A Didactic Activity for Introducing Design and Optimization of Experiments Assisted by Revised Bloom's Taxonomy

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Abstract

The methodology used in this study was action-research and the considered activity is been applied successfully for at least five years to undergraduate and to master classes for Industrial Engineering students in Brazil. It showed a significant result in both cases, providing the basis for the deepening in the subject in further lessons. Therefore, the main purpose of this paper is to present this didactic activity that uses a statistical software to introduce the subject Design of Experiments (DoE) starting from a simple process of everyday life. Despite DoE in Brazil being emphasized in Industrial Engineering, this issue is extremely relevant in all areas of research where there is experimentation. The activity's idea was to make students able to interact and understand the concepts of planning and optimizing experiments in a natural and intuitive way by following seven steps proposed in the literature: 1. Recognition and statement of the problem, 2. Choice of factors, levels, and ranges, 3. Selection of the response variable, 4. Choice of experimental design, 5. Conduction of experiment, 6. Statistical data analysis, and 7. Conclusions and recommendations. In order to confirm and strengthen the learning process, some exercises are then offered to students. To ensure the effectiveness, the exercises were designed based on the new version of the Taxonomy of Educational Objectives, also called Revised Bloom's Taxonomy. This proposed exercises discuss the content at all levels of the cognitive domain.

Keywords: Teaching strategies, Design of experiments, Optimization of experiments, Revised Bloom's taxonomy

1. Introduction

Teaching requires critical reflection on practice. The teacher must be aware of the fact that teaching is not only to transfer knowledge but also create possibilities for their own production and construction (Freire, 1996). Under these assumptions, the idea of this paper is to show an activity that makes students interact to better understand introductory concepts of a specific discipline in a natural and intuitive way, offering the basis for deepening in the subject in further lessons.

Conduct experiments and analyze data are an integral parts of the engineer's work, therefore the statistic is present in his daily life. Although the Design of Experiments (DoE) is still insufficiently utilized in the industrial environment, it is known that its use increases the engineers effectiveness and the process efficiency (Tanco, Viles, Ilzarbe, & Alvarez, 2009). The use of Six Sigma methodology has made the DoE even more necessary, as this is a key tool that aims to minimize the waste of time and resources while promotes a more reliable result for experimentation.

Researching for "Design of Experiments" at the database *ISI Web of Science,* it is possible to observe that the term appears in approximately six thousand articles in various areas of knowledge, and both numbers of articles published and citations in this subject have been increasing since 1994, as illustrated in Figure 1.
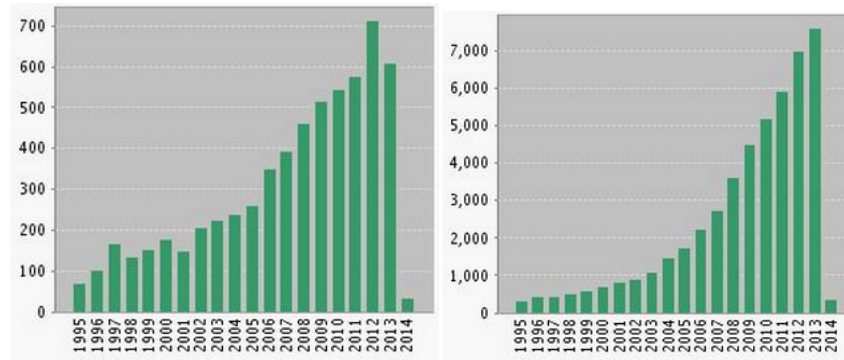
Figure 1. Number of published articles (a) and citations (b) about "Design of experiments" at the database *ISI Web of Science*

The methodology used in this work was action-research due to the fact that the central idea is to use a scientific approach to study a problem together with those who are directly linked to it (Coughlan & Coghlan, 2002). It was applied several times for at least the last 5 years at the Federal University of Itajubá-MG, Brazil with Industrial Engineering students (undergraduate and postgraduate).

There is a considerable amount of literature about nontraditional approaches for instruction and the benefits derived from implementing such approaches, but the student's opinions were left out in this discussions. Therefore Johnson & Dasgupta (2005) surveyed introductory statistics students about various aspects of their class preferences and proved statistically (p-value<0.001) that the overall percentage of students preferring non-traditional methods was significantly higher than the percentage of students preferring lecture style classes.

However, while learning can be better acquired through problem-solving experience, Wang, Wu, Chen, & Spector (2013) state that the knowledge learnt from this experience is difficult to be retained and reused. Therefore, they proposed a visualization-based learning environment that helped learners to articulate and connect complex problem-solving and knowledge-construction processes. For that reason, the visual factor is extremely emphasized at the didactic proposal described in this work. This kind of situation is a perfect example of active learning because the students are not just a recipient of teacher's knowledge.

