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Evaluation of undergraduate Logistics & Transportation Management curriculum change from traditional lecturing to student-centered Problem-Based Learning (PBL) active learning environment

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ABSTRACT

Problem This paper presents the outcomes of the Problem Based Learning (PBL) methodology implementation in the undergraduate Logistics & Transportation (L&T) Management course at the Federal University of Itajubá (UNIFEI), Brazil. The research explores a curriculum change evaluation by using Survey data from two stages, in two semesters of the L&T course, with different PBL scenarios and students. L&T course addressed several concepts of Logistics Management and the PBL approach empowered students to self-learning, citical thinking, social and process skills. It was demonstrated that the majority of the students, over 91%, appreciated the benefits of PBL based curriculum in both semesters, with positive evaluation in all course dimensions. To support the conclusions of the study, special attention was given to the development of the questionnaires. The first stage, the pilot questionnaire, had a set of 21 scaled and structured questions, covering the course concepts and learning objectives. The second stage questionnaire was redesigned to a new set of 15 questions, modeled to three constructs by Factor Analysis, keeping up with the reliability and validity requirements.

Keywords: Problem-Based Learning, Survey, curriculum change, Logistics & Transportation Management, Industrial Engineering.

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1. Introduction

One of the paths for evaluating the benefits of the PBL methodology is to seek actual student's responses, using surveys that address the proposed PBL approach, after the end of the course. Survey questionnaires can also focus on student's satisfaction to compare traditional lectures to the problem-based approach, as proposed in Tick (2007). Other approaches from literature aim 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 the project completion and searching for necessary information, including knowledge from other courses (Koromyslova and Garry 2016). Some characteristics of PBL also can impact student's perception and should be considered by instructors on a progressive improvement basis. Seman et al. (2017) collected the perceptions of Electrical Engineering students regarding the knowledge formation process in a PBL implementation. Among other conclusions, the research 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's involvement, clear upfront explanations of the process and more awareness of the group.

Silva Filho and Calado (2013) discussed the use of PBL for student learning in a graduate Supply Chain Management course using Lean Manufacturing A3 report. The results showed that PBL encouraged students to develop professional skills and attitudes. Besides that, the authors concluded that the PBL approach was very close to PDCA (Plan, Do, Check, Act) cycle, giving the similarity with the steps for solving problems. In their research, the students' assessment was not collected. Da Silva et al. (2012) collected students' feedback in a Civil Engineering course and results indicated very positive perceptions.

The evaluation of curriculum changes to PBL in Brazil's undergraduate Industrial Engineering Education context, grounded by adequate statistical analysis, are not widely deployed in the literature. This opportunity motivated the authors to pursue a relevant literature contribution and respond to the Research Question (RQ): Can a positive students' perception of the benefits of L&T curriculum change to PBL be demonstrated statistically, using surveys that adequately cover the learning objectives and expected outcomes in two semesters, with different sets of PBL scenarios and students?

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

2. Literature Review

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-centered approach that gives learners more control over the research they are conducting. PBL is able to 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. Students work in collaborative groups and identify what they need to learn in order to solve a problem, promoting self-directed learning, new knowledge application and reflection on the process, aligned with L&T learning objectives and future professional roles. Other features of PBL are also well aligned with the course demands, such as (Guimarães et al. 2016):

- The student looks for opportunities to acquire knowledge by organizing their time;

- The student is encouraged to discuss his difficulties with the people involved in the dissemination of knowledge and others when needed;
- The instructor ceases to be the transmitter of knowledge and starts to guide and motivate the students to discover knowledge as a leading actor.

As per Barrows (1985, 1986) and Norman and Schmidt (1992), PBL promotes several learning objectives, helping students to construct an extensive and flexible knowledge base, develop effective problem-solving skills, become effective collaborators, develop self-directed learning skills and become intrinsically motivated to learn.

This research follows the PBL typical process cycle (Hmelo-Silver 2004):

1. Identification of the problem scenario.
2. Defining the problem by analyzing the facts arising from the scene.
3. Formulation of hypotheses about possible solutions with existing knowledge.
4. Identify new learning needs.
5. Research achievement in search of new knowledge, self-directed.
6. Application of new knowledge-generating new hypotheses and selecting the best solution.
7. 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 desired from the course learning objectives, the change of the instructor's role makes students increase the use of tools and techniques to articulate, reflect and develop their cognitive processes (perception, memory, learning, and consciousness). 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's universities, L&T has been taught in different forms since the establishment of the Industrial Engineering major a few decades ago. In this field, some general applications exist from literature. 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 analyzed 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). Grasas and Ramalhinho (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 95% of students responded that PBL activities stimulated teamwork and over 93% 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, grade distribution, students’ perception of the level of challenge in their work on a design project as well as teaching evaluation scores from students. The conclusions were that the PBL environment was better for student scores and learning outcomes. Other authors report the effective use of PBL with other tools like Lean Manufacturing, A3 Report and Games (Tortorellaa and Cauchick-

Miguel 2017; Silva Filho and Calado 2013; Kanet and Stöblein 2008), indicating positive benefits in all cases. Using Survey for catching student's perception of PBL implementation in Logistics & Transportation and other Operations Management courses, Alvarstein and Johannesen (2001) reported that the students found the teaching method interesting and contributor to greater knowledge, although it was too time-consuming. Bamford et al. (2012) and Koromyslova and Garry (2016) approached PBL implementation in comparison to grade's evolution. One of the conclusions was that after the introduction of additional active learning problem-based techniques, the percentage of A grades increased from 19% to 25% from one period to the next. Gudmundsson and Nijhuis (2001) mixed the use of PBL with 3-Way Interact Method (3WIM) applied to Logistics & Transportation. The results indicated that most of the students appreciated the 3WIM and PBL as a first choice in courses that offered this option. Cardoso and Lima (2012) focused on PBL outcomes in Logistics discipline, single-stage survey, using similar problem scenario and brought similar conclusions compared to the first stage of this research.

