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# **Analysis of the perception of engineering students regarding sustainability**

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## **Abstract**

The objective of this research is to evaluate the engineering students' perception regarding sustainability. For this, a survey was developed based on sustainability parameters from a detailed analysis of the Global Reporting Initiative (GRI) and the Brazilian Institute of Corporate Governance (IBGC). The parameters were initially divided into seven groups: Financial and Productivity Aspects (FPA); Concern with employees (CWE); Support for Local Communities (SLC); Ethical and corporate governance issues (ECI); Environmental aspects (ENA); Sustainable aspects in the operations network (SON); Customers, development of new products and services (CPS). The survey was conducted with engineering undergraduate students from two Brazilian universities. The data were analyzed through structural equation modeling technique, more precisely by means of the PLS-SEM algorithm. We obtained 162 answers, which enabled the validation of the model tested, and showed that the students, in general, do not consider support for local communities and concern with employees when they are analyzing sustainability. Additionally, the most important construct for them is the customers, development of new products and services. This is an exploratory study and we believe that these findings may contribute to expand the debate about the sustainability insertion in engineering courses, helping educators in their didactic activities. As future research, it is suggested the replication of this study in other higher education institutions.

## Introduction

Social and environmental degradation has been a matter of increasing concern to many stakeholders. This problem is even more difficult to handle when it is considered the necessity of economic growth to meet society demands (Fiorini and Hoekman, 2018; Marques et al., 2018; Opoku, 2019; Saunila et al., 2018). In this sense, the 17 Sustainable Development Goals (SDGs), from United Nations (UN) perform an important role to establish guidelines that companies, government and societies should seek in order to do not prejudice the future generations (Brundtland, 1987; Sales Moreira, 2018; Srivastava, 2018; UN, 2017). The Global Reporting Initiative (GRI) is aligned with these guidelines and is an important guide for companies to understand what are the items that should be reported regarding sustainability dimensions (GRI, 2018; Rosati and Diniz Faria, 2018). Additionally, ethical issues are also associated with sustainability and, in this context, guides such as those disseminated by Brazilian Institute of Corporate Governance (IBGC) play an important role in the quest for sustainable development (IBGC, 2007). However, for organizations to insert sustainable practices into their routines, professionals must be prepared.

In this sense, there is a growing need for universities to prepare their undergraduate students to work towards sustainable development (Balsiger, 2015; Hollos et al., 2012; Iyer-Raniga and Andamon, 2016; Sharma et al., 2017). Nonetheless, there are many factors that hamper the satisfactorily implementation of an Education for Sustainable Development (ESD). Among them, it may be highlighted the transdisciplinary character of sustainability and the excessive focus on environmental issues to the detriment of economic and social issues. Thus, it is evident in the literature that there are many challenges to be overcome by higher education institutions to achieve an ESD (Balsiger, 2015; Guerra, 2017; Hanning et al., 2012; Rampasso et al., 2018a). In addition to the challenges intrinsic to this insertion, the problems arising from the absence or even poor implementation an ESD must also be considered.

An important consequence of this difficulty is the negative impact that the lack of an ESD can generate in the undergraduate students when considering the importance of the academic formation in the students world view (Dagiliūtė et al., 2018). There are studies arguing that undergraduate students tend to give greater importance to the parameters related to environmental sustainability (Dagiliūtė et al., 2018; Yuan and Zuo,

2013), which is related to the difficulty of higher education institutions in providing a broader vision of sustainability (Guerra, 2017; Tejedor et al., 2018).

In engineering education this reality is no different and, given the importance that future engineers have for sustainable development, this theme has been receiving prominence in the literature over the years (Ashford, 2004; Hanning et al., 2012; Holgaard et al., 2016; McCormick et al., 2015; Segalàs et al., 2012; Sharma et al., 2017). Given this context, the present research aims to evaluate the students' perception of engineering in relation to sustainability.

For this, the following section will introduce the theoretical background regarding sustainability insertion into engineering education. Section 3 will present the methodological procedures that were used for data analysis, which is presented in section 4. The discussion and conclusion are in section 5, followed by bibliographical references.

