Journal of Cleaner Production

Volume 193, 20 August 2018, Pages 363-371

https://doi.org/10.1016/j.jclepro.2018.05.079

Analysis of the difficulties associated to sustainability insertion in engineering education

Rampasso, I.S[a]; Anholon, R[b]; Silva, D[c]. Cooper Ordoñez, R.E[d]. Quelhas, O.L.G[e]; Leal Filho, Walter[f*]; Santa-Eulália, L.A[g]

[a] Department of Manufacturing Engineering and Materials, State University of Campinas. Mendeleyev Street, 200. Campinas, São Paulo, Brazil. Phone: +55 19 3251-3312. e-mail: izarampasso@gmail.com

[b] Department of Manufacturing Engineering and Materials, State University of Campinas. Mendeleyev Street, 200. Campinas, São Paulo, Brazil. Phone: +55 19 3251-3312. e-mail: rosley@fem.unicamp.br

[c] Laboratory of Innovation Technology Applied, Faculty of Education, State University of Campinas, Bertrand Russell Avenue, 801 Campinas, São Paulo, Brazil. Phone: +55 11 4702-8279. e-mail: dirceuds@gmail.com

[d] Department of Manufacturing Engineering and Materials, State University of Campinas. Mendeleyev Street, 200. Campinas, São Paulo, Brazil. Phone: +55 19 3251-3492. e-mail: cooper@fem.unicamp.br

[e] Laboratory of Technology, Business and Environment Management. Federal Fluminense University. Passo da Pátria Street, 156. Niterói, Rio de Janeiro, Brazil. Phone: +55 21 2629-5620. e-mail: osvaldoquelhas@id.uff.br

[f] Hamburg University of Applied Sciences. Faculty of Life Sciences Lohbruegger Kirchstraße 65, Sector S4, Hamburg Germany. Phone: + 49-40-42875-6313. e-mail: walter.leal2@haw-hamburg.de **(*corresponding author)**

[g] Université de Sherbrooke. 2500, boul. de l'Université. J1K2R1 - Sherbrooke, - Canadá. Phone: (819) 821-8000 (ext. 65042), e-mail: l.santa-eulalia@usherbrooke.ca

Abstract

This paper aims to understand how the difficulties associated to the insertion of sustainability in engineering education are related. From the literature review, eleven difficulties were compiled and posteriorly, a panel of experts was conducted to divide them in two groups, named “difficulties associated with structure and planning” and “difficulties observed in didactic practice”. These groups were used as a base of a questionnaire by survey, with lecturers who work with sustainability in engineering courses. The collected data were analysed through Structural Equation Modeling. A causal relationship between the two groups was verified through the present research, that is, the greater the difficulties associated with the structure and planning, the greater will be the difficulties observed in didactic practice. The results of this paper may be used by researchers in their future studies and by lecturers and coordinators as a guide to the insertion of sustainability in engineering education. The authors believe that these results may contribute to the engineering education improvement.

1. Introduction

Higher Education Institutions (HEI) are increasingly concerned about the education of the future professionals who will work in the market. Contrary to what occurred a few decades ago, merely technical training no longer meets the requirements stipulated by society; it is necessary to develop a professional that, in addition to the technical content mentioned, also have a critical sense regarding environmental and social aspects (Barba-Sánchez and Atienza-Sahuquillo, 2017; Chan et al., 2017; Fan and Yu, 2017; Glassey and Haile, 2012). According to Staniškis and Katiliūtė (2016), sustainability needs to be central to the design of educational policies in HEI. Faced with a wide variety of possible practical applications, this concern becomes even more critical in engineering courses (Glassey and Haile, 2012; Ortega-sánchez et al., 2017).

The traditional teaching of engineering, with exclusive focus on optimizing solutions from the economic point of view, is changing. Nowadays, responsibility for the negative impacts generated by these solutions also includes social and environmental aspects. This new concept of "engineering responsibilities", which permeates different values towards sustainability, must be included in the education of future engineers (Guerra, 2017; Palacin-Silva et al., 2017; Staniškis and Katiliūtė, 2016). The new generation of professionals should meet the needs of society without compromising the capacity of future generations to attend their necessities (Hugé et al., 2017; Soini et al., 2018). Therefore, the improvement of the curricula of the engineering courses is essential for universities to follow the evolution of the market and thus better empower its students (Bussemaker et al., 2017).