3. Methodology

3.1 Survey design and data collection approach

This research is exploratory, quantitative and uses Survey as a principal method. Modelling and other inference statistics are also used in the Survey's development, as supporting tools. To conduct the study, the authors adapted the framework proposed by Forza (2002):

a) Develop the original questionnaire and scale;
b) Conduct the first stage survey (pilot test);
c) Process and analyze the data statistically (PBL outcomes, enrolment);
d) Check for reliability and model a simplified questionnaire;
e) Conduct the second stage survey;
f) Process and analyze the data statistically (PBL outcomes, enrolment);
g) Check for reliability and validity of the model;
h) Results and Discussion, generate final conclusions.

For the development of the survey in both stages, the authors used a Google web-based tool that preserved respondents' anonymity so that it would diminish 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 side it had to be as complete as possible to consistently catch feedback for all of the L&T course dimensions under evaluation and from another side it had to be as simple and easy to fulfill as possible to maintain acceptable levels of completeness and promote enrolment. For this reason, the pilot questionnaire of the first stage was developed through a joint collaboration among the researchers, the professor of L&T course and eight graduate students that worked with two groups of undergraduate students in the previous semesters (2013-2014): the Industrial Engineering and the Administration courses, which shared similar L&T learning objectives and contents (Cardoso and Lima 2012). 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. Both, the first stage version and the second stage simplified version, were submitted to statistical analysis to check for data reliability and validity, including PBL evaluation dimensions from literature (Kanet and Barut 2003).

The first stage was planned and implemented in spring 2015 and the second stage in spring 2016.

As a result, the questionnaire of the **first stage**

included twenty-one (21) structured questions, coded as Q1, Q2... Q21. For the scale, it was used the Likert (1932) concepts, where the options were defined as **Very Little (1), Little (2), Moderate (3), Great (4) and Full (5).** The instructors introduced the first problem scenario to students (details are available in Cardoso and Lima [2012: 81-82]) as: **'An entrepreneur needs support on the Logistics Operations for a Mountain Bike assembly company. All market data is available'.** Then, consulting firms formed by eight students had to present possible solutions to the problem situation, covering subjects like component manufacturing identification, customers location, purchasing needs, logistics modals and cost, lead time and paperwork involved in the process (taxes, fees, etc.). Table 1 shows the original first stage questions.

Table 1 - Questions - First Stage Survey

Question
Q1: To what extent did you develop the skills to solve Logistics and Transportation (L&T) problems?
Q2: To what extent did you develop the ability to think analytically?
Q3: To what extent you have improved your ability to draw up opinions and reports?
Q4: To what extent did you learn how and where to find the relevant knowledge for a given problem in Logistics and Transportation?
Q5: To what extent you learned how to define problems from a set of facts and circumstances?
Q6: To what extent did you develop skills in learning to work with others in teams?
Q7: To what extent your team used the structure of problem-solving (ideas, facts, learning, issues, action plan)?
Q8: To what extent teamwork was encouraged during the general theme Logistics and Transportation?
Q9: To what extent the tutor / teacher-guided you through the PBL process?
Q10: To what extent all students (not only your team) were involved in the PBL process?
Q11: To what extent the members of your team were involved in the PBL process?
Q12: To what extent did you become an independent learner?
Q13: To what extent you used the minutes/reports of the last meeting?
Q14: To what extent you have acquired general knowledge in Logistics and Transportation?
Q15: To what extent you have acquired specific knowledge of the concept of SCM?
Q16: To what extent you have acquired specific knowledge of the concept of Logistics Service Level?
Q17: To what extent you have acquired specific knowledge of the concept of Relationship Management?
Q18: To what extent you have acquired specific knowledge of the concept of distribution channels?
Q19: To what extent you have acquired knowledge to differentiate Distribution Channels and Physical Distribution?
Q20: To what extent you have acquired specific knowledge of the concepts of Modal, Intermodal, and Multimodality?
Q21: To what extent you have acquired the ability to select a different Modal?

In the **second stage**, the problem scenario was: **'An entrepreneur needs support on the Logistics Operations for a Sales business in the beverage retail, initially focused on special beers (Craft? Gourmet?). Volumes and revenue projections were available'**. The consulting firms' approach was the same as the first stage, but the questionnaire was redesigned as detailed in the Results & Discussion section.

3.2 Questionnaires' Statistical Analysis Tools

After computing the responses from the students in both stages, the authors checked the questionnaires' reliability by using **Cronbach's alpha** (Cronbach 1951), as a recommended tool from literature (Pestana and Gageiro 2003).