If a teacher never had experienced active learning, he can be reluctant to try something different from lectures. In this case, Roseth, Garfield & Ben-zvi (2008) suggest a collaborative teaching group to help by sharing experiences, providing guidance and support. By working collaboratively, statistics educators can help lead and support each other in moving to a more centered instruction. To implement a new approach, teachers must know their students, but they should also know themselves. Lesser & Pearl (2008) suggest to start off with the lower-risk modes that fit most within their comfort zone or personality.

Thus, to complement the learning process of this work, some exercises are also proposed in order to guide the study and improve the apprenticeship. The exercises were drawn from the "Revised Taxonomy of Educational Objectives" or "Revised Bloom's Taxonomy" and discuss contents at all levels of cognitive domain to ensure the effectiveness of teaching.

This taxonomy is a framework to classify what should be expected from student's learning as a result of lessons that was originally published in 1956 and rewritten 45 years later, when it was called Revised Bloom's Taxonomy (Krathwohl, 2002). The exercises based on this taxonomy could be also used as a way to receive feedback from students about teaching without the teacher feeling uncomfortable for doing this.

In order to achieve the proposed objectives, this article was written in seven sections. The first being the Introduction and the second the Material and Methods to reproduce this study. The third and fourth sessions approach the design and optimization of experiments, respectively. Section 5 concerns the exercises based on revised Bloom's Taxonomy, session 6 the results of this work and some discussions about it, and the last section presents the conclusions and proposals for future work in this subject.

2. Material and Methods

For designing experiments, some guidelines are proposed by Montgomery (2001) and they are divided in seven steps as shown in Table 1. For more details, especially in the industrial applications level, it is interesting to consult Coleman & Montgomery (1993).

Table 1. Guidelines for Designing an Experiment

1. Recognition of and statement of the problem;
2. Choice of factors, levels, and ranges; } Pre-experiment planning
3. Selection of the response variables;
4. Choice of experimental design;
5. Conduction of the experiment;
6. Data analysis;
7. Conclusions and recommendations.

Source: Montgomery (2001)

The first three steps constitute the pre-experiment planning phase. These seven guidelines are usually interactive and its structure is not rigid. Some steps can even be performed simultaneously or in a different order when applied in real experiments and this should be emphasized by the teacher.

The experimental project in this activity will be developed with the support of the software *Minitab*®, but it can be used any other statistical software that support this kind of analysis. All students must follow the procedure on their computers and make the necessary notes in order to reproduce it or replicate it later. The exercises can be done on the computer or on individual sheets, but in both cases the teacher should have access to the student's results to use them as a teaching feedback.

2.1 Designing an Experiment

A simple process of everyday life can be an interesting and funny example to introduce Design and Optimization of Experiments in the classroom. In this activity, the teacher must propose an academic study of "Making popcorn in the microwave" because it is an easy, simple and a well-known process.

A humorous process will strength the relationship between students and teacher. Putting some humor into a statistics based course might make the students more willing to learn because they will feel relax and not afraid of learning it, so, the efficiency of learning can be increased according to Friedman, Friedman & Amoo (2002).

2.2 Pre-Experimental Planning

2.2.1 Recognition of and Statement of the Problem

The first step in planning experiments is the introduction of the process whose general model is illustrated in Figure 2 and the example to be discussed is "make microwave popcorn", an example of simple process that can be easily reproduced by the student at home because is related to an activity of daily living.
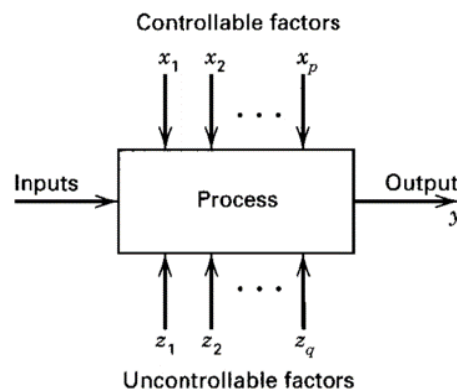

Figure 2. General model of a process or system (Montgomery, 2001)

Before start explaining how the Design of Experiment process should be conducted, it is necessary to consider three recommendations on the efficient use of DoE: use non-statistical knowledge about the problem, keep planning and analysis as simple as possible and recognize differences between statistical and practical significance (Montgomery, 2001).

Students should be asked about each process variable to participate actively on the construction of DoE. The data in

this article results from the application of this didactic activity in a graduating class in Industrial Engineering at Federal University of Itajubá.

2.2.2 Choice of Factors, Levels, and Ranges

Five controllable factors of the process were agreed by the students:

- *Time:* Preparation time should range between 3 and 5 minutes, as described in the instructions on the microwave popcorn's packages, and it is a continuous variable.

- *Power:* In general, the microwave power can be programmable, and in this case it will work with a power of 70% to 100%, being also a continuous variable.