## **Theoretical Background**

### **Sustainability insertion into engineering education**

Due to the importance that engineering has for society in all its aspects (ref), the teaching of this career has been gaining prominence in academic research and discussion forums for educators. Many aspects are discussed, highlighting the sustainability which can greatly contribute to the training of better prepared professionals (Rampasso et al., 2018b). In this context, the present literature review seeks to present the results of some researches that contributes to the debate on the subject.

Tejedor et al. (2018) stresses that in order to be effective, the insertion of sustainability in engineering education must be linked to the development of systemic thinking and transdisciplinarity. This perspective is corroborated by Guerra (2017), in which it is emphasized the important role played by PBL (Problem-Based Learning) to enable the teaching of transdisciplinarity concepts for engineering students. Additionally, the author explain the importance of teaching undergraduate students in order to insert the concerns related to sustainability issues into their professional identities.

Due to the important role played by engineers in societies to enable the sustainable development, there are many examples of cases reporting experiences of sustainability insertion into engineering courses (Thürer et al., 2018). Focusing on environmental

sustainability, Ramanujan et al. (2019) presented an approach to insert this dimension of sustainability into mechanical engineering undergraduate courses. The teaching approach used is classified as a guided discovery instruction. In this kind of teaching method, students need to participate more than in traditional teaching methods. They must seek to solve questions and understand the meaning of their findings. Everything guided by a professor. In their research, Ramanujan et al. (2019) used this approach to teach mechanical engineering students to consider environmental sustainability when performing a shape synthesis design task. The authors found out that guided discovery instruction was effective in enabling students to understand complex issues, such as the difficulties to consider the environmental negative impacts of designs, as well as the importance to take it into account in their decisions.

Although much more discussed nowadays, the analysis of sustainability insertion into engineering undergraduate courses are not new. In 2005, Kumar et al. (2005) evaluated how this issue was being considered at Michigan Technological University, in the course of mechanical engineering. Based on experiences from this university, the authors highlight the need for mechanical engineers to consider the consequences of their decisions not only in the technical perspective but also the impacts for society, environment and economy. Using the concept of interdisciplinary, the authors point out the necessity to relate topics from engineering courses with subjects from humanities and social sciences in order to properly insert sustainability into undergraduate courses. Regarding the approach, they highlight the usefulness of experiences of teaching in which students needs to be more active than they are in traditional teaching methods.

Holgaard et al. (2016) compare two experiences of sustainability insertion into engineering curricula, one in Denmark and the other in Australia. The authors also provide a conceptual framework to explain the sustainability insertion mechanism evaluated. In their framework, actors, resources and activities are considered for both internal and external environment. This framework provides the possibility to analyze how the mentioned insertion should be done or is being done. Both cases studied were analyzed through this framework. In Denmark, authors verified that researches on this theme were growing and partnerships with United Nations Organization for Education, Science and Culture (UNESCO) were enabling initiatives regarding problem-based and project-based learning (PBL). In Australia, the scenario was different, there, the starting point is based in practical experiences. Based on the analysis of these cases, the authors

developed a five-steps model to guide this insertion into engineering curricula. The first step is to identify the activities, actors and resources that the higher educational institution has to promote (or that is promoting) an ESD. The second step is the identification of enablers inside the institutions. The third step is the analysis of the country context and evaluation of former experiences. The forth step is the development of a path to be followed to materialize the insertion. The last step is the establishment of strategic partnerships to enable a long term ESD implementation.

Analyzing the curricular restructuring of a Chemical Engineering course in South Africa, von Blottnitz et al. (2015) focused on the introduction of sustainability concepts in the course. The authors verified that complex issues can be taught in the beginning of undergraduate courses since it be properly done. An important tool used to enable it was a project work, which was used for students to apply the theory and to develop abilities. The development of the capacity for critical analysis in the students was considered well succeed.