To build the second stage simplified questionnaire and insure data validity, the original questionnaire responses (showed in Table 2) were modelled by **Factor Analysis**. Factor Analysis is used in exploratory perspectives and allows the researcher to

identify relationship structures among the variables (Hair et al., 2012). By testing the correlations and detecting the presence of factors and **Latent Constructs**, a simplified questionnaire with a reduced number of variables became possible, eliminating potential double questions, assuming that the reliability and validity are still acceptable and bring equivalent results. The correlation verification and development of the latent constructs with related factors will be done for all original 21 variables (Q1 to Q21) from the first stage questionnaire.

On top of the Factor Analysis and the identification of the relevant constructs and variables of the second-stage model, additional tests are recommended to insure pair to pair comparison is valid among the stages. Due to the non-parametric characteristic of Likert scales, when comparing the data pair to pair, the authors selected **Kruskal-Wallis** for the multivariate analysis (Kruskal and Wallis 1952; Dickhaus and Royen 2015). Statistical software Minitab 17 supported all the statistical calculations.

4. Results & Discussion

4.1. PBL Outcomes from First Stage Survey

In the **first stage**, fifty-one (51) students enrolled in the subject (**90% of the total**) and provided fifty-one (51) valid answers. Table 2 shows the results for the first stage. For each question, the numbers in percentage are the relative contribution of each level of the Likert scale and the numbers right below are the absolute number of responses at each level of the scale. Figure 1 shows the consolidated results of Table 2.

To check for the data reliability in Table 2, the inter-item correlation was calculated by using **Cronbach's alpha**. The alpha value above 0.9 is often considered very good (Pestana and Gageiro 2003). The alpha value of **0.906** presented in Table 3 confirms that our questionnaire scale has very good reliability.

4.2. PBL Outcomes from Second Stage Survey

The **second stage** simplified questionnaire had forty-five (45) students enrolled in the subject (**95% of the total**). It provided forty-five (45) valid answers. The overall results on PBL outcomes are shown in Table 4 (questions descriptions are not repeated). Figure 2 shows the consolidated results of Table 4. The Factor Analysis allowed the following underlying constructs to be derived:

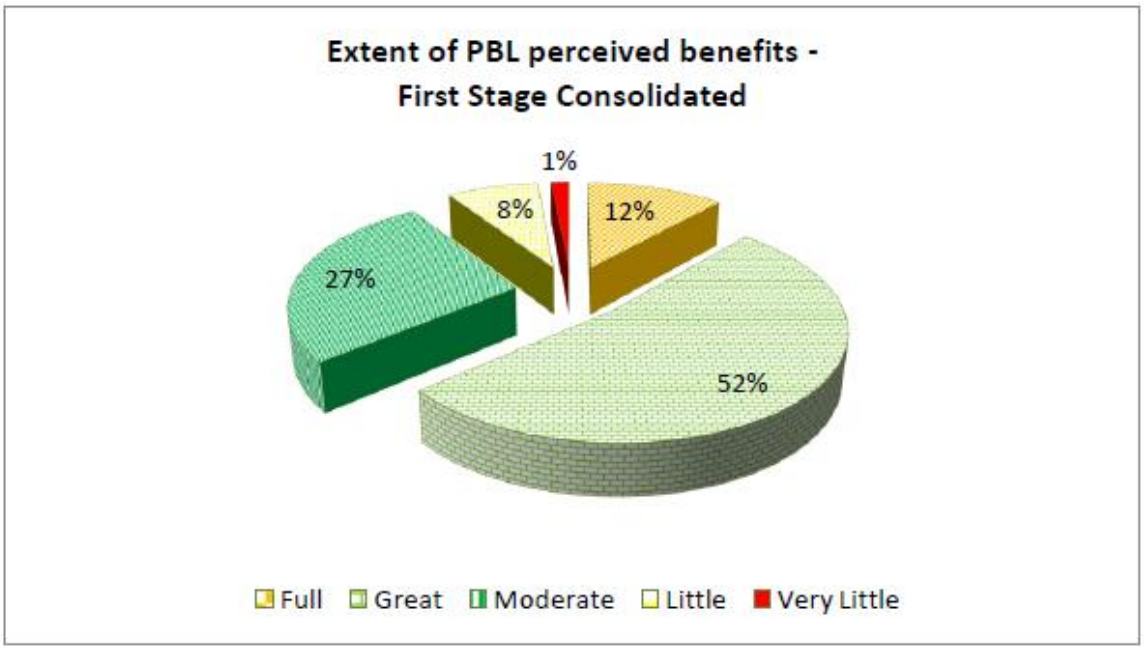

Figure 1 - Consolidated Outcome of PBL at the first stage (from Table 2)

Table 2 - First Stage Questionnaire Scaled Responses & Stats

Question	*V.Little(1)*	*Little(2)*	*Moderate(3)*	*Great(4)*	*Full(5)*
Q1:	2% 1	2% 1	37% 19	59% 30	0% 0
Q2:	0% 0	6% 3	20% 10	63% 32	12% 6
Q3:	2% 1	10% 5	43% 22	41% 21	4% 2
Q4:	0% 0	14% 7	24% 12	59% 30	4% 2
Q5:	0% 0	6% 3	25% 13	59% 30	10% 5
Q6:	2% 1	8% 4	14% 7	57% 29	20% 10
Q7:	0% 0	6% 3	35% 18	47% 24	12% 6
Q8:	2% 1	2% 1	31% 16	47% 24	18% 9
Q9:	0% 0	8% 4	29% 15	37% 19	25% 13
Q10:	6% 3	16% 8	45% 23	25% 13	8% 4
Q11:	6% 3	12% 6	37% 19	35% 18	10% 5
Q12:	4% 2	6% 3	27% 14	55% 28	8% 4
Q13:	6% 3	27% 14	35% 18	25% 13	6% 3
Q14:	0% 0	2% 1	14% 7	80% 41	4% 2
Q15:	0% 0	4% 2	22% 11	69% 35	6% 3
Q16:	0% 0	10% 5	24% 12	61% 31	6% 3
Q17:	0% 0	10% 5	39% 20	45% 23	6% 3
Q18:	0% 0	2% 1	22% 11	65% 33	12% 6
Q19:	2% 1	0% 0	18% 9	55% 28	25% 13
Q20:	0% 0	4% 2	18% 9	49% 25	29% 15
Q21:	0% 0	8% 4	22% 11	53% 27	18% 9