- *Popcorn brands:* The most popular brands of microwave popcorn are X and Y. It is good to use real names to this variables when in class and it will probably differ depending on the place where this activity is applied.

- *Microwave brands:* The most popular brands on Brazilian market are A and B, this variables should also be nominated as suggestions from students.

- *Side of the package:* The popcorn package brings an information about the side it should be positioned on the microwave glass plate. The influence of this curious variable for the outcome of the process can also be investigated.

The uncontrollable factors are those that the experimenter cannot manipulate and probably its effects can be ignored to the experiment. For example, the usage time of the microwave, the amount of corn in the popcorn package, the time elapsed since the corn harvest until they were used in the experiment, the size of each corn, etc.

2.2.3 Selection of the Response Variables

Two important outputs of the process were agreed between the students:

- *Amount of Unpopped Popcorn:* This output is related to productivity and can be measured by counting the unpopped corn after the process. It is deemed to have this output values near from 0 (zero). Therefore, the closer to the lower limit, the better is the process.

- *Quality of Popcorn:* The values of this output must be defined through a survey and can be represented with scores ranging from 0 (zero) to ten (10) or following a Likert scale for the agreement's level with "This popcorn is good" whose responses vary from "Strongly Disagree" to "Strongly Agree". In both cases, the more approximate to the upper limit, the better is the process.

2.2.4 Summary Table

An experiment seeks to manipulate the controllable factors and analyze their effects on the process outputs. Thus, the process variables in fact will be considered in design and optimization of experiment are summarized in Table 2.

Table 2. Summary of the variables of interest in the Design of Experiments

Controllable factors	x_1 = time [3; 5]
	x_2 = power [70; 100]
	x_3 = popcorn [X; Y]
	x_4 = microwave [A;B]
	x_5 = side [right; wrong]
Outputs	y_1 = amount of unpopped popcorn [0-200]
	y_2 = quality of popcorn [0-10]

2.3 Choice of Experimental Design

To set the number of popcorn packets (input) that must be purchased for the experiment, it is necessary to start the *Minitab®* and access the options in '*Stat / DOE / Factorial / Create a Factorial Design*'.

The box "*Number of factors*" should be filled with the amount of controllable factors to be considered in the experiment, i.e. five. Then it is possible to check the amount necessary or sufficient of experiments on the button *"Display Available Designs"*. As can be observed in Figure 3, for five factors, eight tests are inconclusive (red) and 16 or 32 experiments are sufficient (green). Consequently, thinking about the operational cost reduction, 16 experiments will be conducted, i.e., it will take 16 popcorn packages to perform the experimental procedure.

Run	Factors													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	Full	III												
8		Full	IV	III	III	III								
16			Full	V	IV	IV	IV	III	III	III	III	III	III	III
32				Full	VI	IV	IV	IV	IV	IV	IV	IV	IV	IV
64					Full	VII	V	IV	IV	IV	IV	IV	IV	IV
128						Full	VIII	VI	V	V	IV	IV	IV	IV

Figure 3. *Minitab*: "*Display Available Designs"* for setting the quantity of experiments to be performed

This information allows to define at "*Design"* button the quantity of experiments as illustrated in Figure 4.

1/4 fraction	8	III	2**(5-2)
1/2 fraction	16	V	2**(5-1)
Full factorial	32	Full	2**5

Figure 4. *Minitab*: *"Design"* to define the style of the experiment

On "*Factors"*, the controllable factors shall be also filled. The Figure 5 illustrates this table. The software *Minitab®* provides for each process a maximum of five controllable factors with two levels. Those levels could be numerical values, as preparation time and microwave power, or texts, as microwave or popcorn brands and package side.

Factor	Name	Type	Low	High
A	Time	Numeric ▼	3	5
B	Power	Numeric ▼	70	100
C	Microwave	Text ▼	A	B
D	Popcorn	Text ▼	X	Y
E	Side	Text ▼	wrong	right

Figure 5. *Minitab*: *"Factors"* to enter the controllable factors

Experiments can be random or sequential, this choice is made on "*Options"*, by checking or not the option "*Randomize runs"*. To standardize all experiments designed by students, it is interesting to use it randomized with a random number as set base, 10 for example. Figure 6 shows this option. In this work, the experiments will be realized by simulation and analyzed just for an academic purpose, but in case of real experiments, put data in sequence can facilitate filling the spreadsheet with the collected data.

☑ Randomize runs

  Base for random data generator: | 10|

☑ Store design in worksheet

Figure 6. *Minitab*: *"Options"* to set random or sequential for the experiments

After following these instructions, *Minitab®* provides to user at the tab worksheets the design of experiment of the process discussed and also the structure used in the creation is shown at the session. The table with the experiments is shown in Figure 7. Thus, the fourth step of DoE is completed.

