Developing Learning Assessment Strategies with a MCDA-C (Multicriteria Decision Analysis - Constructivist) Approach

Carlos Alberto Prado da Silva Junior[*+], Antônio Nélson Rodrigues da Silva[*]

*Department of Transportation Engineering, School of Engineering of São Carlos, University of São Paulo, 13566-590, São Carlos, SP, Brazil
[+] Civil Engineering Program, State University of Paraná, Campus of Cascavel, 85819-110, Cascavel, PR, Brazil

Email: carlos.junior@unioeste.br, anelson@sc.usp.br

Abstract

The aim of this study was the development of a decision-making process for improving the assessment procedures of undergraduate students enrolled in engineering courses. The method allowed the definition of indicators to assess the teaching-learning processes involved in active learning and, more specifically, in PBL. The framework of this decision-making process encompasses planning and implementation phases that were developed in four workshops conducted with students and lecturers/instructors. The results suggest that multicriteria approaches, such as MCDA-C, which take into account the distinct experiences and viewpoints of the most important agents directly involved in the process, are promising alternatives to draw coherent, dynamic and flexible assessment strategies. Eight groups of indicators were obtained in the workshops, 52.0 % of which were classified as indicators for the assessment of active learning, in addition to 38.4 % of indicators that can be used for the assessment of either active or passive learning.

Keywords: Learning Assessment Strategies; Active Learning, PBL - Problem Based Learning, Learning Outcomes.

1 Introduction

The teaching-learning process involves a number of aspects to be planned, such as: course contents, teaching methods and learning assessment strategies for reaching the desired learning outcomes; procedures for matching students' learning preferences with teaching styles, etc. The strategies adopted for each aspect of the process have to be coherent with the teaching-learning approach considered, i.e., active or passive learning. Teaching-learning activities in engineering programs in general are now starting to rely on Problem Based Learning (PBL), which essentially involves active learning. Thus, it requires learning assessment strategies compatible with this teaching-learning approach.

The assessment of the teaching-learning processes is a complex phase of engineering education. Many factors have to be considered, preferably in clear and well-structured procedures. This is essential to avoid injustices and the lack of motivation that may affect the students as a consequence of wrong evaluations. This is not simple, particularly if one considers teaching-learning approaches that most lecturers are not used to, such as active learning and its variations. These approaches demand changes, and maybe even improvements, in the traditional methods of learning assessment.

Equally important in the teaching-learning processes are the learning outcomes that must be achieved along the education progression. In the case of engineering, these outcomes should be clearly defined and must be aligned with the official directives that regulate the contents of the courses. One of the tools that can be used to design learning outcomes is the Bloom's Taxonomy of educational objectives. This taxonomy allows setting goals in two dimensions (knowledge and cognitive process) and three levels of cognitive processing (knowledge, skill and competency).

The aim of this study was the development of a decision-making process for improving the learning assessment procedures of undergraduate students enrolled in engineering courses. A multicriteria approach, which takes into account the distinct experiences and viewpoints of the most important agents directly involved in the process, was explored as an alternative to support in the identification of indicators that can be used to assess the teaching-learning processes involved in active learning.

The paper is organized in four parts, in addition to this introduction. In the second section we introduce a few elements of the literature that are essential for understanding the procedures conducted thereafter. These procedures are carefully explained in the methodology section, which is followed by the results and the main conclusions.

2 The Teaching-Learning Process

In general, engineering education at the undergraduate level involves decisions at least about: the contents to be taught, the teaching methods, and the learning assessment strategies. The definition of these elements can rely on different theoretical backgrounds. The taxonomy of educational objectives proposed in 1956 (Bloom, 1972) and later revised in 2001 (Ferraz & Belhot, 2010), for example, can support: the definition of learning outcomes, the organization of teaching strategies that suit the teaching-learning method selected (e.g., active or passive learning), and the planning of effective forms of assessment for the process as a whole. All phases of the process are permanently open for debate. However, the assessment phase is probably the one that raises more discussions, given the subjective nature of the assessment activity. It seems that the problem starts with a poor or inadequate definition of assessment instruments. Thus, the organization of tangible and measurable indicators of learning assessment would certainly help the instructors in this task.