- **Construct 1**: Built with variables Q1, Q2, and Q5, named **'Critical Skills Development'**. A critical analysis by the authors concluded that either Q3 or Q4 should be added back to the questionnaire, even with loading factors lower than our original minimum value of 0.70. Adding variable Q4 (0.481 loading value) showed better results, with Cronbach's alpha changing from 0.53 to 0.66. So, construct 1 is defined by Factor 1 with variables Q1, Q2, Q4, and Q5.
- **Construct 2**: Built with variables Q7, Q9, Q10, Q11 and Q12, named **'PBL Process Adherence'.**

- **Construct 3**: Built with variables Q15, Q16, Q18, Q19, Q20 and Q21, named **'Technical Knowledge Assessment'.**

The result was a set of **15** selected questions, according to the criteria of the model.

Table 3 - Cronbach's Alpha of first stage survey

Variable	Total Count	Mean	StDev
Q1	51	3,529	0,644
Q2	51	3,804	0,722
Q3	51	3,353	0,796
Q4	51	3,529	0,784
Q5	51	3,725	0,723
Q6	51	3,843	0,903
Q7	51	3,647	0,770
Q8	51	3,765	0,839
Q9	51	3,804	0,917
Q10	51	3,137	0,980
Q11	51	3,314	1,010
Q12	51	3,569	0,878
Q13	51	2,980	1,010
Q14	51	3,863	0,491
Q15	51	3,765	0,619
Q16	51	3,627	0,747
Q17	51	3,471	0,758
Q18	51	3,863	0,633
Q19	51	4,020	0,787
Q20	51	4,039	0,799
Q21	51	3,804	0,825
Total	51	76,451	9,749

Cronbach’s alpha = 0,906

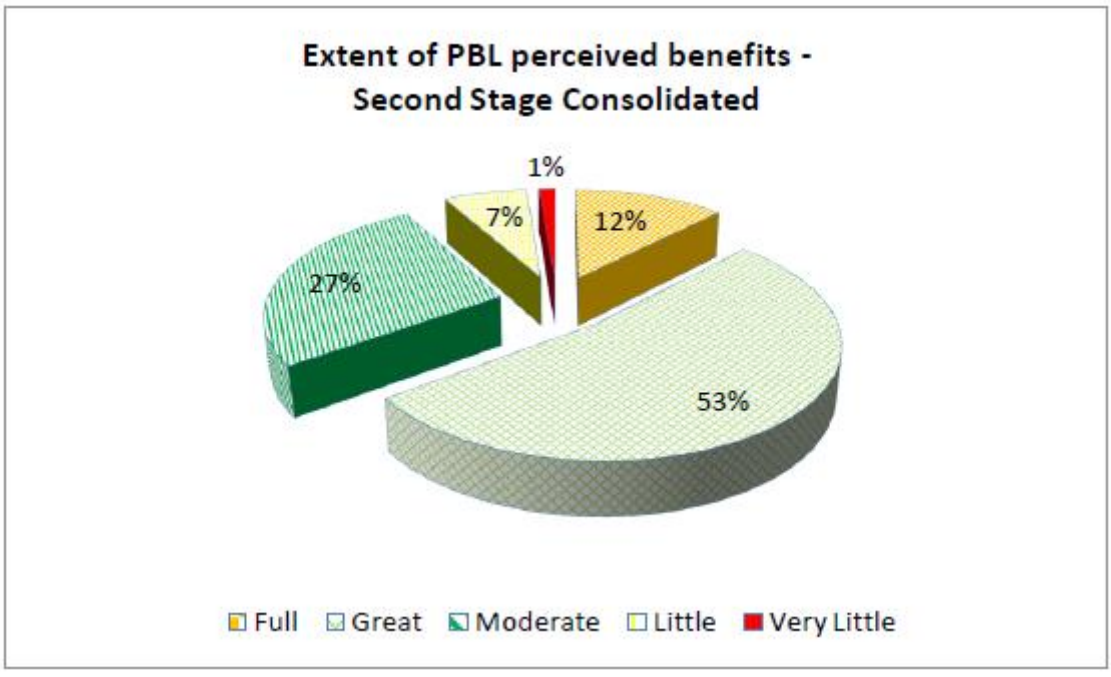

Figure 2 - Consolidated PBL Outcome at the second stage (from Table 4)