Although desired, this new conception of "engineering responsibilities" is still being inserted in most educational institutions. From the three sustainability strands, the economic one has always been present in the mentioned courses; the environmental sustainability, for its turn, is getting more and more space (Edvardsson Björnberg et al., 2015; Fisher and McAdams, 2015; Hamid et al., 2017); and the social dimension still needs more attention, according to Edvardsson Björnberg et al. (2015). There are many challenges to be overcome to fully integrate sustainability into the curricula of engineering courses (Glassey and Haile, 2012; Holgaard et al., 2016; Hugé et al., 2017; Mulder, 2017; Palacin-Silva et al., 2017; Sivapalan et al., 2017). Examples of these difficulties are the lack of integration among the areas that compose the courses (Bussemaker et al., 2017; Fan and Yu, 2017), the low understanding of the importance of interdisciplinarity by teachers (Fan and Yu, 2017) or aspects of education for sustainability in relation to educational theories of the affective domain (Shephard 2008), among others.

Against this background, the present paper aims to analyse the difficulties associated to the insertion of sustainability in engineering education and try to confirm the hypothesis that the difficulties associated with structure and planning have a causal relationship with the difficulties observed in didactic practice. There is no article in the studied literature that statistically proves this causal relationship, this being the research gap identified by us. Additionally, it will also be present the average intensity noted of each difficulty according to the perception of lecturers involved with sustainability initiatives in engineering courses. The main contribution, in turn, lies in the fact that the results presented here can be used in future researches or as a guide for lecturers and course coordinators.

Besides this introduction, the article contains four more sections. Section 2 is dedicated to the literature review about sustainability in engineering education and the difficulties associated with its insertion. Section 3 describes the methodology used, showing the research classification and the procedures that allow the replication of the study by other researchers. Section 4 presents the results of the statistical treatment through Structural Equation Modeling, as well as the debates related to them. Section 5 presents the conclusions of the research. Finally, the bibliographic references used are listed in the end.

2. Background

2.1 Reports about the insertion of sustainability in engineering education

The development of an adequate curriculum to engineering education, that contemplates the sustainability concepts requires planning, time and involvement of stakeholders (Mälkki and Paatero, 2015). Debating and planning the most appropriate manner to insert these concepts increases the chances of success and contributes to the continuity of actions (Ávila et al., 2017; Danos et al., 2014; Mälkki and Paatero, 2015). Leal Filho et al (2016) corroborate with this point of view, arguing that the results and benefits of the mentioned insertion may be impaired by the lack of a previous planning.

The existing literature about the insertion of sustainability in engineering education presents interesting reports that may greatly contribute to the improvement of these courses (Edvardsson Björnberg et al., 2015; Holgaard et al., 2016; Salvatore et al., 2016; Svanström et al., 2012). The following paragraphs synthesize some of these reports, presenting their main characteristics and contributions.

In a survey conducted at eleven US universities, Salvatore et al. (2016) identified that only six of them had sustainability actions in their courses. It is important to emphasize that these actions were done in a complementary way through the provision of extra courses and not through the full integration of concepts in the great majority of disciplines.

Fenner et al. (2005) analyse the insertion of sustainable development at Cambridge University. They point out that the breadth provided in the early years of their courses facilitates moving to a multidisciplinary approach. Besides, the motivation of those involved was also important for such insertion.

Kamp (2006), in turn, investigated this integration at Delft University of Technology, in Netherlands. In 1998, three interconnected operations were approved in the University, they were: 1) the insertion of an elementary (introductory) course on sustainable development for all students of the institution; 2) the integration of this theme into all engineering courses; 3) the possibility of specialization in this subject during the graduation. The authors highlight that, for the second item, the greater challenge was to convince the lecturers that their discipline could be integrated to the sustainable development concept.

Specifically addressing one of the sustainability strands, Edvardsson Björnberg et al. (2015) reports the insertion of social responsibility at KTH Royal Institute of Technology, an important technical university of Switzerland. The authors emphasize the difficulties observed to conduct this insertion and they point out useful didactic tools as problem-based learning (PBL). The approach favours the integration of sustainable development into the engineering curriculum (Guerra, 2017; von Blottnitz et al., 2015), since students have opportunities to develop critical thinking and problem-solving skills through a self-directed study that requires interdisciplinary knowledge (Guerra, 2017).

Holgaard et al. (2016) present in their study two interesting cases of the attempt to insert sustainability in engineering education, one in Denmark (Aalborg University) and the other in Australia (Royal Melbourne Institute of Technology - RMIT). For the case os Aalborg University, especially, they highlight the importance of PBL for the success of the mentioned insertion. For the case of RMIT, they emphasize the curriculum based on capability, in which the education is focused on the necessary capabilities for students professional life.

