complex problems that do not have a single correct answer. Other features of PBL are also well aligned with the course demands, such as a) the students look for opportunities to acquire knowledge by organizing their time; b) the students are encouraged to discuss their difficulties with others when needed, and c) the instructor ceases to be the transmitter of knowledge and starts to guide and motivate the students to discover knowledge as a leading actor (Guimaraes et al., 2016).

Recent studies in Operations used PBL as a learning tool and addressed Architecture and Urban Logistics, where the subject for the course was the creation of residential development in the municipality of a city. The stakeholders were the authorities from the Urban Development Department of the mentioned municipality and Real Estate Developers that owned the site (Aparicio et al., 2020). The interdisciplinarity approach of PBL was presented as a challenge that attempted to anchor the pedagogical development within theoretical frames of reference that contextualize the interdisciplinary PBL simulation (Wood, 2020). The impact of PBL in a professional learning program for teachers by using both qualitative and quantitative analyses identified a significant change in their beliefs, from teacher-centred domination at the program's start to more learner-centred beliefs by the end. The participants reported a significant increase in using classroom interactions and formative assessment, yet keeping content delivery (Du et al., 2020). Technology has also played a role in recent PBL approaches. Social network analysis (SNA) was used to study online collaborative learning in PBL. Online interaction data were collected and processed following a standard data mining technique and the relevant parameters to knowledge sharing and construction were calculated on the individual and the group (Saqr et al., 2018). Technology has played a special role for remote learning in the current COVID-19 pandemic context.

Barrows (1986) and Norman and Schmidt (1992) concluded that PBL promotes several learning objectives, helping students to construct an extensive and flexible knowledge base, develop effective problem-solving skills, become effective collaborators and develop self-directed learning skills. In this study the PBL typical process cycle was followed (Hmelo-silver, 2004):

- Identification of the problem scenario.
- Defining the problem by analysing the facts arising from the scene.
- Formulation of hypotheses about possible solutions with existing knowledge.
- Identify new learning needs.
- Research achievement in search of new knowledge, self-directed.

- Application of new knowledge-generating new hypotheses and selecting the best solution.
- Evaluation, abstraction, and reflection on the learning process.

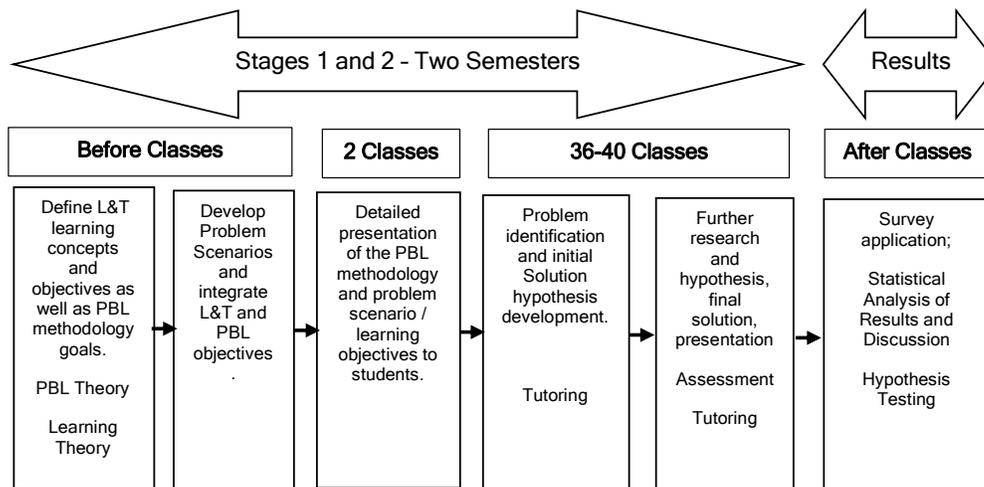
In PBL projects, instructors are mentors of students, becoming active participants in the teaching and education process (Fruchter, 1999). As an active learning methodology, PBL is relatively well-deployed with many Science, Technology, Engineering, and Mathematics (STEM) disciplines, in general (Zolin et al., 2003) but in some contexts, traditional lectures are better approaches, as concluded by Garnjost and Brown (2018) in their study for undergraduate business courses. In Brazilian universities, L&T has been taught in different forms since the establishment of the Industrial Engineering major a few decades ago. In this field, Prado da Silva et. al (2015) implemented a combination of PBL and blended-learning (B-learning) in a Transportation course for Civil Engineering, where they analysed the students' grades in course activities. Questionnaires and cognitive maps assessed the effects of PBL. As a result, a gradual increase in the average scores obtained by the students in the project activities (from 6.77 to 8.24) was concomitant with a better evaluation of the course as a whole (90% and 97% for options “good” and “very good”, respectively). Gragas and Ramalinho (2016) presented a PBL project mixed with a decision support system (DSS) to teach Vehicle Routing. Students had to solve a typical vehicle routing case from the very beginning, challenging them to face a rather complicated problem. The authors concluded that PBL acceptance was very positive according to the student feedback survey conducted after the activity. The summarized results showed that over ninety-five percent of students responded that PBL activities stimulated teamwork and over ninety-three percent responded that PBL workload was well balanced among team members. Koromyslova and Garry (2016) presented the outcomes of teaching the Supply Chain Management course in two semesters, comparing the semester's results by the average class grade. They concluded that the PBL environment was better for student scores and learning outcomes. Using survey to gather student's perception of PBL implementation in Operations Management courses, Alvarstein and Johannesen (2001) reported that the students found the teaching method interesting and a contributor to greater knowledge, although it was too time-consuming. Gudmundsson and Nijhuis (2001) mixed the use of PBL with the 3-Way Interact Method (3WIM), which was applied to L&T. The results indicated that most of the students appreciated 3WIM and PBL as a first choice in courses that offered this option. Cardoso and Lima (2012) focused on a single-stage survey to collect PBL outcomes in L&T and inspired the construction of the problem scenarios as part of the first stage of this research. Other studies reported the effective use of PBL with tools like Lean Manufacturing and Games, reporting positive benefits in all cases (Kanet & Stöblein, 2008; Silva Filho & Calado, 2013; Tortorella & Cauchick-Miguel, 2017).