Leal Filho et al. (2018) performed case studies in seven countries to analyze the education for sustainability in higher educational institutions of these countries. Two of these studies involved engineering undergraduate courses: Manchester Metropolitan University, UK; and Polytechnic University of Catalonia, Spain. In Manchester Metropolitan University, engineering undergraduate students were involved in PBL interdisciplinary projects related to local community. A group of these students earned the Global Dimension in Engineering Education European award, an award to initiatives for sustainable development in engineering. In Polytechnic University of Catalonia, initiatives to promote training focused on sustainable development into engineering courses have been taken for years, in order to develop critical thinking in students. Participation in Non-Governmental Organisations (NGOs) are used to enable academic activities in this sense.

Rampasso et al. (2018b), through action research, analyzed the development of critical thinking regarding sustainability in students of mechanical engineering at University of Campinas. The research was conducted in a discipline called “Productive Systems” and focused on the economic, environmental and social aspects of sustainability. The main difference of the approach used in the analyzed discipline was the focus on social and environmental aspects of sustainability, since the economic dimension is traditionally addressed in this kind of course. During the explanatory classes,

different points of views are presented to the students regarding organization of work, that is, besides the traditional perspective of it, the critics made for this organization of work are also presented. Positive and negative impacts for local communities and for the environment are discussed too. A final project of the discipline demands that students consider all these perspectives to present a reasonable productive system. The authors highlight the importance of using innovative ways of teaching to properly insert sustainability into engineering education.

From the information presented, it can be seen that the debate about the insertion of sustainability in engineering courses can still be expanded. And, understanding how students think about sustainability can contribute to improving the training of engineers. Thus, the importance of the present study.

## **Methodological Procedures**

This section is dedicated to the presentation of the methodological procedures used to conduct this research. We believe they can be very useful to other researchers who want to understand how engineering students think in terms of sustainability. The reliability of this research is thus sought.

### **3.1. Research classification**

This research was based in three research strategies: literature review, to base the research's importance and to collect data to develop the questionnaire; a panel of experts, to organize the constructs of the model to be tested; and a survey with undergraduate students, in order to understand how they think about sustainability, that is, what are the parameters that really matters when sustainability is considered. The simultaneous use of qualitative and quantitative approaches used characterized a mixed approach (Gray, 2017). The statistical treatment of the data is quantitative, while the analysis of the parameters and the panel of experts are characterized as qualitative. Additionally, this research presents an applied nature and exploratory objectives. The data was collected through a questionnaire and analysed via Partial Least Squares - Structural Equation Modeling (PLS-SEM). The next subsections detail better the steps taken.

### 3.2. Compilation of parameters and panel of experts

The compilation of the parameters used were conducted through an analysis of the Global Report Initiative (GRI) and the Sustainability Guide for Companies of the Brazilian Institute of Corporate Governance (IBGC). The parameters were divided according to the panel of experts, which was composed by 8 members. They all have experience in sustainability issues. The members selected have more than ten years of experience. The panel of experts is a qualitative technique that may be used in a preliminary phase of the research (Campos et al., 2010; Pinheiro et al., 2013). In this research, one meeting was conducted and the consensus regarding the constructs was achieved in the fourth round. The result of the panel was the first model to be tested through PLS-SEM. The Table 1 was structured with the parameters used in this research.

Table 1. Sustainability parameters. Source: Adapted from (GRI, 2018; IBGC, 2007)