Svanström et al. (2012) report the insertion of sustainable development concept at Chalmers University of Technology, in Switzerland. According to them, the mechanical engineering program of the University uses conceive-design-implement-operate (CDIO) framework, which favour the mentioned insertion. The CDIO is a model that aims to make engineering education better suited to the demands of the job market.

The literature also points out other useful methodologies to insert sustainability concepts into engineering couses. They are: lecturing, writing exercises, problem demonstrations, case studies, and role play (Biswas, 2012; Edvardsson Björnberg et al., 2015; Segalàs et al., 2010). Leal Filho et al (2016) mention a broader approach than problem-based learning, named project-oriented learning, that can also be used to support the integration of sustainability and engineering education.

Additionally, it is important to present some tools and methodologies to evaluate the insertion of sustainability into engineering education. Naturally, since they can be applied in all higher education courses, they may also be applied in engineering courses. Lozano and Lozano (2014) highlights these tools and methodologies, they are: Auditing

Instrument for Sustainable Higher Education (AISHE), Graphical Assessment for Sustainability in Universities (GASU), Sustainability Tracking, Assessment & Rating System™ (STARS), Sustainability Tool for Assessing Universities' Curricula Holistically (STAUNCH®). However, to obtain a positive evaluation, it is essential that the curriculum planning has been satisfactory.

At last, Segalàs et al. (2009) argue that there is no standard manner by which sustainability should be embedded in higher education. The academic community still has much more to discuss on this issue, being the disclosure of reports and the understanding of the difficulties associated with each case important elements for maturing ideas (Tejedor et al., 2017). The difficulties associated with the insertion of sustainability in engineering education will be discussed in the following item.

2.2 Difficulties associated with the insertion of sustainability in engineering education

To analyse the main difficulties associated with the insertion of sustainability in engineering education, it is important to define the concepts of multidisciplinarity, interdisciplinarity and transdisciplinarity. In multidisciplinarity, a certain challenge is split into different parts and people from distinct areas work together to solve it, with different focuses. In transdisciplinarity, a holistic approach is sought, an approach that crosses the limits of the knowledge areas, allowing full integration of different concepts. At last, in the interdisciplinarity approach, people from different areas work together to create new knowledge that does not fit into any of the original areas (Ashford, 2004; Guerra, 2017; Shields et al., 2014).

Multidisciplinarity, interdisciplinarity and transdisciplinarity, each one in its evolutionary stage, are important approaches to insert the concepts of sustainability in higher education courses, since this concept has large dimensions and can hardly be addressed in a single discipline. In engineering courses, the difficulties for using the mentioned approaches seem to be greater. The curricula of the engineering courses present very technical and relatively embedded disciplines in relation to the changes (Ashford, 2004; Desha and Hargroves, 2010; Martins et al., 2006; Mulder et al., 2012). Although they have to work in a complex global market, in which sustainability stands out as an important multidisciplinary issue, engineering students are educated in courses with restricted and isolated disciplines (Sharma et al., 2017).

For Nowotny et al. (2018), most of the difficulties associated to the adoption of interdisciplinary is due to the lack of adequate and fully integrated didactic materials that allow a broad vision of sustainability. In the same line of reasoning, Fenner et al. (2005) comment that the few existing materials become rapidly outdated due to the rapid changes noted.

Still in relation to the interdisciplinary character of sustainability, in order to satisfactorily insert this issue into engineering courses, it is important that universities be able to develop lecturers with new mentalities. These lecturers need to learn more about sustainability strands and work collaboratively with their co-workers (Iyer-Raniga and Andamon, 2016). Although this is the desired situation, Mulder et al. (2012) emphasize the resistance of lecturers as an obstacle to achieve better results from the insertion of sustainability in engineering courses.

Another barrier pointed out by Biswas et al. (2012) to obtain better results is associated to the lack of interest of engineering students in relation to sustainability concepts, highlighting in particular the social aspects. There are many reasons for it, according to the authors, who emphasize the students' lack of maturity to deal with the intrinsic complexity of the theme of sustainability. These authors also point out that during graduation, students are usually more interested in their grades than in the possible applications of concepts taught throughout their careers. It should also be noted that in some cases the disinterest may be due to the lack of alignment between what is taught in universities about sustainability and what is demanded by the market and by society (Hanning et al., 2012; Sivapalan et al., 2017).

Returning to lecturers, the lack of motivation and insecurity of them may also be characterized as a hindrance and hamper the achievement of better results. Specifically in relation to social sustainability, the lack of a clear definition of its meaning generates insecurity in lecturers during debates with their students (Edvardsson Björnberg et al., 2015). In addition, some teachers also fear losing autonomy by inserting concepts of sustainability in their disciplines and acting in a collaborative way with other lecturers (Bryce et al., 2004; Sivapalan et al., 2017). There is still a cultural perception that, when acting in isolation in their disciplines, professionals dominate a certain area of knowledge. For Mulder et al. (2012), this difficulty will only be overcome with a cultural change of the lecturers.