2.1 Integrating Learning Outcomes and Bloom's Taxonomy

The definition of educational objectives and learning outcomes is an important stage of the planning process of any instructional program, course, or even an assessment test. The Bloom's Taxonomy is among the methods that can be used to assess the consistency of educational objectives in relation to the activities and assessments proposed for a given teaching unit (Silva Junior & Rodrigues da Silva, 2011a). Originally published in 1956, the taxonomy had its theoretical assumptions updated in 2001 because of psycho-pedagogical and technological advances that occurred during the last decades. As emphasized by Ferraz & Belhot (2010), the updated version has two dimensions: knowledge and cognitive processes.

Kyte, Dixon, Abdel-Rahim, & Brown (2010) observe that some courses involve comprehensive and multidisciplinary contents. This is certainly the case of courses dealing with current transport and mobility issues. In this case, the teaching-learning methods applied should necessarily lead students to the high levels of cognitive processes and knowledge-based dimensions of the Bloom's taxonomy. That is the reason why Silva Junior & Rodrigues da Silva (2011b) used knowledge tables based on Bloom's taxonomy to analyze the learning outcomes and the application of active learning methods in Transportation or Mobility Engineering programs. The authors have showed that no differences were found, in terms of course contents, learning outcomes, and teaching methodologies, from the comparison of Transportation or Mobility Engineering programs with selected Civil Engineering programs. In summary, the procedures used for "transferring" contents and the learning dynamics of the students in the knowledge dimensions and in the cognitive process dimensions were nearly the same in all cases investigated. Author's like Biggs (1999) and Cowan, George, & Pinheiro-Torres (2004) provide good frameworks for a discussion regarding the importance of ensuring compatibility within the curriculum, between the learning outcomes of a course, the teaching and learning activities, and the assessment. According to Biggs (1999), they should all be "aligned".

2.2 Active Learning and PBL

PBL is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2006). Thus, PBL can be considered an instructional method that brings to the academic environment, in a controlled manner, current and relevant issues or problems.

Some of the reasons listed by Mills & Treagust (2003) to justify the use of PBL in engineering education are: the programs need to incorporate more opportunities for students to develop communication skills and teamwork experience; and the awareness of social, environmental, economic and legal issues that are part of the reality of modern engineering practice should be developed amongst students. Also, as a consequence of the current promotion systems that reward research activities and not practical experience or teaching expertise, the existing faculty often lacks practical experience. As a consequence, these instructors are not able to provide design experiences or to adequately relate theory to practice. Therefore, students have to learn how develop these skills autonomously.

2.3 MCDA-C - A Constructivist Approach for Multicriteria Decision Analysis

MCDA-C is an approach that can help in the management of a problem by taking into account the perceptions of the agents involved and the qualitative and quantitative aspects that are part of the context. Ensslin, Montibeller & Noronha (2001) emphasize that a problem is a personal construction that is related to the decision context. Therefore, personal values influence decision making.

The application of the MCDA-C approach basically involves three distinct, but interrelated steps: the structuring of the decision context, the construction of a model for the evaluation of alternatives, and recommendations for actions

deemed more appropriate to the context of the problem under analysis. The use of MCDA-C in education can be found in the study of Mazon, Serra, Andrade Lima & Soares (2012). The authors used the approach to evaluate the performance of a graduate program by considering several aspects.

3 Methodology

The aim of this study was the development of a decision-making process for improving learning assessment strategies. Thus, the generation of indicators to assess the teaching-learning process was an important part of the method. The study began with the specification of a knowledge table with learning outcomes based on the updated version of Bloom's Taxonomy and on the official directives issued by the Brazilian Ministry of Education for engineering degrees (MEC - CNE/CES 1.362/2001). The purpose of this knowledge table, which was adapted from a table originally produced by Silva Junior and Rodrigues da Silva (2011), was to highlight the learning outcomes aligned with the characteristics of PBL. The resulting table is shown in Figure 1.

The next step was the identification of indicators that were suitable to assess the teaching-learning process in a PBL approach. This was done with a MCDA-C approach during four workshops, in which the problem structuring phase has been developed with the participants. The main goal to be achieved was labeled as 'Identification of Actions for the Assessment of Teaching and Learning'. The workshops were conducted with the following groups of agents: undergraduate students (in the field of civil engineering) and graduate students (in the field of transportation engineering), university lecturers (in the fields of industrial, civil, and environmental engineering) and instructors of technical courses of freight transportation and related topics. Table 1 contains the institutions where the workshops were held and the amount of participants in each one of them.