Table 4: Second Stage Questionnaire Scaled Responses & Stats

Construct	Question	V.Little(1)	Little(2)	Moderate(3)	Great(4)	Full(5)
1. Critical Skills	Q1:	2% 1	2% 1	37% 19	59% 30	0% 0
	Q2:	0% 0	6% 3	20% 10	63% 32	12% 6
	Q4:	0% 0	14% 7	24% 12	59% 30	4% 2
	Q5:	0% 0	6% 3	25% 13	59% 30	10% 5
2. PBL Process Adherence	Q7:	0% 0	6% 3	35% 18	47% 24	12% 6
	Q9:	0% 0	8% 4	29% 15	37% 19	25% 13
	Q10:	6% 3	16% 8	45% 23	25% 13	8% 4
	Q11:	6% 3	12% 6	37% 19	35% 18	10% 5
	Q12:	4% 2	6% 3	27% 14	55% 28	8% 4
3. Technical Knowledge Assessment	Q15:	0% 0	4% 2	22% 11	69% 35	6% 3
	Q16:	0% 0	10% 5	24% 12	61% 31	6% 3
	Q18:	0% 0	2% 1	22% 11	65% 33	12% 6
	Q19:	2% 1	0% 0	18% 9	55% 28	25% 13
	Q20:	0% 0	4% 2	18% 9	49% 25	29% 15
	Q21:	0% 0	8% 4	22% 11	53% 27	18% 9

The Cronbach's alpha analysis using the same criteria as before resulted in an alpha value of **0.8612**, a good reliability level, without any perceived loss of quality in the results. For further verification, individual construct's alphas are shown in Table 5. A minor reliability loss happened after the factor analysis and simplification strategy on the new design, but the authors assessed every variable fundamental, from a practical point of view and concluded that the model is acceptable. Still, the lower alphas are 0.66 and 0.69, near 0.7, a value considered reasonable from the literature (Pestana and Gageiro 2003).

It was possible to check for the acceptance of PBL in each one of the built constructs and verify that they actually follow the same proportion profile as the overall second stage survey results, consolidate data. Table 6 shows the results:

Figure 3 shows the consolidated data comparison between first and second stage surveys results.

Table 5 - Cronbach's Alpha per Construct

Construct	Cronbach’s alpha
Construct 1 - Q1,Q2,Q4,Q5: **Critical Skills**	0,66
Construct 2 - Q7,Q9,Q10,Q11,Q12 : **PBL Process Adherence**	0,69
Construct 3 - Q15,Q16,Q18,Q19,Q20,Q21: **Technical Knowledge Assessment**	0,84

Table 6: Comparison of consolidated data: constructs versus the second stage

	Very Little	Little	Moderate	Great	Full
Construct 1: Critical Skills	1%	7%	26%	60%	6%
Construct 2: PBL Process Adherence	3%	9%	34%	42%	12%
Construct 3: Technical Knowledge Assessment	0%	5%	20%	59%	16%
Second Stage Consolidated	1%	7%	27%	53%	12%

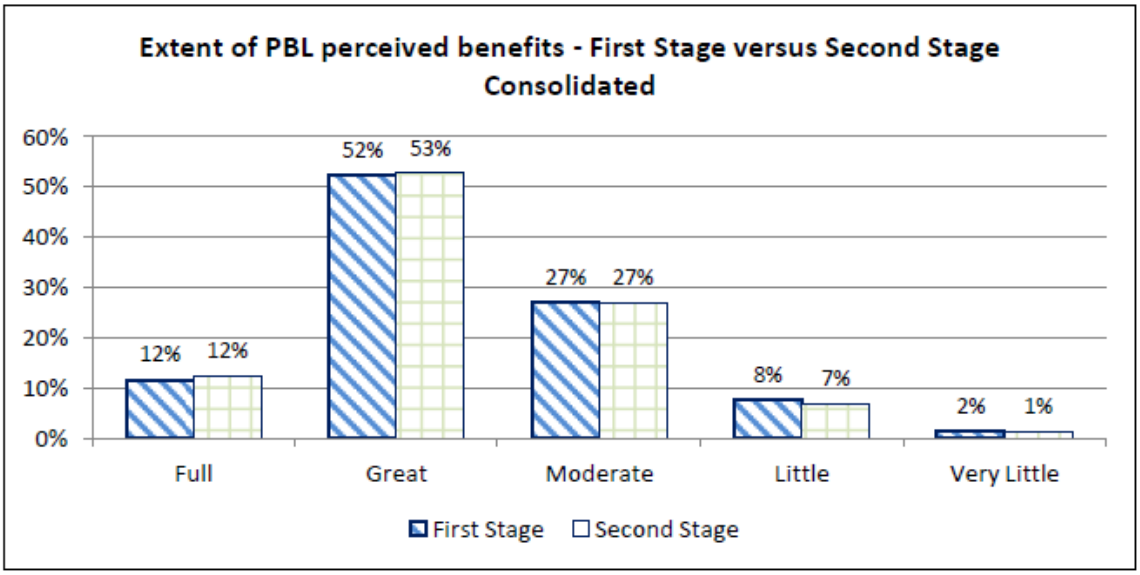

Figure 3 - Data comparison First and Second Stages - Perception of PBL

4.3. Background details on the redesign of the second stage questionnaire

The modelling by Factor Analysis followed four steps: a) Principal Component Factor 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, **82.2%** of the total variability was explained by eight (8) factors. As per Hair et al. (2012), a minimum of 60% of explained variability is acceptable and the authors followed this criterion, so eight (8) factors were chosen as principal components for explaining the correlations among the variables. See Table 7 for details.