Some authors as Guerra (2017), Hopkinson and James (2010), Schneider et al. (2008), Shields et al. (2014), and Sivapalan et al. (2017) also mention that the overload of existing disciplines in engineering courses may be an obstacle to the inclusion of sustainability in the curriculum. Many lecturers need to work in different courses and the lack of time prevents them from developing new ideas, preparing new materials or improving existing disciplines (Desha and Hargroves, 2010).

Besides the teachers lack of time, the scarcity of resources and/or facilities to develop activities related to sustainability is emphasized by several authors as a difficulty found when it aims to insert sustainability in engineering education (Iyer-Raniga and Andamon, 2016; Rydhagen and Dackman, 2011; Sivapalan et al., 2017). The availability of resources for the development of content related to sustainability is essential to train teachers and, thus, enable them to master sustainable development concepts (Rydhagen and Dackman, 2011).

Logically, university commitment and constancy of purpose in relation to activities linked to sustainability is important to achieve better results, as mentioned by Rydhagen and Dackman (2011). However, it is still observed in several universities a conservative vision, strongly associated to institutional processes that preclude the change towards the insertion of sustainability in engineering education (Bryce et al., 2004; Hopkinson and James, 2010). The importance of the flexibility of institutional structures is due to the rigidity of these structures generates challenges for the insertion of sustainability in engineering courses (Iyer-Raniga and Andamon, 2016). The teaching of concepts associated with sustainability should be considered a priority issue (Sivapalan et al., 2017) and, for this, universities must rethink their models and institutional processes (Rydhagen and Dackman, 2011).

Focusing on the traditional disciplines of engineering courses, it is observed that many of them are taught in an isolated way and, therefore, it is difficult to insert sustainability according to a transdisciplinary vision (Sivapalan et al., 2017). When taught in specific disciplines, sustainability is generally approached in a partial way with greater focus on environmental aspects (Hanning et al., 2012). Besides, Sivapalan et al. (2017) point out the difficulty of understanding the relationship between engineering and social and environmental sustainability. Social aspects, particularly, are a great challenge for the teaching related to sustainable development in engineering education due to lack of clarity on this topic (Edvardsson Björnberg et al., 2015; Hopkinson and James, 2010).

Table 1 below summarizes the difficulties associated with the insertion of sustainability in engineering education discussed above.

Table 1. Difficulties associated with the insertion of sustainability in engineering education (Source: vide Table)

Dificulties	References
Difficulty in integrating disciplines and contents aimed at transdisciplinarity in teaching sustainability	(Ashford, 2004; Desha and Hargroves, 2010; Hopkinson and James, 2010; Schneider et al., 2008; Shields et al., 2014)
Difficulty to debate the inclusion of new activities related to sustainability because many professionals believe that the curricula of engineering courses are overloaded	(Crofton, 2000; Guerra, 2017; Hopkinson and James, 2010; Schneider et al., 2008; Shields et al., 2014; Sivapalan et al., 2017)
Lack of access to adequate and constantly updated didactic material that contemplates all sustainability strands for engineering courses	(Fenner et al., 2005; Nowotny et al., 2018)
Difficulty in debating economic and social aspects in engineering disciplines, with sustainability generally presenting a very environmental focus	(Edvardsson Björnberg et al., 2015; Guerra, 2017; Hanning et al., 2012; Hopkinson and James, 2010; Schneider et al., 2008; Sivapalan et al., 2017)
Lack of alignment between what is taught in engineering courses about sustainability and the real market needs	(Hanning et al., 2012; Sharma et al., 2017; Sivapalan et al., 2017)
Difficulty in qualifying lecturers for current needs linked to sustainability teaching	(Iyer-Raniga and Andamon, 2016; Martins et al., 2006; Mulder et al., 2012)
Lack of interest of engineering undergraduate students for subjects related to sustainability	(Biswas, 2012; Rydhagen and Dackman, 2011)
Lack of motivation of lecturers in relation to the insertion of sustainability in the engineering course	(Bryce et al., 2004; Edvardsson Björnberg et al., 2015; Fenner et al., 2005; Guerra, 2017; Iyer-Raniga and Andamon, 2016; Mulder, 2017; Mulder et al., 2012; Rydhagen and Dackman, 2011; Schneider et al., 2008; Sivapalan et al., 2017)
Lack of adequate facilities and/or resources to develop of activities associated with sustainability	(Desha and Hargroves, 2010; Iyer-Raniga and Andamon, 2016; Rydhagen and Dackman, 2011; Sivapalan et al., 2017)
Difficulty in changing disciplines and/or implementing new practices for the teaching of sustainability due to the rigidity of institutional structures	(Iyer-Raniga and Andamon, 2016; Sivapalan et al., 2017)
Lack of support from university's top management and/or the establishment of a broad program aiming at greater promotion of sustainability teaching	(Bryce et al., 2004; Holgaard et al., 2016; Hopkinson and James, 2010; Kamp, 2006; Rydhagen and Dackman, 2011; Sivapalan et al., 2017)