Table 1: General characteristics of the workshops

Institutions	Number of Participants	City/State
Department of Transportation Engineering, University of São Paulo at São Carlos	9	São Carlos/São Paulo
Civil Engineering Program, State University of Londrina, Group A	30	Londrina/Paraná
Civil Engineering Program, State University of Londrina, Group B	26	Londrina/Paraná
Federal University of Rio de Janeiro, COPPE, Transportation Engineering	8	Rio de Janeiro/Rio de Janeiro

The MCDA-C approach applied in the workshops was conducted by a facilitator and supported by an electronic spreadsheet. The following themes were organized in distinct sheets: *i*) label of the problem; *ii*) ideas and concepts involved in teaching-learning assessment; *iii*) maps of relationships between means and ends, and *iv*) fundamental viewpoints. The spreadsheets were filled in with contributions from the participants during approximately 8 hours per workshop, in two blocks of four hours each (in most cases, in two different days). The role of the facilitator was to conduct the process. This was carefully done, in order to avoid interferences in the participants' opinions.

The workshops began with a brief presentation of the objectives of the initiative. A general introduction about indicators was also provided. The participants were then requested to work in groups of 2 to 4 people. Their first task was to list, based on their experience or intuition, at least five indicators that could be used for learning assessment in the case of engineering education. The outcomes of this activity were saved for further investigation and will not be discussed in this paper. Next, another presentation was delivered to the participants by the facilitator. The topic of the presentation, entitled "Education and Labor Market", was the basis for the MCDA-C procedures. The objective of the speech was to introduce and to compare aspects of the traditional teaching approach, which is essentially based on passive learning for knowledge transfer, with innovative teaching-learning strategies. Learning assessment was another issue discussed in the context of both traditional and innovative approaches. The MCDA-C procedures using the spreadsheets started right after that, as shown in the schematic representation of the process in Figure 2.

From that point on, the participants of the workshops would have to consider the possible indicators of learning assessment based on a process of active learning (PBL - Problem Based Learning) and the learning outcomes that are usually associated to this approach (e.g., teamwork ability, communication skills, etc.).

		Cognitive Process Dimension					
		Knowledge		Competency	Skill		
		Remember…	Understand…	Apply…	Analyze…	Evaluate…	Create…
Knowledge Dimension	Effective/ Factual	... ways to identify, formulate and solve engineering problems					
	Conceptual			… efficient forms of written, oral and graphic communication			
	Procedural		... the process of monitoring the operation and maintenance of systems … THE APPLICATION OF ETHICS AND PROFESSIONAL RESPONSIBILITY	... mathematical, scientific, technological and instrumental knowledge to engineering ... procedures to design and conduct experiments ... KNOWLEDGE ON PLANNING, MONITORING, DESIGN AND COORDINATION OF ENGINEERING PROJECTS AND SERVICES ... TEAMWORK SKILLS ... procedures for continuous professional development	… ENGINEERING SYSTEMS … ENGINEERING PRODUCTS AND PROCESSES	... results ... critically the operation and maintenance of systems … IMPACTS OF ENGINEERING ACTIVITIES ON SOCIAL AND ENVIRONMENTAL CONTEXTS … THE ECONOMIC VIABILITY OF ENGINEERING PROJECTS	
	Metacognitive						… PROJECTS, SYSTEMS, PRODUCTS AND PROCEDURES ... forms to develop and/or apply new tools and techniques

Figure 1: Knowledge table constructed by Silva Junior and Rodrigues da Silva (2011a) based on the updated version of Bloom's Taxonomy and on the official directives issued by the Brazilian Ministry of Education for engineering degrees (MEC - CNE/CES 1.362/2001). The learning outcomes aligned with the characteristics of PBL are highlighted.

Two results of the MCDA-C workshops are of particular interest for this study: indicators and fundamental viewpoints. These elements may have common characteristics regarding teaching-learning assessment, which can be used to organize groups of indicators that meet the conditions described in Figure 2. Once organized, the results can be used to draw conclusions regarding the overall relevance of the groups of indicators. They can be used also to identify relationships between the groups of participants, the groups of indicators and the fundamental viewpoints, as well the indicators that are suitable for the assessment of active learning.

4 Results

In this section we summarize the main results of the strategy used to generate indicators for the assessment of the teaching-learning process in a PBL approach. An overview of the strategy is displayed in Figure 3. The use of a MCDA-C approach in this context took into account the learning outcomes highlighted in Figure 1, which are based on the official directives for engineering degrees and aligned with the characteristics of PBL. It is interesting to notice that the indicators produced in the end of the cycle are linked to the learning outcomes that originated the cycle.