## Theoretical Framework

The L&T course in traditional lecture-based methodology covered several aspects of the logistics field such as L&T fundamental activities, Supply Chain, Service Level, Warehouse & Transportation, Costs and Relationship management as Vehicles Routing and Information Technology applications (Ballou, 1997). To apply PBL and change the teaching and learning practices, the required content was integrated into the problem scenarios to fulfil the learning objectives, aligned with other aspects of PBL methodology. The theoretical framework shown in Figure 1 guided the PBL-based practices' change in L&T and created a reference, together with the problem scenarios, for future research and applications by faculty and institutions where PBL is desired for L&T and similar courses:

**Figure 1**

*PBL Teaching and learning change practices: Theoretical framework*



## Method

The PBL process cycle, as presented by Hmelo-silver (2004) and implemented through the theoretical framework involved a systematic methodological approach, which demanded negotiation and commitment from the students, authors, and support personnel. Based on the learning objectives of the L&T, the research team, formed by the authors and eight graduate students who worked as support personnel for the undergraduate students in the previous semesters, developed 2 training sessions on the PBL methodology. The students knew beforehand about the challenges of the PBL process and that the results of the surveys to be applied would be used for research purposes and provided their agreement and commitment. To help protect their anonymity and follow the university ethics guidelines, the surveys (quantitative and qualitative methods) were anonymous and were applied using Google forms. The following 36 classes were enriched by continuous group discussions, L&T material, web research, and tutoring service by the authors and support team. The problem approach was designed to allow multiple possible solutions and motivated the students on self-learning. The surveys were applied at the end of the semesters.

### **Survey design and data collection approach**

Survey method can follow a unique strand as quantitative or qualitative approach. The data collection in this research followed a mixed methods approach. But instead of an isolated quantitative and qualitative strand, the authors approached a connection between these two main strands. For the quantitative approach, the questionnaire was designed based on a Likert scale from 1 to 5 (Likert, 1932). By using exploratory factor analysis, the main constructs were derived. Aligned

with this approach, the responses from students from the open question in the qualitative approach were categorized based on the defined constructs. This approach followed an exploratory design, as seen in Creswell and Clark (2018), where the mixed-method designs were presented in four major types: Triangulation Design, the Embedded Design, the Explanatory Design, and the Exploratory Design. The link between the two main strands, quantitative and qualitative is discussed in Creswell John W (2009). Besides that, this research targeted educational data and used modelling and other inference statistics for the survey's development, such as exploratory factor analysis and can be further categorized as a Level IV type, based on the multilevel classification suggested by Teddlie and Tashakkori (2009). In the area of Operations Management, which includes the L&T branch of knowledge, the authors adapted the framework proposed by Forza (2002) in eight steps, to conduct the study.

### *1. Develop the original questionnaire and scale*

The step 1 of the framework took place during the initial development of the surveys for both stages. The authors used a Google web-based tool that preserved respondents' anonymity so that it diminished potential bias in the results. The answers were individual; only the date and time stamp were registered. The questions were sent to all students participating in the course and the answers were voluntary. The development of the questionnaires in this research played a critical role: from one hand it had to be as complete as possible to consistently catch feedback for all of the L&T course and PBL dimensions under evaluation and on the other hand, it had to be as simple and easy to fulfil as possible to maintain acceptable levels of completeness and promote enrolment (Koromyslova & Garry, 2016; Tick, 2007). For this reason, the questionnaire was developed through a collaboration among the authors, who are also professors of L&T courses, and eight graduate students who worked with two groups of undergraduate students in the previous 2 semesters. Concerning the quantitative approach, care was taken to avoid double questions with minimal overlap. Besides that, existing constructs and questions associated with PBL implementation were used as a source of information so that the questionnaires could be validated accordingly. The questionnaire was submitted to statistical analysis to check for data reliability and validity, including PBL evaluation dimensions from literature (Kanet & Barut, 2003).

### *2. Conduct the first stage survey (pilot test)*

At step 2 of the framework, the first stage was planned and implemented in spring 2015. During the development, the original questionnaire started with 21 structured questions, available as supplemental material from the authors.

### *3. Check for reliability and validity of the questionnaire*

Complying with step 3 of the framework the questionnaire was validated by statistical tests such as a) Principal Component Analysis; b) Maximum likelihood; c) Varimax rotation; d) Constructs identification. As a result, the authors concluded that, based on the variance contribution of each resulting factor, seventy percent of the total variability was explained by the 8 selected factors and 15 questions. As per Hair et al. (2012), a minimum of sixty percent of explained variability is acceptable for exploratory research and the authors followed this criterion.

As a second step in the correlation analysis, the maximum likelihood method showed how each factor influenced each variable, by examining the loading patterns. On exploratory factor analysis, an acceptable value of loading that reflects a strong correlation is above 0.70 (Yong & Pearce, 2013),

which was the criteria used by the authors. Additionally, to make it easier for interpretation a Varimax rotation was performed, for clear assessment, because each original variable tended to be associated with a small number of factors (Kaiser & Breslin, 1958), as shown in Table 1. Minitab® software was used to make the calculations.