3. Methodology

Firstly, this section presents the research classification and, subsequently, the developed methodological procedures.

From the point of view of research strategies, this study was based on bibliographical research, panel of experts and a survey. The bibliographical research was used to raise the difficulties associated with the insertion of sustainability in engineering education, the panel of experts allowed the division of the referred difficulties into two groups and, finally, the survey provided the understanding of lecturers' perception about the difficulties. A mixed approach to the problem was used, with both qualitative and quantitative aspects of research, as Gray (2017) points out. Studying the difficulties associated with the insertion of sustainability in engineering education, we are studying educational phenomena and, therefore, we have a qualitative approach. On the other hand, using a numerical scale to quantify the degree of observation of each difficulty in the institutions' environment and to carry out statistical analyzes, we performed a quantitative approach. Considering its nature, this is an applied research and in relation to its objectives, it can be classified as exploratory. We understand that there is still much to be discussed with regard to the theme of insertion of sustainability in engineering education. Finally, the instrument for data collection was a questionnaire and the analysis of the data was done through modeling of structural equations.

The following steps were taken to achieve the results: literature review, a panel of experts to create a first theoretical model, a survey to collect data from lecturers who participated or still participate in initiatives associated to the insertion of sustainability in the engineering courses and, finally, an attempt to validate the proposed model through modeling of structural equations. Each mentioned stage will be detailed below, allowing the replication of this research by other researchers.

The review of the literature was conducted through scientific articles found in the bases Springer, Science Direct, Taylor and Francis and Emerald Insight. The terms used for the search were "engineering education", "sustainability", "sustainable development", "difficulties", "challenges", "barriers". We highlight that 50 references were used for the preparation of this article, and 22 of them were used for the structuring of Table 1.

After listing the difficulties via literature review, a panel was held with experts in engineering education. This panel was composed of 4 lecturers of mechanical engineering, 2 lecturers of production engineering, and 3 lecturers of chemical engineering. This panel's objective was to verify the need to insert difficulties not covered by the literature and to stratify them all into thematic constructs, thus creating a first theoretical model.

With the first theoretical model, it was possible to structure a questionnaire and use it as a basis for collecting data from lecturers who participated or still participate in initiatives associated to the insertion of sustainability in engineering education. The questionnaire used was composed of 18 questions, of which 11 were related to the difficulties and 7 related to respondents information. For each of the difficulties, the participants should indicate, on a scale of 0 to 10, how much they observed it in the mentioned initiatives. At extremes, note 0 indicated an unobserved difficulty while note 10 indicated a difficulty observed in an intense manner.

In Brazil, all research involving the participation of human beings, even in the character of opinion, must pass through the appreciation of an ethics committee in research. The research project and the questionnaire were submitted to the Research Ethics Committee of the University where the research was conducted and was approved, allowing researchers to perform the survey.

The questionnaire was sent to 821 lecturers of engineering and 112 answers were obtained, thus characterizing a return rate of 13.64%. Regarding the institutions where the respondents experienced the insertion, 20.87% were state, 46.96% were federal, 27.83% were private and 4.35% of the respondents did not answer. Among the seventeen different engineering courses in which the respondents taught, Mechanical Engineering, Production Engineering and Civil Engineering stand out. To facilitate data collection and tabulation, we chose to use the Google Forms platform. The questionnaire was available on the mentioned platform for a period of two months.

The resulting survey database was used to analyze the model proposed in the panel of experts and the attempt to validate this model was conducted using the Structural Equation Modeling (SEM) technique, using the Partial Least Squares method (PLS). In the SEM, the correct allocation of parameters in thematic constructs is analyzed and, later, the causal relations between these constructs are studied (Henseler et al., 2016). In order to facilitate the presentation of the results, the validation of a PLS-SEM model were divided into nine different steps, based on the considerations proposed by Hair et al. (2014) and Ringle et al. (2014). This sequence will be used to describe the results. The softwares used were G*Power and SmartPLS. These steps were also used in other researches of the group to which the researchers belong.