Time	Power	Microwave	Popcorn	Side
3	70	A	X	right
5	100	A	X	right
3	70	A	Y	wrong
5	100	B	X	wrong
5	100	B	Y	right
3	100	A	Y	right
3	70	B	X	wrong
5	70	B	X	right
5	70	B	Y	wrong
5	70	A	Y	right
3	100	A	X	wrong
5	100	A	Y	wrong
3	100	B	Y	wrong
3	70	B	Y	right
5	70	A	X	wrong
3	100	B	X	right

Figure 7. Design of the experiment "Make microwave popcorn"

2.4 Conduction of the Experiment

In fact, the focus of this study is not the result of the experiments, but the teaching of the necessary procedures to conduct a DoE and the analysis of their results. Therefore, the students should be instructed to assign values to the outputs of the simulated process.

In the case of this experiment, two outputs are expected from the process: the Quality and the Amount of unpopped popcorn. For the generated results be equal in all student's computers, it is recommended to use a random set base that could be asked in class.

In this work, it was used a *Set Base = 5* for the quality of popcorn. It is possible to consider a uniform distribution to the simulated values of survey's result between 0 and 10. These values can be generated on *Minitab®* following options '*Calc / Set Base*' and filling with the value 5, then '*Calc / Random Date / Uniform*' as shown in Figure 8.

Number of rows of data to generate: 16

Store in column(s):

Quality

Lower endpoint: 0,0

Upper endpoint: 10,0

Figure 8. Generation of output results y1: Quality of Popcorn

In the case of unpopped popcorn, it was used a Set Base = 100 and the result may be simulated as a random integer from 0 to 200. It means, 0, if all corn had popped and 200, if none. These values can also be generated in *Minitab®* following options '*Calc / Set Base*' and filling with the value 100, then '*Calc / Random Date / Integer*' and completing as in Figure 9.

A table with the experiment's data and results will be ready on *Minitab®*'s worksheet as in Figure 10.

Number of rows of data to generate: 16

Store in column(s):

Amount

Minimum value: 0

Maximum value: 200

Figure 9. Generation of output results y2: Amount of Unpopped Popcorn

Time	Power	Microwave	Popcorn	Side	Quality	Amount
3	70	A	X	right	0,36366	92
5	100	A	X	right	2,55212	153
3	70	A	Y	wrong	3,52174	168
5	100	B	X	wrong	0,38507	37
5	100	B	Y	right	1,40108	79
3	100	A	Y	right	2,68532	157
3	70	B	X	wrong	4,04698	167
5	70	B	X	right	3,94334	61
5	70	B	Y	wrong	1,90322	73
5	70	A	Y	right	7,65910	144
3	100	A	X	wrong	2,34012	120
5	100	A	Y	wrong	7,59635	142
3	100	B	Y	wrong	9,11012	91
3	70	B	Y	right	8,45221	46
5	70	A	X	wrong	9,45199	130
3	100	B	X	right	4,80044	22

Figure 10. *Minitab®*'s worksheet with data and results of the previously outlined experiment

2.5 Data Analysis

From the simulated experimental data, it's possible to make conclusions about the influence of controllable factors in process outputs. This analysis can be easily done on the software *Minitab®* following options *'Stat / DOE / factorial / Analyze Factorial Design'*. The responses to be considered are the two process outputs and to analyze the factors interaction effects, on *"Graphs"* it should be selected *"Pareto"*. The Figure 11 shows the Pareto Chart for each process output.
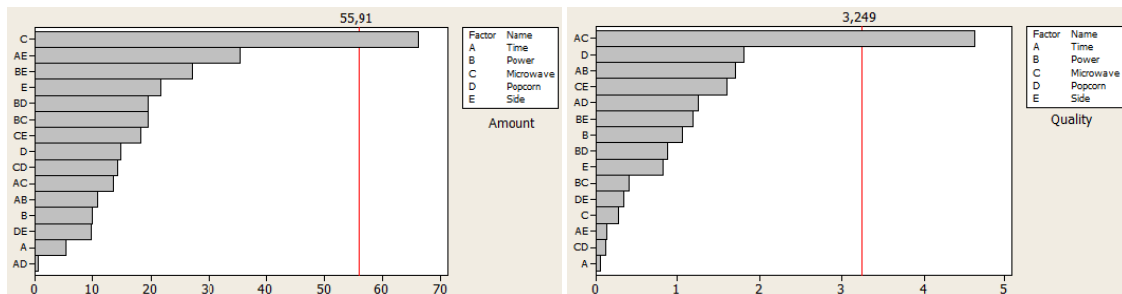

Figure 11. Pareto Chart of the controllable factor's effects on each output

The Figure 11 allows to conclude about output y1, Quality of Popcorn. The interaction between cooking time and microwave's brand has more influence in this output than other interactions or even other factors individually. For output y2, Amount of Unpopped Popcorn, the most significant factor is the microwave's brand, followed by the interaction between time cooking and package side, which is not significant because it's behind the line.