Table 7 - Principal Components Analysis

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor 6	Factor7	Factor8	Communality
Variance	4,9600	1,5070	1,3495	0,8950	0,7903	0,6304	0,5487	0,4314	11,1186
% Var	0,367	0,111	0,100	0,066	0,058	0,047	0,041	0,032	0,822

As a second step in the same scenario, to help interpret the above data, the analysis was repeated with the 8 factors using the maximum likelihood method. This method showed how each factor influenced each variable by examining the loading patterns, so it helped further clarification and a robust selection of more specific factors. On exploratory factor analysis, an acceptable value of loading that reflects strong correlation is above 0.70 (Yong

and Pearce 2013), which was the criteria used by the authors. After examination of the loading patterns, it was possible to determine the factors that had the most relevant influence on each variable. 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 1958). Table 8 presents the results.

Table 8 - Rotated Maximum Likelihood Components Analysis

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Communality
Q1	0,767	-0,037	-0,029	-0,045	0,217	-0,018	-0,023	0,208	0,684
Q2	0,738	-0,120	-0,066	-0,217	0,146	-0,161	-0,015	-0,030	0,660
Q3	0,571	-0,238	0,054	0,013	-0,100	-0,082	-0,169	0,121	0,445
Q4	0,481	-0,166	-0,298	-0,091	-0,069	-0,236	-0,288	-0,032	0,501
Q5	0,635	-0,163	-0,073	-0,159	-0,157	-0,101	-0,152	0,139	0,538
Q6	0,002	-0,529	-0,006	-0,254	0,061	-0,372	-0,017	-0,246	0,546
Q7	0,146	-0,819	0,013	-0,214	0,165	-0,015	-0,139	0,094	0,793
Q8	0,313	-0,474	-0,031	-0,323	0,170	-0,318	0,015	0,045	0,560
Q9	0,266	-0,640	-0,211	-0,009	-0,020	-0,133	-0,177	0,204	0,616
Q10	0,250	-0,217	-0,011	-0,898	0,223	-0,137	-0,126	0,002	1,000
Q11	0,170	-0,451	0,001	-0,614	0,214	-0,075	-0,112	0,242	0,731
Q12	0,414	-0,274	-0,069	-0,146	0,153	-0,806	-0,202	0,112	1,000
Q13	0,295	-0,237	0,024	-0,235	-0,062	-0,200	-0,134	-0,023	0,261
Q14	0,591	0,041	-0,071	-0,352	0,290	-0,101	-0,368	0,178	0,741
Q15	0,474	-0,354	-0,056	-0,164	0,118	-0,135	-0,744	0,185	1,000
Q16	0,400	-0,166	-0,230	-0,135	-0,019	-0,055	-0,190	0,838	1,000
Q17	0,353	-0,222	-0,014	-0,266	-0,086	-0,299	-0,412	0,213	0,557
Q18	0,054	-0,178	-0,082	-0,212	0,748	-0,076	0,023	0,070	0,657
Q19	0,009	-0,020	-0,399	-0,060	0,807	-0,019	-0,072	-0,112	0,833
Q20	-0,034	-0,097	-0,915	-0,048	0,180	-0,036	-0,077	0,112	0,902
Q21	0,129	0,004	-0,813	0,042	0,158	-0,004	0,031	0,054	0,708
Var	3,514	2,337	1,878	1,848	1,665	1,198	1,182	1,108	14,733
%Var	0,167	0,111	0,089	0,088	0,079	0,057	0,056	0,053	0,702

From the model, 14 questions remained. These questions, as variables, were grouped in the following classes, on a similarity basis:

- Variables Q1 (0.767), Q2 (0.738) and Q5 (0.635) have large positive loadings on Factor 1. These variables can be grouped under a class, based on the subject field, named "Critical Skills Development" for PBL.
- Variables Q7 (-0.819) and Q9 (-0.640) have large negative loadings on Factor 2. By the same criteria, this class is named "Lack of discipline and guidance during PBL application".
- Variables Q20 (-0.915) and Q21 (-0.813) have large negative loadings on Factor 3. This class is named "Lack of knowledge on Modal concepts".
- Variables Q10 (-0.898) and Q11 (-0.614) have large negative loadings on Factor 4. This class is named "Lack of involvement in PBL process".
- Variables Q18 (0.748) and Q19 (0.807) have large positive loadings on Factor 5. This class is named "Distribution Concepts".
- Variable Q12 (-0.806) have large negative loadings on Factor 6. This class

is named "Lack of learning independence".

- Variable Q15 (-0.744) have large negative loadings on Factor 7. This class is named "Lack of SCM knowledge".
- Variable Q16 (0.838) have large negative loadings on Factor 8. This class is named "Service Level concept".