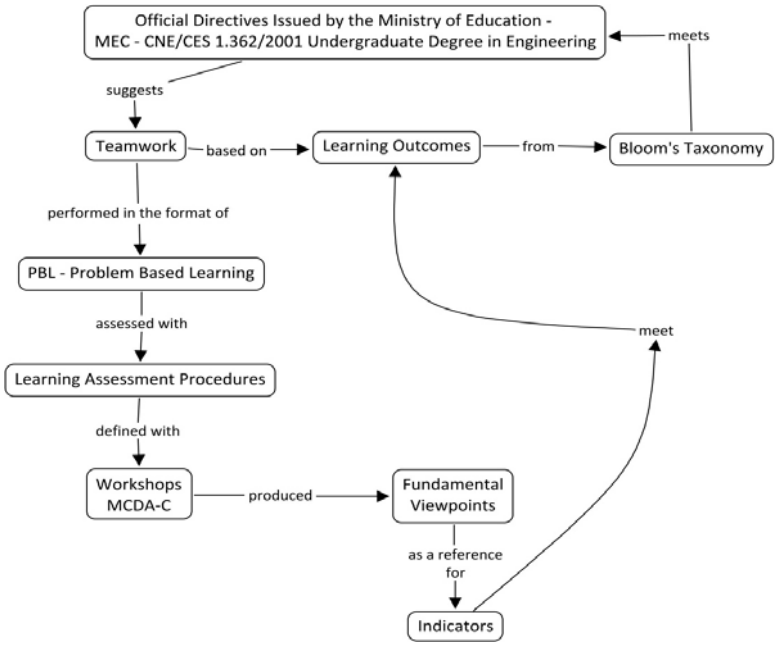

Figure 2: General outline of the method used for developing learning assessment strategies

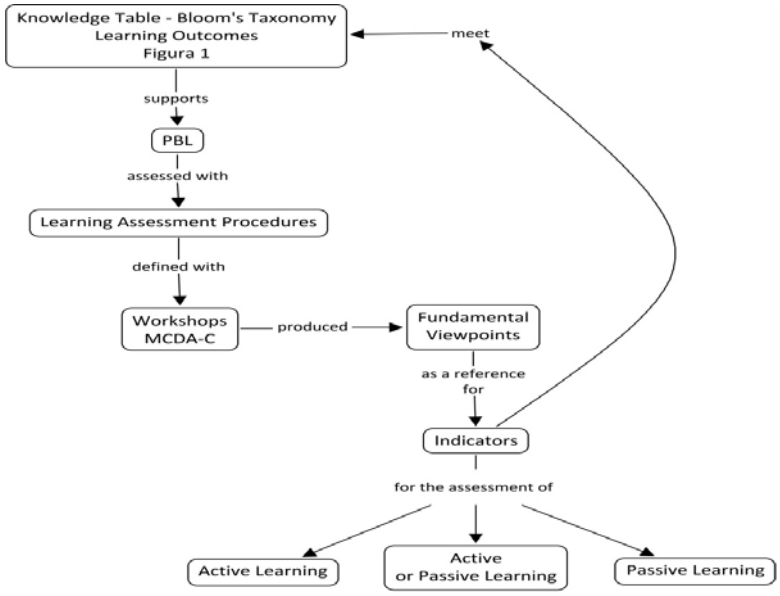

Figure 3: Overview of the strategy used to generate indicators for the assessment of the teaching-learning process in a PBL approach

An MCDA-C approach provided the framework for the identification of indicators suitable to assess the teaching-learning process in a PBL approach. An initial list with 69 indicators was produced in the four workshops mentioned in Table 1. These indicators were linked to 31 fundamental viewpoints, as summarized in Table 2. However, repetitions were found in the different places where the workshops took place. In some cases the indicators were exactly the same or quite similar. Either way, they were reorganized in a smaller list, with 52 indicators. These 52 indicators were

then combined to form 8 groups, linked to 6 fundamental viewpoints, based on similarity. The other 17 indicators were not considered in the analysis because they could not be included in any of the 8 groups or indicators. Also, they could not be combined to form additional groups, given their very distinct characteristics.