Further analysis of results can be made from the graphs generated in *Minitab*® following the options *'Stat / DOE / Factorial / Factorial Plots'*. The first two graphics options should be selected, as shown in Figure 12. In *'Setup'*, it is possible to choose which outputs or controllable factors should be considered for the graphics. The Figure 12 also shows the filling of this dialog box to examine all the options available.
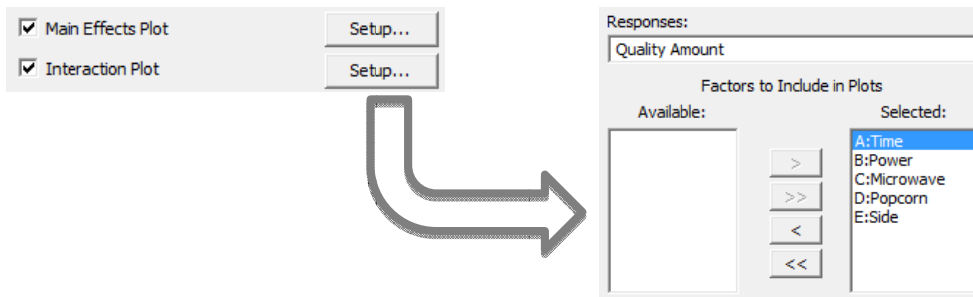

Figure 12. *Minitab*: *'Factorial plots'* and options available on *'Setup'*

The Figure 13 shows the Main Effects Plot for the two outputs of the process. About the Quality of Popcorn (y1) there is a big influence of popcorn's brand and microwave's power; the popcorn's brand Y and the power of 70% have far better results in terms of popcorn's quality than the opposite. This output also shows better results for the package in a wrong position and the microwave's brand A has slightly less influence on it. For the cooking time, there's almost none significant difference.

For the Amount of Unpopped Popcorn (y2), the analysis should be done for the lowest points since the lower the value, the better the outcome. Accordingly, the microwave's brand B presents a much better result than A. This output also shows slightly better results for 100% of power, the popcorn's brand X and the right position for the package, however, the cooking time seems not to be a significant influence for this output.
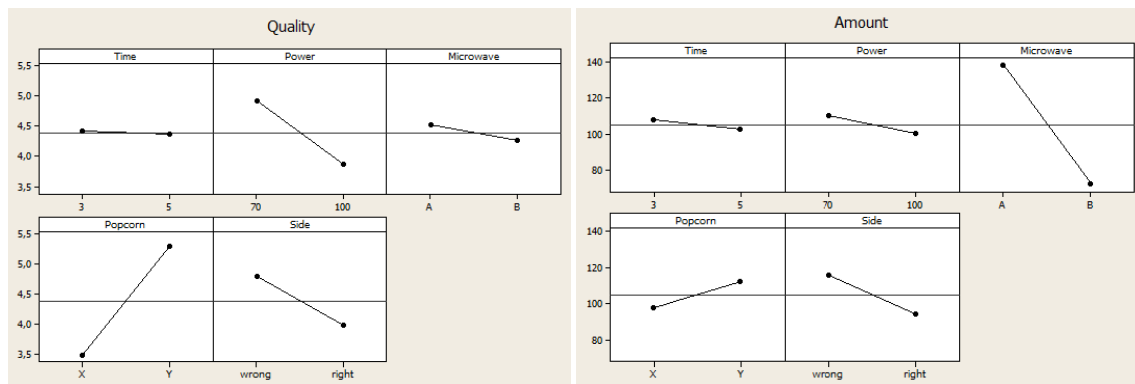

Figure 13. Main Effects Plot for each output

The Interaction Plot shows the interaction between the controllable factors. It can be seen in Figure 14 that for y1, Quality of Popcorn, there is almost no interaction between the cooking time and the package side, the microwave's and the popcorn's brand or between the package side and the popcorn's brand. However, all other interactions alter the outcome of this output. The most meaningful interaction is between the microwave's brand and cooking time.