Constructs	Code	Parameters
<b>Financial and Productivity Aspects (FPA)</b>	FPA_1	Generation and distribution of revenues for investors.
	FPA_2	Concern about investing in projects that guarantee the continuity of the company in the long term.
	FPA_3	Analysis of risks and opportunities made on an ongoing basis.
	FPA_4	Constant concern about increased productivity and efficiency.
<b>Concern with employees (CWE)</b>	CWE_1	Combat any kind of discrimination of gender, age, salary aspects, etc.
	CWE_2	Granting benefits to employees (examples: health plan, retirement plan, etc.)
	CWE_3	Providing training and refresher courses / training to employees
	CWE_4	Maintaining constant discussions and discussions with unions in the categories.
	CWE_5	Concern about minimizing (or eliminating) risks of occupational accidents and diseases.
<b>Support for Local Communities (SLC)</b>	SLC_1	Investments in projects that favor local communities (e.g. health centers, schools, etc.).
	SLC_2	Hiring employees living in local communities, including employees for management positions.
	SLC_3	Constant monitoring of needs presented by local communities.
	SLC_4	Establishment of goals and performance indicators to follow the evolution of social projects.
<b>Ethical and corporate governance issues (ECI)</b>	ECI_1	Establish guidelines and mechanisms to combat internal corruption.
	ECI_2	Compliance with laws and transparency in disclosure of information.



	ECI_3	Absence of anti-competitive behavior (e.g. antitrust and monopoly practices)
	ECI_4	Excellence in the management of tax benefits obtained from the government.
	ECI_5	Equal treatment of all stakeholders
	ENA_1	Adequate use of energy resources and water resources.
	ENA_2	Minimizing emission of polluting gases (e.g. CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub> , etc.)
<b>Environmental aspects (ENA)</b>	ENA_3	Compliance with environmental laws and regulations.
	ENA_4	Concern about reverse logistics.
<b>Sustainable aspects in the operations network (SON)</b>	SON_1	Application of criteria that contemplate all aspects of sustainability in the selection of suppliers.
	SON_2	Insertion of the sustainable aspects in the projects developed with the other partners of the operations network.
	SON_3	Concern about the sustainable performance of the whole productive network and not only the company.
<b>Customers, development of new products and services (CPS)</b>	CPS_1	Understanding customer needs in relation to new products, services and sustainable trends.
	CPS_2	Insertion of sustainability in the development of new products or services.
	CPS_3	Analysis of the perception of the client regarding the use of a product or service that contemplates the sustainable aspect.
	CPS_4	Concern to spread concepts of sustainability for all clients and society in general.
<b>General note for sustainability (GNS)</b>	<b>GNS</b>	General note for sustainability (GNS)

### 3.3. Survey

From the parameters collected in GRI and IBGC a questionnaire was developed and applied in undergraduate students from University of Campinas (Unicamp) and Federal Fluminense University (UFF – campus Niterói). The students of UFF were from Mechanical Engineering. The students of Unicamp were from Mechanical Engineering and Control Automation Engineering. Both courses of Unicamp were used due to the similar structure of them.

The questionnaire had 38 questions (8 related to respondents' information and 30 regarding the model to be validated). For each of the aforementioned parameters, the respondents should point to a scale from 0 to 10 as they observed it in companies in Brazil. At the extremes, note 0 indicates the non-observation of the parameter and note 10

indicates intense observation of said parameter. The questionnaire was approved by the ethics committee in research, as required for research in Brazil.

A total of 1,552 questionnaires were sent, for 1,151 students of Unicamp and 401 students of UFF. After two months, 162 questionnaires were received, characterizing a response rate of 10.43%. The sample was characterized by 79% of students from Unicamp and 21% from UFF; 83% of mechanical Engineering students and 17% of Control Automation Engineering. Regarding the percentage of the course already completed, 18.5% completed until 25%; 21.6% completed between 25% and 50%; 24.1% completed between 50% and 75%; 35.8% completed between 75% and 100%. All the respondents were over 18 years old.

### **3.5. Data analysis**

The Structural Equation Modeling (SEM) “is a powerful statistical approach for the testing of hypotheses about networks of direct and indirect theoretical causal relationships in complex data sets with intercorrelated dependent and independent variables” (Lamb et al., 2014, p. 2434). Linear relationships between latent and observed variables can be tested from hypothesized models (Harring et al., 2015). There are two techniques in SEM, the first is the Partial Least Squares (PLS) method and the second is the covariance based (CB) method (Hair et al., 2014). PLS is a more appropriate approach for research with causal-predictive analysis, allowing exploratory research to be carried out. While CB is best suited to test more established theories (Nejati et al., 2017). This study uses the first technique, since it presents an exploratory character.