**Table 1**

*Rotated Maximum Likelihood Components Analysis*

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Communality
Q1	0.767								0.684
Q2	0.738								0.660
Q3	0.481								0.501
Q4	0.635								0.538
Q5		0.819							0.793
Q6		0.640							0.616
Q7				0.898					1.000
Q8				0.614					0.731
Q9						0.806			1.000
Q10							0.744		1.000
Q11								0.838	1.000
Q12					0.748				0.657
Q13					0.807				0.833
Q14			0.915						0.902
Q15			0.813						0.708
<b>Variance</b>	3.514	2.337	1.878	1.848	1.665	1.198	1.182	1.108	14.733
<b>%Variance</b>	0.167	0.111	0.089	0.088	0.079	0.057	0.056	0.053	0.702

*Combining eight factors into three theoretical constructs*

Even though the exploratory factor analysis allowed the verification of the correlations and factor loadings for the questionnaire optimisation during pilot test, a critical analysis and synthesis process was implemented by the authors to derive the theoretical constructs that built the structure of the survey questionnaire.

From Table 1, it is noticeable that the eight factors from the exploratory factor analysis were loaded by the 15 variables in a spread fashion, except for Factor1, which combined Q1, Q2, Q3 and Q4, all of them designed to operationalize one of the underlying theoretical constructs proposed for the questionnaire: Process Skills. These questions were designed for responses related to self-learning, initiative, knowledge, critical thinking and problem analysis, targeting higher cognitive levels of Bloom's taxonomy (Bloom, 1956). The Factor2, Factor4 and Factor6 are loaded by Q5, Q6, Q7, Q8 and Q9. Although these variables loaded in different factors, they were designed to inform the perception about the procedures of the PBL process, such as the structure of problem-solving, tutoring roles, work as a team, open and independent learning process. The underlying theoretical construct proposed for these questions was: PBL Discipline.

The Factor3, Factor5, Factor7 and Factor8 are loaded by Q10, Q11, Q12, Q13, Q14 and Q15. Similar to previous discussion, these variables also loaded in different factors. But they were designed to inform the perception about the specific content learning objectives of the L&T course, such as the concepts of supply chain, service level, distribution, transportation and so on. The underlying theoretical construct proposed for these questions was: Technical Skills. The factor structure remained valid and was not changed or reduced, just combined (Hayton et al., 2004). In summary, for the sake of parsimony, three underlying constructs were derived:

**Construct 1.** Built with variables Q1 to Q4 and Factor 1, named 'Process Skills', that address teamwork, critical thinking, and other group work and problem-solving skills.

**Construct 2.** Built with variables Q5 to Q9 and Factors 2, 4, and 6, named 'PBL Discipline' that address systematic work, meetings, and task orientation, as well as the methodological process for problem-solving.

**Construct 3.** Built with variables Q10 to Q15 and Factors 3, 5, 7, and 8, named 'Technical Skills' that address L&T concepts, Supply Chain, Marketing, and L&T management.

A critical analysis by the authors concluded that Q3 should remain in the questionnaire, even with loading factor lower than 0.70, because the variable brought relevant data on PBL self-learning and Cronbach's alpha changed from 0.5 to 0.7 for the Construct 1. The result was a set of 15 selected questions and constructs, as shown in Table 2.

**Table 2**

*Questionnaire design*

Construct	Question
1. Process Skills	Q1: To what extent have you acquired the skills to solve Logistics and Transportation (L&T) problems?
	Q2: To what extent have you acquired the ability to think analytically?

Construct	Question
2. PBL Discipline	Q3: To what extent have you learned how and where to find the relevant knowledge for a given problem in Logistics and Transportation?
	Q4: To what extent have you learned how to define problems from a set of facts and circumstances?
	Q5: To what extent has your team used the structure of problem-solving (ideas, facts, learning, issues, action plan)?
	Q6: To what extent the tutor/teacher has guided you through the PBL process?
	Q7: To what extent all students (not only your team) have involved themselves in the PBL process?
	Q8: To what extent the members of your team have involved themselves in the PBL process?
	Q9: To what extent have you become an independent learner?
	Q10: To what extent have you acquired specific knowledge of the concept of SCM?
	Q11: To what extent have you acquired specific knowledge of the concept of Logistics Service Level?
3. Technical Skills	Q12: To what extent have you acquired specific knowledge of the concept of distribution channels?
	Q13: To what extent have you acquired knowledge to differentiate Distribution Channels and Physical Distribution?
	Q14: To what extent have you acquired specific knowledge of the concepts of Modal, Intermodal, and Multimodality?
	Q15: To what extent have you acquired the ability to select a different Modal?

Likert scales were used (Likert, 1932) to address the L&T concepts, where the options were defined as very little (1), little (2), moderate (3), great (4), and full (5). The authors introduced the first problem scenario to students, as part of new teaching and learning practices:

An entrepreneur would like to invest in the region and believes that the business plan already prepared for it will provide a good return in a few years. He is confident because of the projection of market data for years to come. This is a bicycle assembly company and initially, the models are defined as MTB (Mountain Bike) for use in diverse terrain. These bikes will initially be sold in the domestic market for some regions of the country, with an expected volume of about 100,000 units in the first year, with a potential of 300,000 in the following years. In the first year, absolutely all components are purchased, there is no manufacture of parts. The entrepreneur has sufficient knowledge of the production process and the potential market. However, he has no experience concerning the "logistics process of the company" and would like to enlist the help of a consulting firm to direct it better. This consultancy will be responsible for developing the entire supply chain management project of this new company. As a customer, the business owner wants some questions answered, such as (some): How to build the organization of the company? What equipment and technologies will be needed? What are the risks involved? What problems he can expect during the operation of the business? What performance indicators should be used for evaluation? But he expects topics not identified by him are also covered, as is a consulting company "with experience in the business." He knows he will have difficulties with these processes, as the variety of components is great. These components are divided into 12 families (related to each type of bike) and at least 31 different categories (the components of each family). Each category has a large number of options related to costs, models, and manufacturers, making the list of possible items to purchase extremely long. The bikes will be mounted to meet those considered "entry" markets and "intermediate" (prices ranging from R\$ 900.00 to R\$ 5,000.00), as the product of the "high-end market" is strongly associated with international brands, making the list of possible product items

extremely long. Then, consulting firms formed by eight students had to present possible solutions to the problem situation, covering subjects like component manufacturing identification, customer location, purchasing needs, logistics modals and cost, lead time, and paperwork involved in the process (taxes, fees, etc.).

4. *Process and analyse the survey mixed data statistically (PBL outcomes, student responses, enrolment)*

The quantitative data was collected and processed in step 4 and the qualitative approach addressed one simple open question: What have you appreciated in the PBL curriculum that truly improved your learning in L&T management? Use examples, as much as possible, of your experience in the PBL Process.

5. *Conduct the second stage survey*

The second stage was developed in spring 2016, according to step 5 of the framework.

6. *Check for reliability and validity of the questionnaire*

During the implementation, the second stage questionnaire has passed statistical tests for validity and reliability, according to step 6 of the framework.

In the second stage, the problem scenario was:

An entrepreneur would like to invest in the region and believes that the outlined business plan for it will provide a good return in a few years. He is confident because of the projection of market data for years to come. It is a company for sales in the "beverage retail", initially focused on so-called "special" beers (handmade? craft beers?). The businessman is still not sure in which retail branches he will act, but have decided it will operate in the local retail store with a physical location and in Brazil via the online store. It has also been decided not to work with manufacturing, just sales, choosing "only" the special ones because of trust that success in this market is obtained with a good network and vendor management and offering good options and a good level of service to its customers. This entrepreneur has sufficient knowledge of the bureaucratic process to open the company. However, he has no experience in what he refers to as the "logistics process of the company" and would like to enlist the help of a consulting firm to direct it better. This consultancy will be responsible for developing the entire supply chain management project of this new company. As a customer, the business owner wants some questions answered, such as (some): How to build the organization of the company? Selecting suppliers? Which customers to focus on? How to distribute the products? What are the risks involved? What problems he can expect during the operation of the business? What performance indicators should be used for evaluation? How to work the aspect of sustainability in business? But he hopes, especially which topics not identified by him are also covered by the consulting company, "with experience in the business." He knows he will have difficulties with these processes, as the variety of domestic and imported labels is great. The main setting is the wide variety of brands to offer (at least 500 labels, national and imported beers), to a very diverse audience (labels of R\$ 7.00 to R\$ 200.00). The businessman has also analysed the franchise options available in the market and none of

them alone meets what he wants (although it can learn from the positive experiences observed in this mode).

The consulting firms' approach was the same as during the first stage.

*7. Process and analyse the survey mixed data statistically (PBL outcomes, student responses enrolment)*

The quantitative data was collected and processed in step 7 and the qualitative approach addressed the same one simple open question: *What have you appreciated in the PBL curriculum that truly improved your learning in L&T management? Use examples, as much as possible, of your experience in the PBL Process.*

The new practices that took place in spring 2015 and 2016 continued until spring 2019, but were strongly impacted in 1S2020 due to the COVID-19 pandemic. A reflection on implications for teaching practices as well as the PBL implementation difficulties and challenges in this new scenario are provided in the Discussion section.

## **Results**

### ***PBL outcomes from first and second stage surveys – quantitative approach***

This section responds to the step 8 of the survey framework (8- Organize the results and develop grounded discussion; generate conclusions) and included the summarized results, discussion, and conclusions (Forza, 2002) for both stages.

During the first stage, 51 students out of 57 in the class enrolled in the subject (90% enrolment) and provided 51 valid answers. The second stage had 45 students out of 47 in the class enrolled in the subject (95% enrolment) and provided 45 valid answers. The overall results of PBL outcomes are shown in Table 3. Score means and standard deviations are shown for both stages.

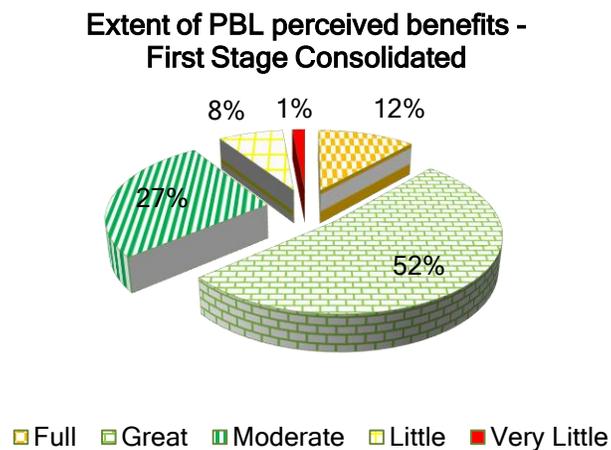
**Table 3***First and second stage questionnaires scores mean, standard deviation and alpha values*