Concerning y2: Amount of Unpopped Popcorn, there is almost none interaction between cooking time and popcorn's brand. Nonetheless, there's a lot of significant interactions, for example, cooking time and package side, microwave's power and package side, microwave's and popcorn's brand or microwave's brand and package side.
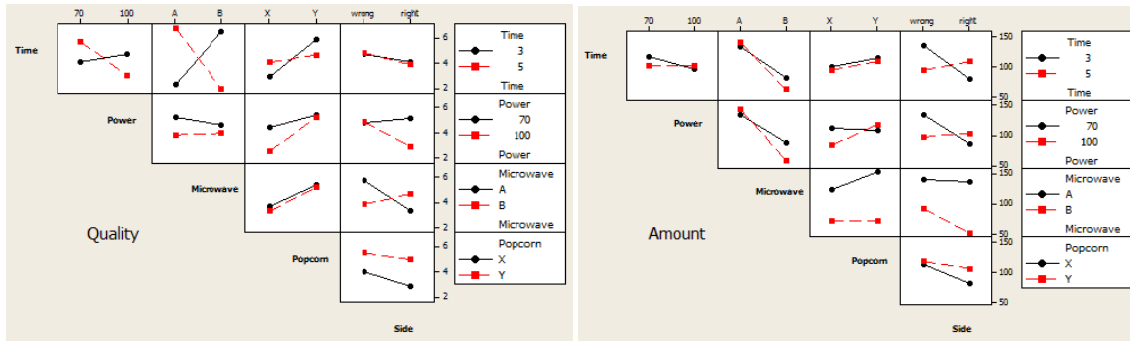
Figure 14. Interaction Plot for each output

2.6 Conclusions and Recommendations

It is important that all the practical conclusions made by the experimenter from the analyzed data be used to recommend a course of action. The conclusions should be validated, archived and presented to others; in this case it is highly recommended to use graphic and visual tools.

At this point, the teacher could also emphasize the importance of experimentation to understanding the process. Hypotheses are tested and the results can and should be used to base a new trial. A successful experiment requires knowledge of the important factors, ranges of variation, appropriate number of levels to use and the proper units of measurement for these variables (Montgomery, 2001). Generally these factors are not perfectly known but they can be discovered or refined through the process.

2.7 Optimizing an Experiment

It is possible to optimize the experiment's responses through a *Minitab*'s tool accessed in *'Stat / DOE / Factorial / Response Optimizer'*. All answers must be selected on the setup button and the table should be filled in as shown in Figure 15. The field *'weight'* must be filled as the instructions in the dialog box, with the expected behavior of the output. Additionally, the field *'importance'* must be assigned weights to each output.

	Response	Goal	Lower	Target	Upper	Weight	Importance
C10	Quality	Maximize ▼	0	10		0,1	1
C11	Amount	Minimize ▼		0	200	10	1

Figure15. *Minitab*: '*Setup*' of Response Optimizer

The tool *'Response Optimizer'*, shown in Figure 16, allows to identify the best options for the process and the expected results, or the adjustments required, if some changes must be done at choice of factors.
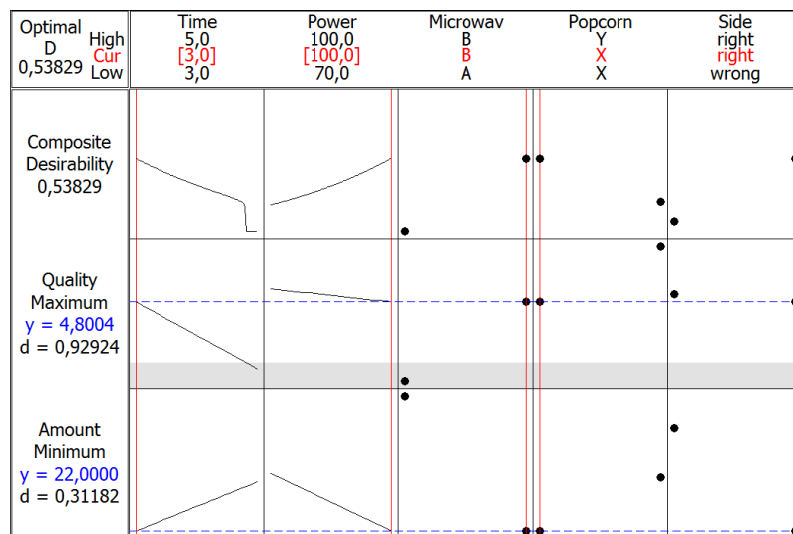

Figure 16. *Minitab*'s tool Response Optimizer

2.8 Exercises Based on Revised Bloom's Taxonomy

The idea of creating a classification system for reference in evaluations was born at informal meetings in 1948 (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1973). This work was discussed annually until its publication in 1956 titled "Taxonomy of Educational Objectives", but also known as "Bloom's Taxonomy", despite being a group project.