PLS-SEM has been used in the academic world as a tool for data analysis (Chekima et al., 2017; Diaz-Ruiz et al., 2018; Rehman et al., 2016). Its popularity is partly due to the fact that it is a tool that does not require large samples to analyze data (Kuei et al., 2015; Laguir et al., 2015). In addition, because it is a technique called soft modeling, PLS has greater flexibility in handling data than other techniques. However, it is important to note that only distribution assumptions are characterized by being "soft", the model estimates provided by this technique are very robust. The term "soft" is more related to the idea of "plasticity" or "flexibility" of the technique (Hair et al., 2014). The path coefficient presented by PLS-SEM represents the strength of association between the analyzed constructs (Hwang et al., 2016). The PLS-SEM aims to maximize the

explained variance of dependent latent constructs (Gallardo-Vázquez and Sanchez-Hernandez, 2014). This approach is divided into nine steps, described below. These steps are based on Ringle et al. (2014).

The first step is to define a structural model to be statistically tested. This model should take into account the initial hypotheses of research. After the model is structured, the minimum sample size should be calculated. For this, the G \* Power software may be used (second step), with test power of 80% and median effect size of 15%, according to the recommendations of Hair et al. (2014).

The third step consists in the validation of the structural model using the least squares (PLS) method. For this, the collected data must be saved in .csv format and must be loaded in the SmartPLS software. When running the PLS algorithm, the following parameters should be used: Path Weighting Scheme, zero mean and variance of 1, the maximum number of interactions to converge the model was 300; and the criterion of stopping the calculations was 0.00001. A series of information is then provided by the software and the criteria for analyzing this information are detailed in the next steps (Ringle et al., 2014).

In step 4, the convergent validity is measured through the analysis of the Average Variance Extracted (AVE). For results to be considered satisfactory, all values for AVEs must be greater than 0.50. Step 5 consists of checking the internal consistency, through Cronbach's Alpha and Composite Reliability. To be satisfactory, the values should be greater than 0.60 and 0.70 for Cronbach's Alpha and Composite Reliability, respectively. According to Ringle et al. (2014), the Composite Reliability is more appropriate for the Modeling of Structural Equations.

The discriminant validity is evaluated in step 6. This is the verification of the correct allocation of the parameters in their respective constructs and the certification that the constructs are independent. For this, Ringle et al. (2014) recommend cross-load analysis. Through it, one must verify if the factorial load of each parameter is greater in its own construct than in other constructs. In step 7, the Pearson's coefficients ( $R^2$ ) are analyzed.  $R^2$  values of 2%, 13% and 26% are considered low, medium and great effect for administrative sciences (Cohen, 1988).

Step 8 is characterized by the evaluation of linear correlations and regressions. When running Bootstrapping in SmartPLS software, the values obtained must all be

greater than 1.96 (which shows p-values  $\leq 0.05$ ). This indicates that the correlations and regressions are valid for at least 95% of the cases. It is important to note that Bootstrapping presents different results (although very close) every time it is run, since it uses random sub-samples.

Finally, step 9 is composed by the analysis of the Relevance or Predictive Validity ( $Q^2$ ) and Cohen Indicator or Communalities ( $f^2$ ) parameters. To obtain them, it is necessary to run Blindfolding. Values above zero for Predictive Validity and above 0.15 for Communalities are considered satisfactory (Ringle et al., 2014). Through these nine steps, it is possible to statistically validate a model via PLS-SEM. These steps were performed in this research.

## **Results**

### *Panel of experts*

After collecting several parameters from GRI and IBGC, the panel of experts was performed. As a result of the panel of experts, the first theoretical model to be tested was obtained. The division of the parameters into more than three constructs is due to the fact that there are parameters that would fit into more than one construct, for example, the parameter “Establish guidelines and mechanisms to combat internal corruption” could be allocated either into social or economic dimension of sustainability. As well as “Compliance with laws and transparency in disclosure of information” could fit into social, economic or even environmental dimensions. This discussion was performed during the panel of experts and resulted in the division of the parameters into seven constructs are presented in Figure 1.