Construct	Question	First Stage $\bar{X}(SD)$	Second Stage $\bar{X}(SD)$
1. Process Skills	Q1:	3.529 (0.644)	3.467 (0.661)
	Q2:	3.804 (0.722)	3.822 (0.684)
	Q3:	3.529 (0.784)	3.822 (0.583)
	Q4:	3.725 (0.723)	3.578 (0.638)
2. PBL Discipline	Q5:	3.647 (0.770)	3.578 (0.727)
	Q6:	3.804 (0.917)	3.844 (0.690)
	Q7:	3.137 (0.980)	3.844 (0.783)
	Q8:	3.314 (1.010)	3.711 (1.014)
	Q9:	3.569 (0.878)	3.711 (0.674)
3. Technical Skills	Q10:	3.765 (0.619)	3.578 (0.661)
	Q11:	3.627 (0.747)	3.578 (0.704)
	Q12:	3.863 (0.633)	3.422 (0.638)
	Q13:	4.020 (0.787)	3.422 (0.638)
	Q14:	4.039 (0.799)	3.489 (0.661)
	<b>Q15:</b>	<b>3.804 (0.825)</b>	<b>3.489 (0.802)</b>

**Error! Not a valid bookmark self-reference.** and Figure 3 show the consolidated results of Table 3.

**Figure 2**

*Consolidated PBL outcomes during the first stage (from Table 2)*



**Figure 3**

*Consolidated PBL outcomes during the second stage (from Table 3)*

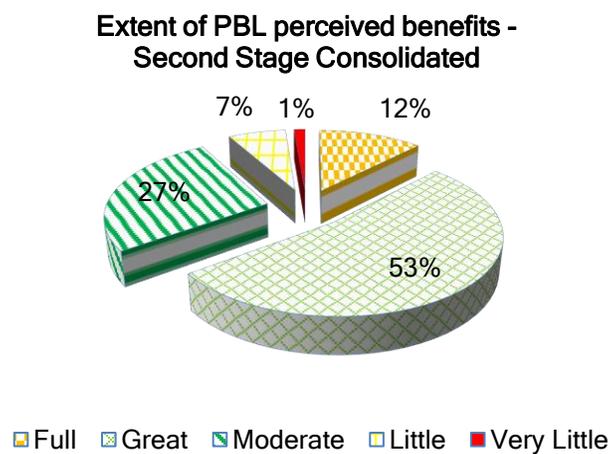
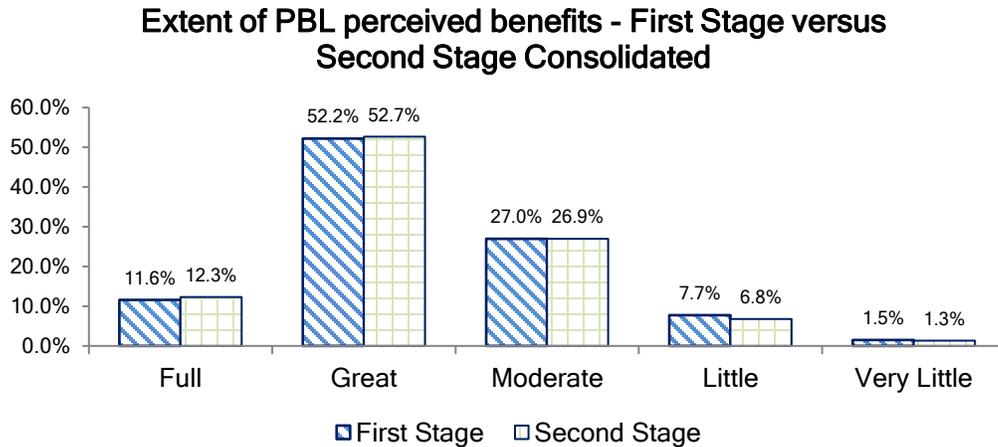


Figure 4 shows the consolidated data comparison between first and second stage survey results.  
**Figure 4**

*Data comparison for the first and second stages - perception of PBL benefits*



To check for the data reliability, the inter-item correlation for each construct was calculated by using Cronbach's alpha. For exploratory research, the alpha values between 0.50 and 0.75 are often considered acceptable as moderated reliability (Hinton et al., 2004). Values above 0.70 are considered moderate to high reliability (Pestana & Gageiro, 2003). On the variable's correlations, generally for practical considerations in educational research (Beavers et al., 2013) values exceeding 0.30 provide enough evidence to justify comprising factors (Tabachnick & Fidell, 2018). Even with some low correlation values like in Q8-Q9, Q7-Q9 and Q11-Q15, there is not enough evidence to suggest that factoring would not be beneficial because the overall alpha values per construct confirm the questionnaire scale of acceptable reliability, from moderate to high values, as shown in Table 4. Minitab® software was used to make the calculations.

### Learning Improvements consolidated from both Stages – Qualitative Approach

**Figure 5**

*Consolidated responses by PBL aspect associated with the learning goals*

Figure 5 shows the consolidated data of the total 49 responses, grouped by PBL aspect associated with the learning goals.

Table 5 summarises the results of students' perception of their learning improvements, associated with the three constructs presented in the questionnaire. Answers were edited to keep only the keywords of the complete sentences provided by the students to save table space and improve clarity.