Table 2: Total number of contributions in each workshop

Institution/Place/Participants Profile	Number of Fundamental Viewpoints	Number of Indicators - MCDA-C
University of São Paulo, São Carlos Participants: graduate and undergraduate students	8	28
State University of Londrina, Group A, Londrina Participants: undergraduate students	9	12
State University of Londrina, Group B, Londrina Participants: undergraduate students	8	15
Federal University of Rio de Janeiro, Rio de Janeiro Participants: university lecturers (in the fields of industrial, civil, and environmental engineering) and instructors of technical courses of freight transportation and related topics	6	14
Total	**31**	**69**

The overall structure produced is displayed in Figure 4, in which the 8 groups of indicators are placed in the center, the groups of participants are on the left side and the fundamental viewpoints are on the right side of the figure. The lines linking the elements in the center with those on the right side of Figure 4 indicate the connections between groups of indicators and fundamental viewpoints. Given that the number of connections was in some cases relatively high, we replaced multiple lines with the respective number of connections. One example can be found in the line connecting the group of participants *Graduate and Undergraduate Students* and the group of indicators *Number of Solutions to Problems*, where the number 10 was used to replace 10 parallel links. The same logic applies to the connections between groups of indicators and fundamental viewpoints. The sum of numbers in both cases (i.e., left and right) is 52, which is the total number of indicators considered.

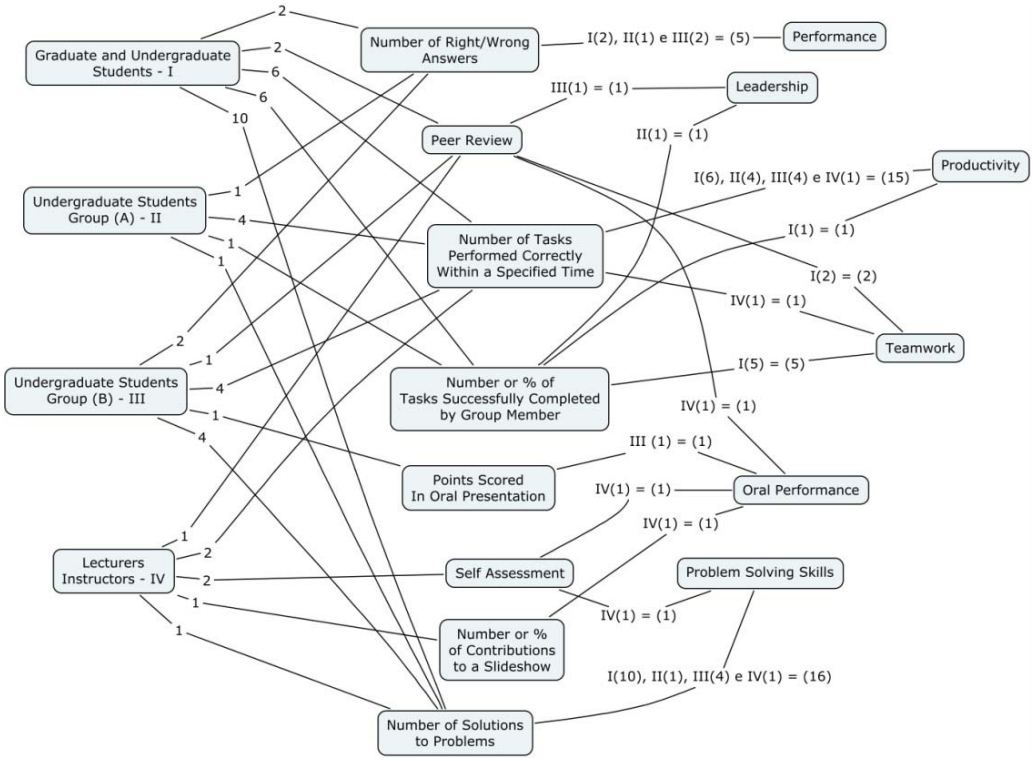

Figure 4: Relationships between groups of participants, groups of indicators and fundamental viewpoints

The analysis of Figure 4 also helps to identify the distribution of the 52 indicators in the 8 groups created to represent them, which are shown in the center of the figure. The number of connections arriving to each of the central boxes indicates the strength of each group of indicators in relation to the other groups of indicators. In other words, the groups of indicators *Number of solutions to problems* and *Number of tasks performed correctly within a specified time* can be considered the most important ones, given that they had 16 (out of 52) connections each. This represents 30.8 % of the total. The percentages of the 8 groups were used to build the graph of Figure 5, in which the contributions are also shown per group of participants.