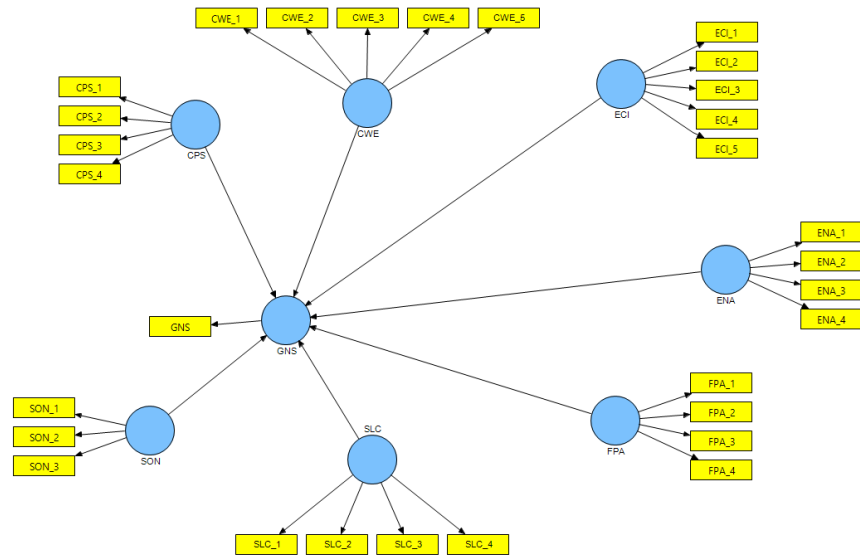


Figure 1. First Theoretical Model. Source: Authors

### *Problems faced during the validation through PLS-SEM*

The validation through PLS-SEM aims to obtain the best fit of the model. Therefore, when results are not in accordance to the literature, researchers should perform changes in order to define this adjustment. In this study, the first attempt to validate the model presented a problem in calculating the AVE for the ECI construct. The AVE was less than 0.5. To solve this, the parameter with the lowest factorial load (ECI\_3 - Absence of anti-competitive behavior (e.g. antitrust and monopoly practices)) was removed from the construct. This change increased the AVE of the construct ECI, showing that the other parameters were sufficient to explain the construct.

The second problem faced in the model was when the Bootstrapping was run. After removing the two with the lowest values (SLC and CWE), the model was validated, with all values above 1.96. The next subsection presents the validation of the final model, obtained after these adjustments. The final model design is presented in Figure 2.

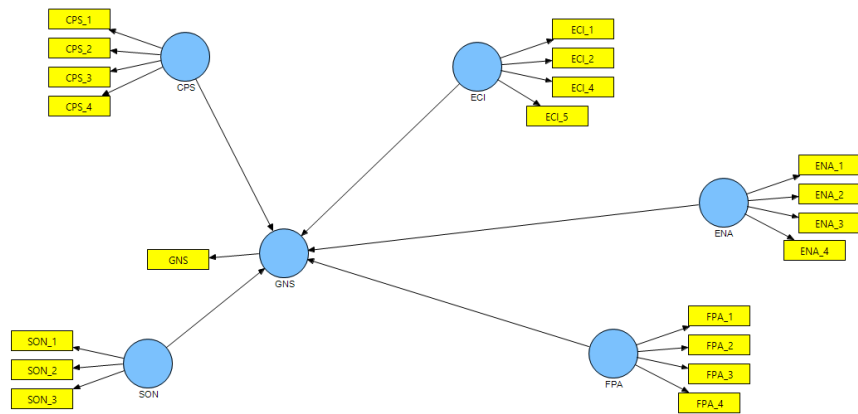


Figure 2. Final Model. Source: Authors

### *Validation through PLS-SEM*

With the theoretical model (step 1), the second step to take was the sample calculation. The software G\*Power presented the need to obtain 103 respondents to have a test power of 80%. Once we had 162 respondents, the test power is 96,24%. After this, the PLS Algorithm was run (step 3) and presented the following Figure 3.