In 1999, it was thought an alteration of this taxonomy in order to incorporate the conceptual and contextual changes that have occurred since its publication (Anderson, 1999). This new version was published in 2001 and became known as "Revised Bloom's Taxonomy." The main differences are shown in Figure 17.
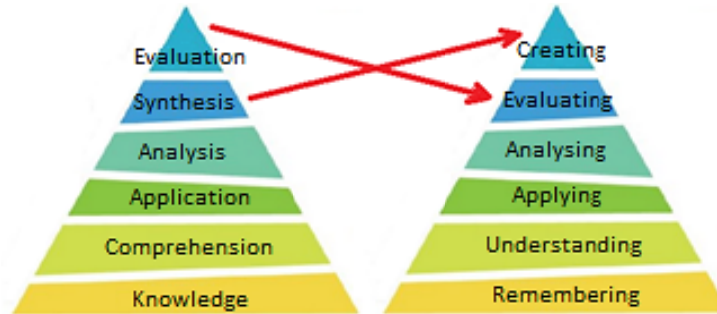

Figure 17. Original and Revised Bloom's Taxonomy

In this taxonomy, the educational objectives were divided into three domains: cognitive, affective and psychomotor. For measuring learning, it must be considered the cognitive domain. Some examples of exercises about DoE and Experiment Optimization in each level of this domain are described below:

- *Remembering*: recognize and remember ideas and theoretical concepts.

The student must remember that these topics were discussed in the text and reproduce the information. Examples: "What are the recommended steps for Design of Experiments?" or "What are the three recommendations that should be considered to use the DoE effectively?"

- *Understanding*: explain with their own words.

The student must establish a connection between the new and the previously acquired knowledge to justify his answer. Examples: "Why are the uncontrollable factors not considered in the experiment?" or "How does the analysis of Pareto Chart works?"

- *Applying***:** use rules, methods, models, concepts, principles, laws and theories.

The student must perform the same procedure done during the class to a new situation. Examples: "If there were seven controllable factors in the process, how many times the experiment should be performed to sufficiently conclusive results? And quite conclusive results?" or "From this table, construct a graph of interactions for each output."

- *Analyzing*: conclude and make statements from graphical or numerical results.

The student must know the tool and verify its results. Examples: "According to Pareto Chart, which of the controllable factors have more influence on each output?", "Analyzing the Interactions Plot, which is the most relevant to the

Quality of Popcorn?" or "What is the status of each controllable factor in the class example to which the outputs are optimized?"

- *Evaluating***:** check consistency of others production.

The student must judge the statement based on previously established criteria and standards. Examples: "The side that the package is positioned does not affect the Quality of Popcorn but the Amount of Unpopped Popcorn. Discuss it." or "About the Amount of Unpopped Popcorn, is it correct to say that there is no interaction between cooking time and microwave's power or microwave's power and popcorn's brand?"

- *Creating*: Use the interdisciplinary and the interdependent of concepts.

The student must develop visions, ideas, and new and original methods. Stimulate with experience and practical examples. Examples: "Which other everyday experiments could be an example for this class?" or "Describe a

process different from the class example and follow the steps performed to Design the new Experiment."

The Bloom's Taxonomy can be used as a guarantee of learning for a student who reaches all needed levels of the cognitive domain, for a particular content or also as a feedback for the quality of instruction.

Hattie (2009) points out feedback from the student to the teacher as the most effective factor for teaching. However, students often do not feel comfortable to give a real feedback either the teacher himself is embarrassed to accomplish a survey. Thus, these exercises could play this role, showing the poorest levels of students and enabling the teacher to conduct corrective actions or changes in his future behavior.

3. Results

When identified the deficiency in learning, how the situation can be reversed? Taking advantage of the free flow of ideas in moments of relaxation, teachers from public and private universities in the fields of Engineering and Management were informally interviewed in order to get suggestions to stimulate student learning at each level of revised Bloom's Taxonomy. A summary of results is presented below:

- *Remembering*: detailed reading of the basis book or related materials.
- *Understanding*: producing schematic summaries of theory.
- *Applying*: solving exercises together.
- *Analyzing*: showing solved and detailed examples in classroom.
- *Evaluating*: teamwork with individual evaluations.
- *Creating*: living the theory and showing practical examples.

After the application of this didactic proposal in a class, 10 (ten) questions about DoE and Experiment Optimization in each level of revised Bloom's Taxonomy were proposed for a group of Industrial Engineering students. Their mistakes were provided on a chart to enable further analysis of learning. The Figure 18 shows a boxplot of student's mistakes.
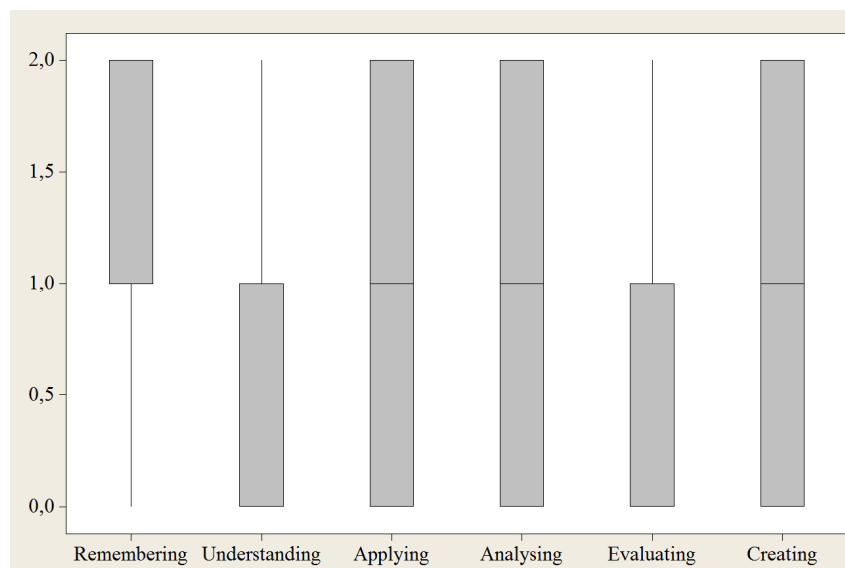