The resulting constructs **'Critical Skills Development', 'PBL Process Adherence' and 'Technical Knowledge Assessment'** were further tested for validity to ensure they were uncovering the PBL process outcomes without perceived loss. One of the forms was to compare, pairwise, each variable from Table 2 (Questions Q1, Q2, ...) with the correspondent variable in Table 6 (those remained in the reduced model), to check for differences (mean or median) by variance analysis. The assumption of normality would make ANOVA the first choice, but previous Minitab 17 screening tests for the data, using the Anderson Darling Normality test, showed that the variables in both tables did not have normal distribution **(p<0.005);** and by using ANOVA it has shown that the data presented in both Tables 1 and 2 have different variances **(p<0.005)**, although the shapes of the distributions were similar. So, for the hypothesis test on individual pairwise variables comparison, the **Kruskal-Wallis** test (Kruskal and Wallis 1952), seemed more adequate as a complement to ANOVA, as it worked with the non-parametric data and medians as well as fitted better to ordinal variables from Likert scales. A higher value of the test statistic **H,** used to calculate the p-value, means a higher probability of rejecting Ho, which means lower p-value. This research accessed specific literature on PBL applications for Logistic & Transportation branch of knowledge and could not uncover similar applications of **Kruskal-Wallis** tests on this subject, but only in several other multivariate analyses (Dickhaus and Royen 2015). See Table 9 for complete results, all extracted from Minitab 17. For illustration, the ANOVA results, which checked for differences in the means for the hypothesis test, were also presented (providing to the algorithm that variances were different, by checking Games-Howell Pairwise Comparisons option in Minitab 17).

Table 9 - Kruskal-Wallis e ANOVA test results

Construct	Variable	First Stage Survey Mean	Second Stage Survey Mean	First Stage Survey Median	Second Stage Survey Median	p-value ANOVA	p-value Kruska-Wallis (adjusted for ties)	Test Statistic H
Construct 1: Critical Skills	Q1	3.529	3.467	4	3	0.639	0.383	0.76
	Q2	3.804	3.822	4	4	0.899	0.840	0.04
	Q4	3.529	3.578	4	4	0.731	0.956	0.00
	Q5	3.725	3.844	4	4	0.394	0.444	0.59
Construct 2: PBL Process Adherence	Q7	3.647	3.711	4	4	0.676	0.560	0.34
	Q9	3.804	3.578	4	4	0.173	0.168	1.90
	Q10	3.137	3.422	3	4	0.117	0.113	2.51
	Q11	3.314	3.489	3	4	0.400	0.354	0.86
	Q12	3.569	3.667	4	4	0.538	0.903	0.01
Construct 3: Technical Knowledge Assessment	Q15	3.765	3.867	4	4	0.439	0.369	0.81
	Q16	3.627	3.778	4	4	0.313	0.300	1.08
	Q18	3.863	3.956	4	4	0.477	0.435	0.61
	Q19	4.020	3.844	4	4	0.232	0.149	2.08
	Q20	4.039	3.800	4	4	0.112	0.087	2.92
	Q21	3.804	3.644	4	4	0.340	0.348	0.88

Observing Table 9, all p-values for variables were higher than the significance level α = 0.05. So, the null hypothesis cannot be rejected. It means the two populations which represent the first and second stage surveys results, for every question (variable) have the same median and, at an acceptable confidence level, are considered equivalent in terms of the outcomes from the student's assessment. The choice for p-value calculation in Kruska-Wallis test as "adjusted for ties" was because the same value appeared in more than one sample, so the calculation was more accurate. For the record, the one way ANOVA test also confirmed that the means are the same (all p-values higher than α = 0.05), not rejecting the null hypothesis, so guiding to the same conclusion as Kruska-Wallis test.

4.4 Discussion:

The data presented in Table 2 and Table 4, from the first and second stage surveys, respectively, bring evidence that the majority of the students showed great appreciation of the benefits and positive outcomes from the PBL application on their learning perceptions. Even in different groups with different problem scenarios, the evidence is statistically confirmed, as an ultimate goal of this research in responding to the proposed RQ. These results align with general perception from the literature that PBL methodology creates an environment that guides to a learner-centered approach, integrating theory and practice; and the students have to take initiative and to work in collaborative groups. The challenges presented by this environment make the students seek for self-learning and for innovative responses of 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 Logistics & Transportation course was profitable to the students, where most of them had good acceptance of the methodology and good absorption of the submitted content.

The opportunity and challenge created by the improvement task of redesigning the questionnaire for the second phase added important value to the results analysis process. It became easier to understand and unfold the categories that were behind the first set of 21 questions (Table 2). The classes of questions that came out of the factor analysis process allowed the authors to build a concise set of constructs with 15 questions and discard some of the variables, potentially doubled or unnecessary, while still keeping good reliability and validity of the questionnaire. The enrolment level was above 90% with a slight increase compared to the pilot stage. Although the authors had no evidence that it happened because of the new design, enrolment was comparable to the first stage at very good levels for a survey, above 90%. Successful analysis and tests using Chronbach's alpha, Anova and Kruska-Wallis confirmed the robustness of the redesigned questionnaire, for every question and construct. Tables 7, 8 and 9 bring all the details. In general, observing consolidated data in Figure 3, the second stage survey results actually confirm the first stage results. One point of attention is noted at the **Very Little** extent comparison (level 1 at Likert scale), where the results of the second stage survey present half of the consolidated points comparing to first stage survey (1% versus 2%). At this level, it is possible to argue that the perception of these few students was that PBL outcomes were quite negative in both semesters, but it decreased from one semester to the next, which is positive. However, the number of responses at this level is just a few, at 1% to 2% level.