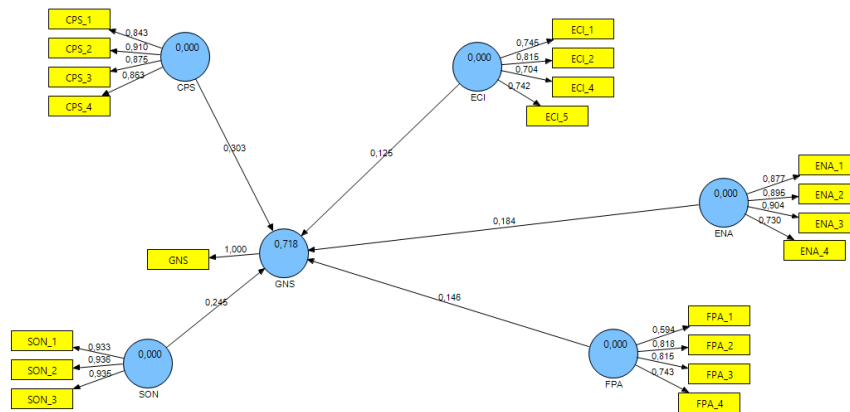


Figure 3. Values obtained by with the PLS-SEM Method. Source: Authors

The Table 2 shows the results presented in the report of PLS Algorithm. They are used to validate the next steps.

Table 2. Quality Criteria results. Source: Authors

Constructs	AVE	Composite Reliability	Cronbachs Alpha
CPS	0.763	0.928	0.896
ECI	0.567	0.839	0.744
ENA	0.730	0.915	0.875
FPA	0.559	0.833	0.731
GNS	1.000	1.000	1.000
SON	0.873	0.954	0.927

As it can be verified in Table 2, all the values from AVE were higher than 0.50 (step 4). Values of Cronbach's Alpha and Composite Reliability were also validated (step 5). These steps checked the convergent validity and the internal consistence of the model. That is, the step 4 shows that the “the model converges to a satisfactory result” (Ringle et al., 2014, p. 62) and the step 5 proves that no bias was detected in the sample data (Ringle et al., 2014).

In step 6, it was verified whether the parameters were correctly allocated in their constructs. The results showed that all the parameters presented their factorial loads higher in their own constructs than in the others, showing that they were correctly placed. In the step 7, the Pearson's coefficient ( $R^2$ ) was checked. In this research, there is only one  $R^2$  since just one endogenous construct (Ringle et al., 2014). The value of  $R^2$  was 0.718, which means that the model presents a great effect regarding its adjustment quality.

The step 8 was characterized by the linear correlations and regressions analysis. Through Bootstrapping, it was possible to verify that all the correlations and regressions are valid for at least 95% of the cases, since no values were below 1.96, as it is showed in Figure 4.

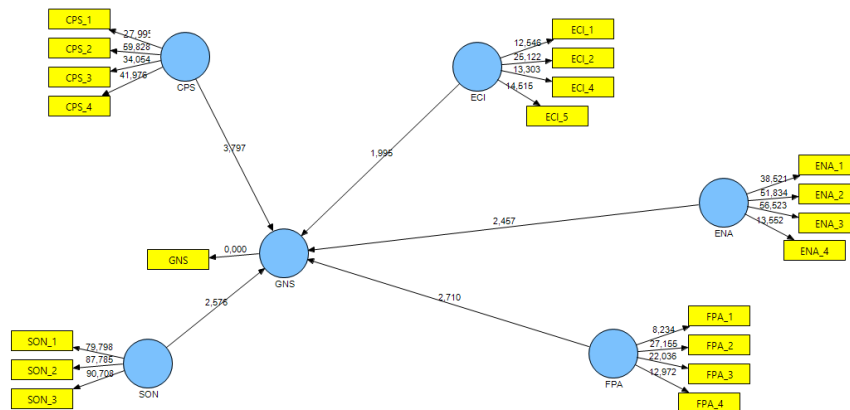


Figure 4. Values from Bootstrapping Algorithm. Source: Authors

In the last step, Predictive Validity ( $Q^2$ ) and Communality ( $f^2$ ) parameters were evaluated and presented satisfactorily results, as it is shown in Table 3. In the Predictive Validity, it is possible to evaluate how close the model is from what it was expected and Communality shows the usefulness of the construct for the model. It is important to highlight that the construct GNS does not present a communality value since it is the dependent variable from the model.