The first step to take is the elaboration of a model, based on the existing literature and experts' opinion, to be statistically tested. The second step is the definition of minimum sample size, through the software G*Power (Ringle et al., 2014). To calculate it, the following parameters should be used: F test for the test family; linear multiple regression, fixed model and R^2 deviation from zero for the statistical test; a test power of 80%; 5% for the probability of error; and effect size of 15% (Hair et al., 2014).

The third step is characterized by the validation of the proposed model and the application of Partial Least Squares Structural Equation Modeling (PLS-SEM). For this, PLS Algorithm must be run, using the software SmartPLS, with path weighting scheme for the weighting scheme; mean 0 and variance 1 for data metric; 300 as maximum number of iterations and abort criterion of 0.00001 (Ringle et al., 2014).

In the sequence, it is possible to evaluate the convergent validity through the average variance extracted (AVE) (forth step). To validate this step, the AVEs must have 0.50 in all constructs (Ringle et al., 2014).

In the fifth step, the internal consistency is analyzed with Cronbach's alpha (CA > 0.60) and composite reliability (CR > 0.70) coefficients. This analysis is conducted to verify the data bias, that is, the accuracy of data (Hair et al., 2014). However, specifically for SEM, composite reliability is better to evaluate the internal consistency (Ringle et al., 2014).

The sixth step aims to verify the correct allocation of the variables. For this, Chin criteria (1998) is used. To be validated, the outer loading of each variable must be higher in its own construct (Ringle et al., 2014). In step seven, the evaluation is carried out over the coefficients of determination (R^2 values). Through this analysis, the predictive accuracy of the model is measured (Hair et al., 2014). For values of 2% characterize small effect; 13% correspond to medium effect; and 26% are for large effect.

The "Bootstrapping", from SmartPLS, is used in the eighth step. This technique enable the analysis of linear correlations and regressions for p-values ≤ 0.05, with 5,000 samples. To be validated, all the calculated values must be higher than 1.96 (Ringle et al., 2014).

Finally, the last step is composed of redundancy (Q^2) and communality (f^2). This is analyzed to verify the quality of structure adjustment (Ringle et al., 2014). The Q^2 verify how much the model structure is close to what was expected for it. It should have values greater than zero. The Cohen Indicator (f^2) shows the usefulness of each construct for the model and should have values greater than 0.15 (Hair et al., 2014). These values are obtained through the module "Blindfolding" in SmartPLS.

4. Results and Discussion

4.1. Panel of experts

The panel of experts aimed to analyze the difficulties compiled from the literature and create a first model of causal relationship. The experts allocated the difficulties into two thematic constructs that are related to each other, namely: construct 1 - “Difficulties associated with structure and planning” and construct 2 - “Difficulties observed in didactic practice”. Tables 2 and 3 present the difficulties allocated in each construct. For the references of the difficulties, vide Table 1.

Therefore, the first theoretical model to be tested was defined, in which, the construct 1 influence the construct 2, as illustrated in Figure 1.

Table 2. Difficulties associated with structure and planning (Source: vide Table 1)

Plan1	Difficulty to debate the inclusion of new activities related to sustainability because many professionals believe that the curricula of engineering courses are overloaded
Plan2	Difficulty in qualifying lecturer for current needs linked to sustainability teaching
Plan3	Lack of access to adequate and constantly updated didactic material that contemplates all sustainability strands for engineering courses
Plan4	Lack of adequate facilities and/or resources to develop of activities associated with sustainability
Plan5	Difficulty in changing disciplines and/or implementing new practices for the teaching of sustainability due to the rigidity of institutional structures
Plan6	Lack of support from university's top management and/or the establishment of a broad program aiming at greater promotion of sustainability teaching

Table 3. Difficulties observed in didactic practice (Source: vide Table 1)

Pr1	Difficulty in integrating disciplines and contents aimed at transdisciplinarity in teaching sustainability
Pr2	Difficulty in debating economic and social aspects in engineering disciplines, with sustainability generally presenting a very environmental focus
Pr3	Lack of interest of engineering undergraduate students for subjects related to sustainability
Pr4	Lack of motivation of lecturers in relation to the insertion of sustainability in the engineering course
Pr5	Lack of alignment between what is taught in engineering courses about sustainability and the real market needs