Figure 18. Boxplot of student's mistakes on the proposed exercises

The results are very similar for all levels of revised Bloom's Taxonomy, however, there were slightly more mistakes in "Remembering" and less in "Understanding" and "Evaluating" compared to others levels. Then, in this case, the first thing teacher should do is to encourage a detailed reading of the basis book or related materials because the students are not remembering as much as they should and this is the most deficient level of revised Bloom's Taxonomy as showed in Figure 18. The other levels could also be better worked and the last levels the teacher should worry about are "Understanding" and "Evaluating" because even if the results are not perfect (zero mistakes), they are closer to zero than the others.

4. Discussion

This activity was applied to undergraduate classes and also to master classes in Industrial Engineering at Federal University of Itajubá. In this work, the data and the results that were showed belong to an undergraduate class but it showed a significant result in both cases, providing the basis for further education and the tools for deepen the teaching of DoE in later lessons.

As a future project, the authors aim to expand the bank of questions based on Bloom's Taxonomy to this subject, improve the suggestions to stimulate the student learning at each level of revised Bloom's Taxonomy with a bigger research and create new teaching guides or techniques following this same pattern to other subjects. It could be also interesting to apply the same questions in a group interviewed without introduce DoE and Experiment Optimization to compare the results of both.

References

Anderson, L. W. (1999). *Rethinking Bloom's Taxonomy: Implications for testing and assessment* (p. 25). Columbia, SC USA.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1973). *Taxonomia de Objetivos Educacionais - 1 Domínio Cognitivo*. (T. de F. M. Sant'anna, Ed.) (1a. edição., p. 179). Porto Alegre: Editora Globo.

Coleman, D. E., & Montgomery, D. C. (1993). A systematic approach to planning for a designed industrial experiment: Response. *Technometrics*, *35*(1), 25. http://dx.doi.org/10.1080/00401706.1993.10484984

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management*, *22*(2), 220–240. http://dx.doi.org/10.1108/01443570210417515

Freire, P. (1996). *Pedagogia da Autonomia - Saberes necessários à prática educativa* (25ª edição., p. 168). São Paulo, SP: Paz e Terra (Coleção Leitura).

Friedman, H. H., Friedman, L. W., & Amoo, T. (2002). Using Humor in the Introductory Statistics Course. *Journal of Statistics Education*, *10*(3). Retrieved from http://www.amstat.org/publications/jse/v10n3/friedman.html

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.

Johnson, H. D., & Dasgupta, N. (2005). Traditional versus Non-traditional Teaching: Perspectives of Students in Introductory Statistics Classes. *Journal of Statistics Education*, *13*. Retrieved from http://www.amstat.org/publications/jse/v13n2/johnson.html

Krathwohl, D. R. (2002). A revision of Bloom's Taxonomy: An overview. *Theory Into Practice*, *41*(4), 212–218. http://dx.doi.org/10.1207/s15430421tip4104_2

Lesser, L. M., & Pearl, D. K. (2008). Functional Fun in Statistics Teaching : Resources, Research and Recommendations. *Journal of Statistics Education*, *16*(3), 1–10. Retrieved from http://www.amstat.org/publications/jse/v16n3/lesser.html

Montgomery, D. C. (2001). *Design and Analysis of Experiments* (5a. edição., p. 684). Arizona State University: John Wiley & Sons, INC.

Roseth, C. J., Garfield, J. B., & Ben-zvi, D. (2008). Collaboration in Learning and Teaching Statistics. *Journal of Statistics Education*, 1–15. Retrieved from http://www.amstat.org/publications/jse/v16n1/roseth.html

Tanco, M., Viles, E., Ilzarbe, L., & Alvarez, M. J. (2009). Implementation of Design of Experiments projects in industry. *Wiley Online Library*, (May), 478–505. http://dx.doi.org/10.1002/asmb.779

Wang, M., Wu, B., Chen, N.-S., & Spector, J. M. (2013). Connecting problem-solving and knowledge-construction processes in a visualization-based learning environment. *Computers & Education*, *68*, 293–306. http://dx.doi.org/10.1016/j.compedu.2013.05.004