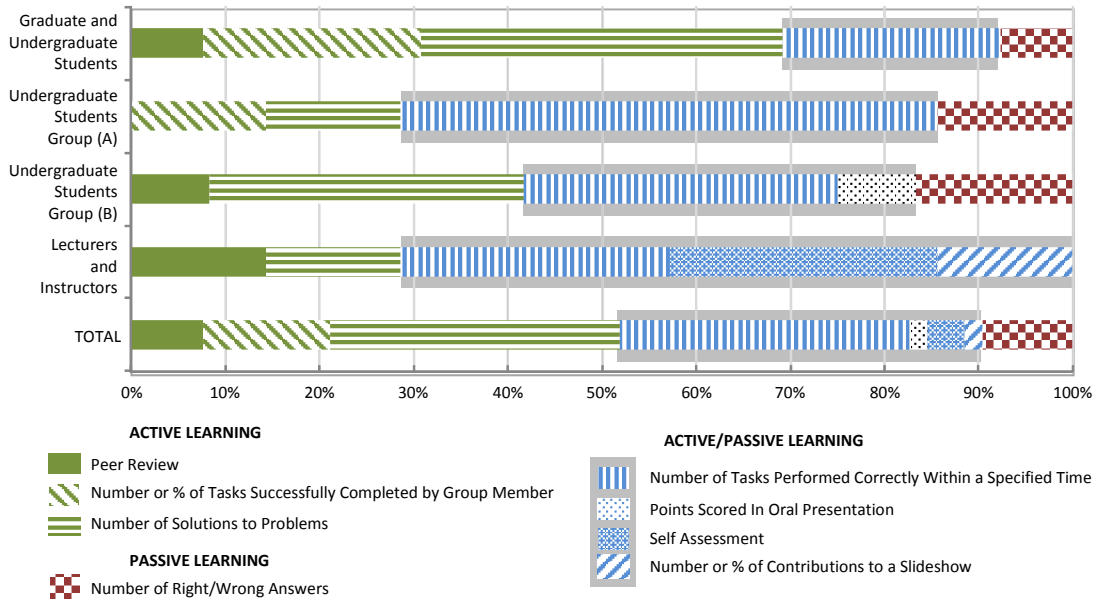

Figure 5: Distribution of the clusters for each of the groups of the participants

The 8 groups of indicators shown in the center of Figure 4 were subsequently merged in 3 clusters according to teaching-learning methods and learning assessment characteristics, as follows: *i*) indicators for the assessment of active learning; *ii*) indicators for the assessment of active or passive learning; and *iii*) indicators for the assessment of passive learning. These clusters can also be seen in Figure 5, in which the groups of indicators for the assessment of active or passive learning are represented in blue (also with a gray box in the background). All groups of indicators displayed on the left of the previous cluster contain indicators for the assessment of active learning (in green), whereas the group of indicators displayed on the right of the previous cluster contain indicators for the assessment of passive learning (in red). The distribution of the clusters for each of the groups of the participants is also shown in Figure 5. The percentages obtained in the bar containing the total values, which are visible in Figure 5, are summarized in Table 3.

Table 3: Distribution of indicators according to teaching-learning methods and learning assessment characteristics

Indicators for the Assessment of Active Learning	Indicators for the Assessment of Active or Passive Learning	Indicators for the Assessment of Passive Learning
52.0 %	38.4 %	9.6 %

5 Conclusions

The method described in this paper allowed the definition of indicators to assess the teaching-learning processes involved in active learning. They are important in the development of a decision-making process for improving learning assessment strategies in which the learning outcomes are aligned with the characteristics of PBL (as suggested in Figure 1). The overall framework of this decision-making process encompasses planning and implementation phases that were developed in four workshops conducted with a MCDA-C approach. The process is flexible enough to be adapted and applied in different contexts, even if different learning outcomes, official directives and teaching-learning methods are considered. The results of the study suggest that multicriteria approaches, such as

MCDA-C, which take into account the distinct experiences and viewpoints of the most important agents directly involved in the process, are promising alternatives to draw coherent, dynamic and flexible assessment strategies.

In practical terms, the adopted approach produced 52 indicators. These indicators were combined to form 8 groups (as shown in the central part of Figure 4) with common characteristics regarding the teaching-learning methods and the expected learning outcomes. The expected learning outcomes were also combined in groups, in this case of 6 fundamental viewpoints (also shown in Figure 4).