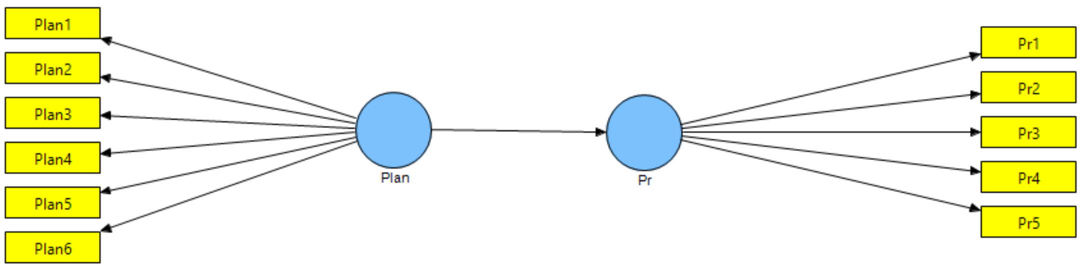

Figure 1. Theoretical initial model proposed by the panel of experts (Source: Authors)

Once defined the model to be tested, it is necessary to calculate the minimum sample size (step 2). For this, G*Power software was used with the parameters recommended by Hair et al. (2014). The results showed that a minimum sample of 55 respondents is necessary. Thus, the database with 112 respondents was fully adequate to the analysis (test power of 98.22%).

In the step three, PLS Algorithm was applied. The values obtained with this method are presented in Figure 2 and Table 4.

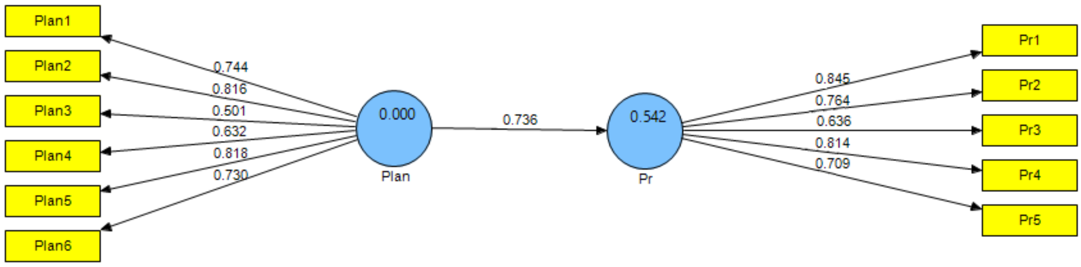

Figure 2. Values obtained by applying the PLS-SEM Method (Source: Authors)

Table 4. Quality Criteria for the analyzed model (Source: Authors)

Contructs	AVE	Composite Reliability	Cronbachs Alpha
Plan	0.512	0.860	0.804
Pr	0.574	0.869	0.813

The forth step was characterized by the analysis of average variance extracted (AVE). As can be observed through Table 4, all the values are higher than 0.50, which indicates that the satisfactory result of the model convergence. For the composite reliability (step five), all the values are higher than 0.70 and the values for the Cronbach's alpha are greater than 0.60, denoting absence of biases as recommended by Ringle et al. (2014).

The cross-loadings were analyzed in step six. This analysis aims to verify the best allocation of each variable (Chin, 1998). Using this analysis it was found that the greatest outer loads for the parameters occur in their own constructs and therefore the difficulties are correctly allocated.

The step seven analyzed the coefficients of determination (R^2 values). For the proposed model, it is necessary to calculate the coefficients of determination only for the endogenous construct, in this case the construct 2, about the difficulties observed in didactic practice. The calculated value of R^2 was 0.542 which means that the effect is large and satisfactory, according to Cohen's (1988) conception. For Ringle et al. (2014), this value denotes the quality of the adjusted model.

To verify the assumption that linear correlations and regressions are valid for at least 95% of the cases, the resampling technique was used (step 8). The t-student values observed between the parameters and their constructs were much higher than 1.96 (the lowest value identified for difficulty Plan3 = 5.025). The t-student value between the two constructs was also shown to be adequate (18.249).

At last, it was analyzed the indicators of redundancy (Q^2) and commonality (f^2), associated to the quality of the adjusted model. Through Table 5 it is possible to verify that all values are adequate, as recommended by Ringle et al. (Ringle et al., 2014).

Table 5. Quality Criteria for the validated model (Source: Authors)

Constructs	Redundancy	Communality
Plan	0.324	0.324
Pr	0.281	0.365

This validates the proposed model, in which the construct "Difficulties associated with structure and planning" directly influences the construct "Difficulties observed in didactic practice".