Some more discussion is necessary on the specifics, focusing on the second stage data in Table 7. **Construct 1**, compounded by Q1, Q2, Q4 and Q5 focus on **Critical Skills**. The majority of 60% perceived that PBL impacted them on a **Great** extent, corresponding to a grade 4 on the Likert scale. **Moderate** extent, corresponding to a grade 3 on the Likert scale was 26%. On this construct, **Full** extent, which is a grade 5 on the

Likert scale did not play high, staying at 6%. Anyway, the positive perception of PBL outcomes adds up to around 92% on this construct. The discussion of the results finds backup in the literature. The students play quite different roles comparing to their posture during the lecture-based classroom. As they are motivated to self-learning, teamwork, discussions, and reports, critical thinking and problem analysis skills, they get much more involved and their level of learning tends to be higher. Then, for this construct, PBL outcomes were strongly perceived. On the negative side, Q1 was the only question with a single Very Little extent. The question is more general and can bring to some students (in this case, just one) the impression that it talks about a list of skills (that are not presented), while, in fact, it focuses on skills to problem-solving. It can be improved in future surveys.

Construct 2, compounded by Q7, Q9, Q10, Q11 and Q12 focus on **PBL Process Adherence**. The majority of 42% perceived that PBL impacted them on a **Great** extent. **The moderate** extent was 34%. On this construct, **Full** extent showed double the level of the previous one, at 12%. The result relates to how the students actually adhere to the PBL process itself, its bureaucracy, reports, meetings, presentations and other procedures of the methodology. Research from the literature presented the level of difficulties and challenges that students perceive when following PBL process, like open-ended problem scenarios, lack of formal instructions, what kind of information to look for, strategy for the project completion, relaxed framework, etc., which partially confirms the findings of this work. The construct, however, still play high on the positive side with 88% of answers, with a good perception of PBL outcomes. On the negative side, questions Q10, Q11, and Q12 did get 3, 3 and 2 respondents in the lowest level (1) of the scale, respectively. Q10 and Q11 talks about the whole group and the members of the specific team involvement in PBL process, which could be explained by the fact that a few students did not perceive inter groups discussions, for example, which could respond better to Q10 and even in some teams, one or another member worked in more low profile than other's expectation. It can also be worked out during the dynamics of the PBL process in next implementations. Q12 tests the self-learning adherence, so, in this case, few (only 2) students did not perceive the independence they should acquire for self-learning. The tutor might treat this case by case as a possible improvement for next PBL implementations.

Construct 3, compounded by Q15, Q16, Q18, Q19, Q20 and Q21 focus on **PBL Technical Knowledge Assessment**. The majority of 59% perceived that PBL impacted them on a **Great** extent. **The moderate** extent was 20%. On this construct, **Full** extent was the highest among the three constructs, at 16%. On the other side of the scale, the **Very Little** extent got a 0% level, i.e. no student reported negatively on PBL outcomes for this construct, quite positive result for the purpose of the research. The construct is related to how the students worked and absorbed the technical and conceptual part of the Logistics & Distribution course. It is strongly related to the learning objectives of the course as it addresses the extent that students perceived PBL as helping them learn and retain knowledge on the subject. The constructs work together to build a complete view of PBL outcomes perception. The authors argue that because construct 1 - Critical Skill showed strong positive students' perception, the technical knowledge got benefit from it. Self-learning, critical thinking, teamwork development, and other critical skills facilitate the process of learning and retaining knowledge during problem resolution challenges, as it happens in real companies and real problems. It is not without cause that Full extent (level 5 perceptions on the positive side) got 16% 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 context, the results align with and complement what PBL research is presenting. This construct also plays very high on the positive side with 95% of answers with a good perception of PBL outcomes. On the negative side, question Q19 did get 1 respondent in the lowest level (1) of the scale. The authors concluded that there may be confusion between these two concepts, but when the subject is selected for building the problem solution or during tutoring time when it is explained by the instructor, technical doubts would go away. There was a gap with this specific student that the authors propose to treat individually case by case, but also remembering this gap during next PBL at the concept explanation, as a form to help retain the correct explanation of the concepts.

4.5. Conclusions & Recommendations

This research explored the outcomes of a PBL methodology implementation in a Logistic & Transportation curriculum change, Industrial Engineering major at a public university in Brazil, based on student's assessment. The research was performed in two stages' Survey methodology. On the research method, the conclusion is that Survey is a powerful tool for collecting true feedback from students to check for effectiveness of results 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. Also, it was based on Google web tool that preserved respondents' anonymity and eliminated any potential bias in the results.

Another lead defined for this research was to use a quantitative approach. Although it had some relatively heavy statistical approach, the decision was positive because it allowed the most 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. The pilot stage survey collected quantitative data in twenty-one (21) structured questions, based on a Likert scale, which were related with outcomes of the new curriculum. The conclusions of this study compare to several other references in the literature on the 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 a simplified questionnaire originated from the original one by using Factor analysis with Rotated Maximum Likelihood Components and additional Kruska-Wallis test which brought consistent evidence of data reliability and validity in the new questionnaire; d) second stage survey used different problem scenario and different group of students with (15) structured questions, already factorized and grouped in three (3) constructs and this structure confirmed the student's quite positive perceptions on outcomes of the PBL curriculum implementation, associated with the learning objectives organized by the constructs; e) observing the results by construct, it was possible to conclude that the students approved the methodology (PBL) and confirmed that it enriches the way of learning, showing and developing other skills compared to traditional classroom.

In general, aligned with the theory from the literature review, 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 process adherence, 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 helped the students to respond very positively on construct 3 - technical knowledge assessment.

This research has limitations on the generalization, as it was focused on just one of the courses (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 instructor show students upfront the importance of involvement and play the role of leadership, motivating colleagues to work with a common and strong focus, so that the learning objectives can be achieved in higher grades.

As for recommendations for future researches, 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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