Table 3. Blindfolding results. Source: Authors

Constructs	Predictive Validity	Communality
CPS	0.589	0.589
ECI	0.276	0.276
ENA	0.549	0.549
FPA	0.281	0.281
GNS	0.660	-
SON	0.696	0.696

After validating the model, the next section will present the discussions and conclusions regarding these results.

## Discussion and Conclusion

The validation performed here enable the establishment of a series of findings. The first issue to be discussed is the elimination of the parameter “Absence of anti-competitive behavior (e.g. antitrust and monopoly practices)” (ECI\_3) and the constructs “Concern with employees” (CWE) and “Support for Local Communities” (SLC). The elimination of ECI\_3 was performed through results from AVE. This means that the construct “Ethical and corporate governance issues” (ECI) can be explained only by the other four parameters. That is, according to the students’ perception, “Establish guidelines and mechanisms to combat internal corruption”; “Compliance with laws and transparency in disclosure of information”; “Excellence in the management of tax benefits obtained from the government”; and “Equal treatment of all stakeholders” are sufficient to explain “Ethical and corporate governance issues”. The reason for the eliminations of CWE and SLC is also related to the students’ perceptions. In this case, the students from our sample did not consider these issues when they are analyzing sustainability. That is, for them, the parameters related to employees and local communities are not included in their sustainability analysis. The reason for this is due to the fact that the students have low correlation with the overall sustainability grade, i.e. when students evaluate sustainability, they are not considering those parameters.

Another item important to consider is the path coefficients. The construct with the greatest influence on sustainability value is the “Customers, development of new products and services” (CPS  $\rightarrow$  0.303), followed by “Sustainable aspects in the operations network” (SON  $\rightarrow$  0.245). This result is interesting when confronted with the literature.

There are many examples of researches that point out the excessive focus on environmental sustainability as a problem in engineering education (Dagiliūtė et al., 2018; Edvardsson Björnberg et al., 2015; Guerra, 2017; Yuan and Zuo, 2013). In this research, the students do not treat this as a primary issue (its construct – ENA – was the third highest grade). The worst value of path coefficient was presented by ECI. This means that students consider its parameters as the least important from the model.

There are lessons that may be learned from these findings. The first one to be mentioned is that PLS-SEM was confirmed as a useful tool to understand how the students think and, therefore, establish plans to improve what is not satisfactory. As a consequence of it, analyzing the results of this study, it is clear that students from the sample must be better prepared in relation to social aspects of sustainability, especially the concerns regarding employees and local communities. This is particularly important when it is considered the role of engineers in the development and improvement of production systems (Rampasso et al., 2018b). Another issue relevant to be addressed is the fact that maybe the environmental sustainability has not been emphasized enough in engineering courses. The link between sustainability concerns and the development of new products and services is important but it is not sufficient. Engineers must present reasonable levels of concern regarding environmental issues, such as a proper use of water and energy, emission of polluting gases, legislations, as well as they must be aware that they are responsible for what they produce and that the disposal of their products is the responsibility of them and their companies.

Although it is an exploratory research, the findings here can be useful for researchers to use this study as starting point for others studies and for professors and coordinators from higher education institutions that can use these findings to analyze their own engineering courses and evaluate what they need to prioritize in the improvements they perform. As a future research, it is recommended that the replication of this methodological procedure in undergraduate engineering courses from other higher education institutions in order to widen the debate about students' perception regarding sustainability issues.

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