**Table 4.**

*Variables Correlation Matrices and Cronbach's alpha*

		Q1	Q2	Q3		
Process	Q2	0.087				
Skills	Q3	0.346	0.377			
	Q4	0.284	0.456	0.430		
$\alpha = 0.657$						
		Q5	Q6	Q7	Q8	
PBL	Q6	0.340				
Discipline	Q7	0.339	0.337			
	Q8	0.412	0.237	0.707		
	Q9	0.309	0.277	0.144	-0.055	
$\alpha = 0.688$						
		Q10	Q11	Q12	Q13	Q14
Technical	Q11	0.571				
	Skills	Q12	0.525	0.484		
	Q13	0.489	0.579	0.708		
	Q14	0.406	0.342	0.410	0.518	
	Q15	0.380	0.179	0.324	0.378	0.763
$\alpha = 0.837$						

**Figure 5**

*Consolidated responses by PBL aspect associated with the learning goals*

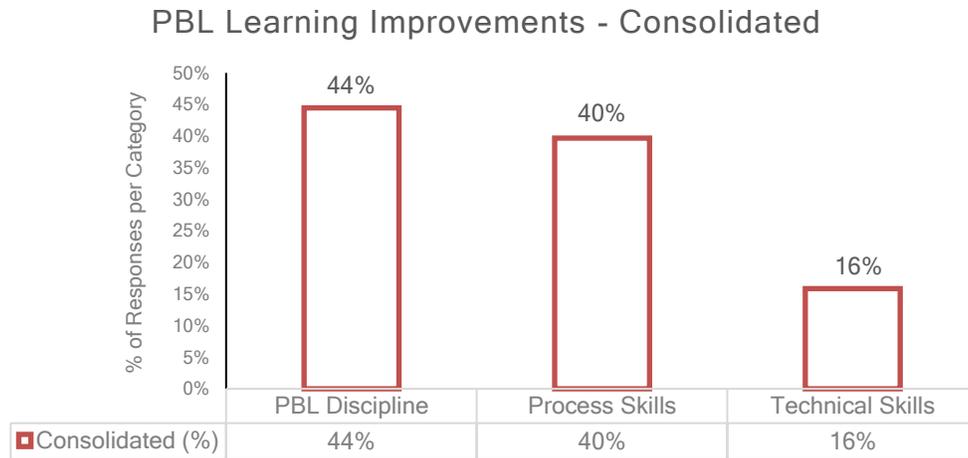


Figure 5 shows the consolidated data of the total 49 responses, grouped by PBL aspect associated with the learning goals.

**Table 5**

*Words from Students - Consolidated Learning Improvements by PBL aspect*

Item	LEARNING Improvements Regarding PBL Implementation (words from students)	CONSTRUCT
1	... Stimulate the autonomy of work. Enable students to think critically on their own.	
2	... A project that approaches the matter of reality.	
...	... Made us look and analyse real data...	
	... We can see how it would be a real problem of logistics ... think of solutions into practice ...	
	... Important to settle what I had learned. the almost real situation, having to think about all aspects...	
	... Concatenate the ideas and make them work together, given the numerous constraints that can be found along the way... we have to go after information...	Process Skills
	...Theory application ... to solve the problem...	
	... real situations are quite complicated, but also very challenging	
	Group work .... and real logistics problems, .... facing complex issues.	
	... Great opportunity for the student to work in a team with different people... criticize and put the ideas in better order ...	
20	... All teams have been proposed to have an entrepreneurial initiative to carry out the project.	
21	... PBL ... was important to obtain feedback at each stage of the project ... it was a stimulus for team unity and greater teamwork...	
...	... PBL methodology helps to learn better and actively, more than in lectures... allows a broader analysis of the problem, in which we can find several options that may be right or wrong, and this generates better learning...	PBL Discipline
	... The method works very well from the moment you understand the proposal... project allowed us to seek for information ...	
	Very good method ...Teamwork ... to solve real problems.	

Item	LEARNING Improvements Regarding PBL Implementation (words from students)	CONSTRUCT
	The theme is also important to encourage people ... the group meetings and the final result of the project. I liked the way the issue was presented to us, in stages...	
40	Autonomy to solve problems that ... Deliveries of the PBL were clear ...	
...	... Issues to be resolved from a series of questions ...through research and consultations ... approaches to professional reality ... The work helped us acquire knowledge beyond the discipline... ...To seek information independently... ... Extremely important for the development of knowledge. Possibility of seeking greater knowledge... It helps increase the pro-activity of each person in learning...	Technical Skills
49	Need to seek information, study on their own...	

## Discussion

PBL methodology brought new learning and teaching practices to the L&T course and the results fully addressed the proposed research questions. On the pedagogy approach, PBL demonstrated to be not only a technique to solve problems but to achieve learning goals. The PBL-based practices required more specific educational goals beyond the skills to solve problems traditionally proposed in the syllabus and subjects. The students had to work with a range of integrated and structured knowledge around real hypotheses, which promoted autonomous learning skills and teamwork.

The student's exposure to such problem scenarios promoted the placement of problem-challenges to students even before proposing theories and fundamental foundations for their solution. The irreducible focus of the method focuses on learning concepts by proposing challenges in the format of problems relevant to the students' professional future. Thus, the methodology promoted challenges, self-learning and problem-solving skills. The learning process promoted the discussion and analysis of problems by self-managed groups. The groups had meetings at least once a week and each student presented their part of the week's task. Often, the students organized their work in such a way that the individual contribution supplemented the work of the group, allowing them to develop a broad perspective of the issues related to the problem. The teacher's role in meetings was primarily to facilitate the learning process (Dochy et al., 2003; Gragas & Ramalhinho, 2016; Guimarães et al., 2016; Ribeiro, 2008). The motivation, transparency, and commitment of the authors before the students have also potentially contributed to their positive perception of PBL process and learning environment. This is not always easy as the administration of PBL operational factors requires advanced organizational and communication skills by the instructors. Even with positive outcomes, some limitations may compromise the activities (Wood, 2020). The students' roles discussed in Ribeiro (2008) and the implications for teaching and learning practices were demonstrated as per Table 6.