It is possible, with this validation, recognize that the overloaded curricula of engineering courses (Crofton, 2000; Guerra, 2017; Hopkinson and James, 2010; Schneider et al., 2008; Shields et al., 2014; Sivapalan et al., 2017), the lack of lecturers qualification (Iyer-Raniga and Andamon, 2016; Martins et al., 2006; Mulder et al., 2012), the lack of an adequate and updated didactic material (Fenner et al., 2005; Nowotny et al., 2018), the lack of adequate facilities and/or resources (Desha and Hargroves, 2010; Iyer-Raniga and Andamon, 2016; Rydhagen and Dackman, 2011; Sivapalan et al., 2017), the institutional structures rigidity (Iyer-Raniga and Andamon, 2016; Sivapalan et al., 2017), and the lack of support from university top management (Bryce et al., 2004; Holgaard et al., 2016; Hopkinson and James, 2010; Kamp, 2006; Rydhagen and Dackman, 2011; Sivapalan et al., 2017), observed during the planning phase directly influences the sustainable teaching practice in engineering courses.

As a consequence, there is lack of transdisciplinarity (Ashford, 2004; Desha and Hargroves, 2010; Hopkinson and James, 2010; Schneider et al., 2008; Shields et al., 2014), excess focus on environmental aspects (Edvardsson Björnberg et al., 2015; Guerra, 2017; Hanning et al., 2012; Hopkinson and James, 2010; Schneider et al., 2008; Sivapalan et al., 2017), students disinterest (Biswas, 2012; Rydhagen and Dackman, 2011), lack of motivation of lecturers (Bryce et al., 2004; Edvardsson Björnberg et al., 2015; Fenner et al., 2005; Guerra, 2017; Iyer-Raniga and Andamon, 2016; Mulder, 2017; Mulder et al., 2012; Rydhagen and Dackman, 2011; Schneider et al., 2008; Sivapalan et al., 2017), and a lack of alignment between what is taught in engineering courses about sustainability and the real market needs (Hanning et al., 2012; Sharma et al., 2017; Sivapalan et al., 2017).

The results presented corroborate the literature, since they reinforce the importance of adequate planning for the success of curricular changes in favor of sustainability (Ávila et al., 2017; Danos et al., 2014; Leal Filho et al., 2016; Mälkki and Paatero, 2015).

In addition, in order to quantify the observation of the validated difficulties in the model for each construct, it is presented through Figures 3 and 4 the arithmetic means for each difficult.

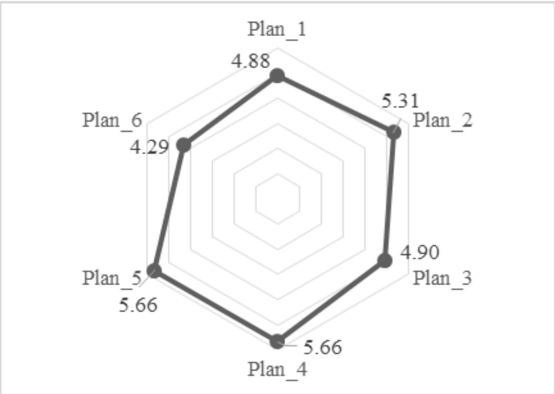

Figure 3. Arithmetic mean for each difficult from planning group
(Source: Authors).

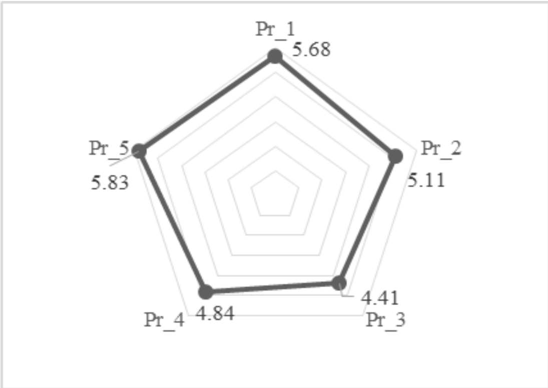

Figure 4. Arithmetic mean for each difficult from didactic practice group
(Source: Authors).

5. Conclusions

It was verified through this research that for the analyzed sample the difficulties in planning the insertion of sustainability in engineering education directly affect the difficulties found in didactic practice. Again, the originality of the present study is emphasized by the lack of studies that statistically prove this relationship.

The authors of this article understand that both the causal relationship mentioned above and the degree of observation of each difficulty can be used by academic researchers in the education area, as a starting point for future research, or by lecturer/coordinators interested in improving their courses. Based on the results presented here, lecturers/coordinators may give greater attention to the planning phase, consequently, minimizing directly the difficulties observed in didactic practice.

The main limitation of this research is due to its exploratory nature. We understand that the theme "sustainability in engineering education" still requires much debate and there are no conclusions that can be generalized for all cases. However, the statistical validation of a causal model through Structural Equation Modeling allows conclusions to be drawn for a considerable sample. As future researches, it is suggested to propose a model for the insertion of sustainability in engineering education, based on the difficulties compiled here.

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