The indicators obtained in the workshops were subsequently classified in three clusters: *i*) indicators for the assessment of active learning; *ii*) indicators for the assessment of active or passive learning; and *iii*) indicators for the assessment of passive learning. The outcome of the process was significantly effective, given that 52.0 % of the indicators were classified in the first group (i.e., indicators for the assessment of active learning), in addition to 38.4 % of indicators that are in the second group (i.e., indicators for the assessment of active or passive learning), as shown in Figure 5 and Table 3. Moreover, the percentages associated to the indicators can be used as weights in an equation to calculate final grades. If based on the total values displayed in Figure 5, for example, the contribution of the indicators exclusively dedicated to passive learning would be smaller than 10 % of the total grade. It must be highlighted, however, that the elements pointed in Figure 4 are more ways or modes of assessment rather than indicators, which afterwards come to be related as more or less suitable for different types of learning (active, passive, or both). Similarly, the viewpoints would be groups in which the learning outcomes could be clustered.

Another interesting outcome of the analysis was the fact that the perceptions about the indicators for the assessment of the teaching-learning process varied from group to group. The values shown in Figure 5 indicate that the group with *Graduate and Undergraduate Students* had the highest percentage of indicators exclusively dedicated to active learning (69.2 %). On the other hand, the groups *Undergraduate Students (A)* and *Lecturers and Instructors* had the smallest proportion of indicators exclusively dedicated to active learning (28.6 %). In the case of *Lecturers and Instructors*, however, another aspect is worth mentioning. It is the fact that there were no indicators classified in the group of indicators for the assessment of passive learning. This can be an indication that these instructors are willing to change the way they assess the teaching-learning process. Another explanation is that students are afraid of changes that can represent additional workload or reduced grades for them.

References

Biggs, J., & Tang, C. (2007). Teaching for quality learning at university. 3rd Ed. Society for Research in Higher Education and Open University Press, Mc Graw Hill, Berkshire, United Kingdom.

Bloom, B. S., Engelhert, M. D., Furst, e. J., Hill, W. H., & Krathwohl, D. R. (1972). Taxonomia de objetivos educacionais: domínio cognitivo. Globo, Porto Alegre, Brazil.

Cowan, J., George, J.W., & Pinheiro-Torres, A. (2004). Alignment of developments in higher education. Higher Education, 48(4), 439–459.

Ferraz, A. P. do C. M., & Belhot, R. V. (2010). Taxonomia de Bloom: revisão teórica e apresentação das adequações do instrumento para definição de objetivos instrucionais. Gestão e Produção, 17(2), 421-431.

Ensslin, L., Montibeller Neto, G., & Noronha, S. M. D. (2001). Apoio à decisão: Metodologia para estruturação de problemas e avaliação multicritério de alternativas. Florianópolis, Brazil: Insular.

Kyte, M., Dixon, M., Abdel-Rahim, A., & Brown, S. (2010). A process for improving the design of transportation curriculum materials with examples. Proceedings of the Annual Meeting of the Transportation Research Board, Washington, D.C., USA.

Mazon, G., Lima, M. V. A., Soares, T. C., & Serra, F. A. R. (2012). O uso da metodologia multicritério em apoio à decisão construtivista para avaliar o desempenho do programa de cursos de pós-graduação Lato Sensu. Revista Economia & Gestão. 28(12), 30-52.

MINISTÉRIO DA EDUCAÇÃO - BRASIL. Diretrizes curriculares nacionais para os cursos de graduação em engenharia - Resolução CNE/CES 11/2002. Ministério da Educação - Conselho Nacional de Educação, Brasília, DF, 2002.

Mills, J., & Treagust, D. (2003). Engineering education - Is problem based or project-based learning the answer? Australasian J. of Engng. Educ., online publication 2003-04.

Silva Junior, C. A. P., & Rodrigues da Silva, A. N. (2011a). Graduação em engenharia de transportes: objetivos instrucionais e diretrizes curriculares oficiais. Proceedings of the XXV Congresso de Pesquisa e Ensino em Transportes, ANPET, Belo Horizonte, Brazil.

Silva Junior, C. A. P., & Rodrigues da Silva, A. N. (2011b). Problem/Project/Practice Based Learning and Transportation Engineering Degrees. Proceedings of the PAEE 2011 - International Symposium on Project Approaches in Engineering Education, Lisbon, Portugal.