In terms of students' perception, the data presented from the first and second stage surveys, respectively, bring quantitative evidence that the majority of the students showed great appreciation of the benefits and positive outcomes from the PBL application concerning their learning perceptions. Even in different groups with different problem scenarios, the evidence is statistically confirmed. These results align with general perceptions from the literature that PBL methodology creates an environment that guides a learner-centred approach, integrating theory and practice; and

the students have to take initiative and work in collaborative groups. The challenges make the students seek opportunities for self-learning and for innovative responses to problems that do not have a single correct solution. Besides that, the concepts and learning objectives that were integrated into the set of questions showed a high level of acceptance. The use of PBL in the L& T course was profitable to the students, as most of them accepted the approach and showed a good grasp of the content. The set of 15 questions that came out of the factor analysis process allowed the authors to build a concise set of constructs and discard some of the variables that were potentially redundant or unnecessary, while still maintaining strong reliability and validity. The enrolment levels to answer the questionnaires were above ninety percent with a slight increase in the second stage compared to the first stage. Successful analysis and tests using Cronbach's alpha confirmed the robustness of the questionnaire, for every construct.

For Construct 1, focused on Process Skills, the raw data (available as supplemental data) showed that sixty percent perceived that PBL impacted them to a Great extent, corresponding to a grade 4 on the Likert scale. To a moderate extent, corresponding to a grade 3 was twenty-six percent. On this construct, the Full extent, which is a grade 5 scored at six percent. The positive perception of PBL outcomes added up to around ninety-two percent on this construct. As the students were motivated to self-learning, teamwork, discussions, critical thinking, and problem analysis skills, they became much more involved and committed to a higher level of learning. For Construct 2, focused on PBL Discipline, forty-two percent perceived that PBL impacted them to a Great extent while thirty-four percent perceived a moderate impact. On this construct, the Full extent scored at twelve percent. The result relates to how the students adhere to the PBL process itself, its administration, reports, meetings, presentations, and other procedures of the methodology. Research from the literature presented a level of difficulties and challenges that students perceived when following the PBL process, like open-ended problem scenarios and lack of formal instructions. Concerning this construct, eighty-eight percent of answers confirmed a good perception of PBL outcomes. For Construct 3, focused on PBL Technical Skills, fifty-nine percent perceived that PBL impacted them to a great extent, while twenty percent was moderate. On this construct, the Full extent was the highest among the three constructs, at sixteen percent. The construct is related to how the students worked and absorbed the technical and conceptual part of the L&T course. It is strongly related to the learning objectives of the course as it addressed the extent to which students perceived PBL as having helped them learn and retain knowledge on the subject. The authors argue that because construct 1 - Critical Skill showed strong positive students' perception, the technical knowledge received benefits from it. Self-learning, critical thinking, teamwork development, and other process skills facilitate the process of learning and retaining knowledge during problem resolution challenges, as it happens in real companies and with real problems. The full extent (level 5) scored at sixteen percent of the overall responses. Besides that, research from the literature presented examples where grades were improved after PBL implementation because students acquired and retained more knowledge during the process. Even with different scenarios and contexts, the results align with and complement what PBL research is presenting. This construct was perceived positively with ninety-five percent of answers with a good perception of PBL outcomes.

On the qualitative approach, looking at the three PBL constructs, which addressed relevant L&T management learning goals, explained by the several examples given by the students, it was possible to demonstrate their perception of learning improvements, even considering all the diversity represented by different students answering a single open question. PBL discipline was perceived to address important L&T learning goals, for instance in the following student's statements...PBL methodology helps to learn better and actively, more than in lectures...; allows a broader analysis of the problem, in which we can find several options that may be right or wrong, and this generates better learning...; ... Plan and understand the methodology for problem-solving...; ... Liked the theme

and teacher availability to remedy the doubts...; ... The method works very well from the moment you understand the proposal. Process Skills were addressed for example in the statements: ... Stimulated the autonomy of work. Enabled students to think critically on their own; ... A project that approaches the matter of reality; ... Made us look and analyse real data to perform ... project allowed us to seek for information; Group work .... We know who in the team did the work ...; ...Meetings forced us (the team) to discuss the issue, etc. Technical Skills were addressed for example in: ... Extremely important for the knowledge development; ... Issues to be resolved from a series of questions ...through research and consultations; ...approaches to the professional reality...; ... It makes students motivate and go deep into the concepts of the discipline. Traditional assessment method by mid and final exams was adapted to include a formative approach for process skills, using rubrics, as shown in Reflections on **implications for teaching practice during COVID-19 pandemic**

As the classes were interrupted at the first lockdown in March 2020, a new approach to remote classes using commercial platforms not yet fully tested by the university either by students or teachers were adopted. The learning process was strongly impacted as remote classes became lecture-based mixed with weekly lessons, overburdening the students with lots of tasks to perform from their homes. The traditional approach to the assessment process had to be implemented right away and was highly exposed because students were free to consult and potentially share with their colleagues. As the 1S2020 semester moved to its end, the authors had to plan for a remote learning environment in 2S2020 and probably beyond. New tests were made in several commercial platforms, but few of them provided an end-to-end solution for the class design and the pedagogy, especially assessment tools. One of them was chosen as the standard platform and one of the authors chose to keep PBL as the main active learning methodology for his own class in another university in the region. To implement that, using all the technology features offered by the web platform, relevant changes were made in the class design and pedagogy compared to the original PBL process. Instead of providing one problem scenario at the beginning of the semester, several remote classes were first provided as lectures to the students covering a certain part of the material (~50%), and a problem scenario related to that part was planned to be solved by the students in 3 or 4 weeks before the middle of the semester. The students were settled in groups through separated learning channels within the platform. This feature provided similar dynamics for the teamwork and discussion as live classes, even with the students working from their homes. The cycle will be repeated to the second part of the material and a new problem scenario will be worked out. Assessments were planned essentially by formative measures, using rubrics as proposed in **Error! Not a valid bookmark self-reference..** The expectation is to inform new research with the results of this experiment and to support new strategies in the coming 2021 and beyond if that becomes necessary due to extended COVID-19 pandemic impact.

Table 7 (Guimarães et al., 2016)

**Table 6***PBL-based – implications for teaching and learning practices*

<b>Traditional Lecture-based teaching (general)</b>	<b>L&amp;T PBL-based teaching and learning practices</b>
Students are seen as tabula rasa or passive recipients of the information.	L&T students were valued by their prior knowledge, initiative and responsibility were encouraged by the teacher.
Students work in isolation.	L&T students interacted with the teacher to provide immediate feedback on the course improvement.
Students absorb, transcribe, memorize, and repeat information to perform specific content tasks, such as questionnaires and exams.	The teacher designed the L&T course based on open context problems that provided room for new roles and self-learning.
Learning is individualistic and competitive.	L&T learning took place based on collaboration.
Students seek the “correct answer” to succeed in an exam.	Open context L&T problems discouraged the unique “correct answer” allowed them to explore alternatives and make effective decisions.
The performance was evaluated concerning specific content tasks.	Students identified, analysed, and solved the L&T problems using knowledge from previous courses and experiences, instead of simply remembering them.
School performance assessment is summative, and the instructor is the only assessor.	Using self and peer assessment, students evaluated their contributions, as well as other members and the group as a whole.
Class-based on unilateral communication; information is passed on to a group of students.	Students discussed L&T issues and worked in groups to solve problems. They found their resources and information, guided by teachers, seeking skills relevant to their future professional practice.

**Reflections on implications for teaching practice during COVID-19 pandemic**

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**Table 7**

*Process skills rubric*

Student name:				
SCALE	4 = Strong	3 = Moderate	2 = Regular	1 = Weak
CATEGORY	100%	75%	50%	25%
Collaboration	Almost always participatory accepts and issues opinions, seeks consensus and balance in group decisions.	Usually participatory accepts and gives opinions on many occasions, seeks to balance the group's decisions.	Often participatory, sometimes it does not accept or issue opinions, it can break the balance of group decisions.	Rarely participatory, most of the time it does not accept or issue opinions, it always breaks the balance of group decisions.
GRADE				
Leadership and Teamwork	Almost always listens carefully, shares with, and supports the efforts of other team members. Try to keep the team working well together.	Usually listens carefully, with, supports the efforts of other team members. It does not cause turbulence in the team.	Often listens and supports the efforts of other team members. But sometimes he is not a good team member.	Rarely listens and supports the efforts of other team members. He is often not a good team member.
GRADE				

## Conclusions and recommendations

This research explored the outcomes of a PBL methodology implementation in a Logistics & Transportation course in an Industrial Engineering major at a public university in Brazil, based on student perceptual assessment. The research was performed in two stages' survey methodology. In terms of the research method, the conclusion was that survey is a powerful tool for collecting authentic feedback from students to evaluate the effectiveness of the approach when exploring new teaching and learning methodologies. The way the survey was developed in the first stage, using previous experiences and expert contributions, insured acceptable validity and reliability, as well as considered the dimensions and objectives of the PBL and L&T curriculum, based on the literature.

Also, it was based on the Google web tool that preserved respondents' anonymity and eliminated any potential bias in the results. Another element of this research was to use both a quantitative and qualitative approach. The quantitative approach allowed appropriate tests for reliability and validity. In the end, the research presented actual students' perceptions of PBL-based curriculum benefits on the Industrial Engineering course at UNIFEI, and the theoretical framework and detailed problem scenarios created a reference for new research and applications by L&T faculty and institutions, regardless of place. The fifteen (15) structured questions, based on a Likert scale were able to produce valuable feedback related to outcomes of the new practices. The conclusions of this study compare to several other references in the literature on PBL outcomes, such as a) the students at our course showed very positive perception of PBL; b) the questionnaires' reliability could be checked by acceptable Cronbach's alpha; c) the second stage of the survey used the questionnaire originated from the first stage and confirmed the consistency of the results even with different problem scenario and different group of students; d) observing the results by construct, it was possible to conclude that the students approved the methodology (PBL) and enriched their way of learning, showing and developing other skills compared to traditional classroom.

In general, aligned with the theory from the literature review, the PBL-based curriculum in L&T exercised general skills as self-learning, critical thinking, and teamwork during the course development, related to Construct 1. PBL Discipline, built on the questions of construct 2, was very positive with few difficulties in terms of group and member's relative participation. The strong perception of general skills formation caused the students to respond very positively to Construct 3 - Technical Skills. Those perceptions of the quantitative approach were confirmed with a simple and direct open question that allowed students to provide their free opinions and present real examples of the PBL process situations where several L&T management learning goals were exercised. It confirmed actual learning improvement under the constructs that by design should address those skills.

The COVID-19 pandemic environment caused a huge impact in the on-going PBL process that required an innovative approach to technology, remote classes, and new pedagogy to keep supporting the L&T teaching and learning goals for 2S2020 and beyond, adapting the PBL process for other L&T courses. This research has limitations in terms of generalisation, as it was focused on just one university course (L&T), which is part of an Industrial Engineering major and it cannot ensure the same results will be confirmed in other courses. For future implementations, it is recommended that the authors tell students upfront the importance of the development and application of process skills to improve focus, teamwork, and leadership so that the learning objectives can be achieved in higher grades. As for recommendations for future research, classroom observations and actual students' grades could be collected to check for active learning

methodologies implementation versus actual learning improvements (e.g. based on concept retention), including a comparison of efficacy level among various methodologies.

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