

ASSESSMENT OF STUDENTS IN THE USE OF MATLAB GUIDE TEMPLATES FOR SOLVING MATERIAL BALANCES. A TEACHING EXPERIENCE IN CHEMICAL ENGINEERING DEGREE

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Abstract

The resolution of material balances is one of the main activities both in Chemical Engineering studies and in the development of the profession. Their resolution translates into a system of algebraic equations that can be quite complex. For its resolution, it is necessary to use mathematical software, as is the case with Matlab. However, students may have a deficit in programming skills with Matlab.

To solve this deficit, students have been provided with a Matlab template, where the student only has to enter the main parameters of each material balance in order to obtain a mathematical solution. With the aim of knowing the acceptance of the mentioned methodology for the mathematical resolution of material balances, a survey has been provided to the students, where anonymously, they respond, at the end of the subject, their main views on the matter.

Key questions such as the usefulness of the methodology, the degree of use, personal assessment, and the relationship between the use of the Matlab template and understanding of knowledge, allow teachers to determine the strengths and weaknesses of the new methodology.

Keywords: Material Balances, Matlab guide templates, survey, Chemical Engineering Degree.

1 INTRODUCTION

The material balances are one of the most used tools in the field of chemical engineering. Both the students, during their formative stage academic, such as graduates, during their professional life, make a continuation of the materials balances calculates. With this, they are able to determine typical variables in chemical processes such as flows, compositions, reactions, etc. from other known variables. The approach to material balances in steady state leads to a mathematical problem consisting of a system of equations algebraic, which can be both linear and nonlinear. In chemical processes of certain complexity, systems can be generated with a high number of equations and unknowns. This supposes, together with the intrinsic difficulty of balance statement, an added difficulty of mathematical resolution of the system of equations to determine the unknown variables of interest of the process.

Today there is general purpose mathematical software, such as Matlab, that allows you to quickly solve different types of mathematical problems, such as they can be systems of algebraic equations. However, if the user does not has adequate competence in computer programming and numerical methods, the existence of this mathematical software is not appreciated as a help and its use is not even contemplated [1].

Taking into account the above, teachers often restrict the real material balance problems that students face simple situations so that the resulting mathematical problem is simple [2]. However, why should we do this today if we have numerical methods, an enormous computing power and mathematical software at our students disposal? How can we help them deal with these problems, even though lack of computer programming skills or deep knowledge of mathematical calculation?

Therefore, the objective of this article is not the approach of material balances but its mathematical resolution through Matlab software. On the other hand, given that on many occasions, due to the aforementioned programming deficiencies on the part of the students, the use of Matlab appears unattractive *a priori*, the authors provided the students with files capable of solving algebraic equations without the need programming.

With the aim of knowing the opinion of the students themselves about this powerful and novel methodology for solving complex algebraic systems present in the material balances, the authors have developed a survey, where the students anonymously answer questions about its use and acceptance. The present study shows the results about the opinion in the implementation of this methodology by the students.

2 METHODOLOGY

First, the methodology used to provide the students with the matlab templates is described. This tool consists of two files called *template.m* and *steady_state_balances_solver.m*. In the first one is where the students introduce the algebraic equations obtained in the material balances problem. Figure 1 shows the structure of the *Matlab template*. In a simple way for the students, it has been divided into four basic points, previously explained in class: specified variables, additional relations, independent material balance equations and summation of the mole or mass fractions for each stream.

```

% Take into account all the independent material balance equations, the
% specified variables, the additional relations and the summation of the
% mole or mass fractions for each stream

% Write the equations following this exemple: eq{1}=F1==3

%% SPECIFIED VARIABLES
eq{1}=;
eq{2}=;

%% ADDITIONAL RELATIONS
eq{3}=;
eq{4}=;

%% INDEPENDENT MATERIAL BALANCE EQUATIONS
% VC1 eq{5}=;
eq{6}=;
% VC2
eq{7}=;
eq{8}=;

%% SUMMATION OF THE MOLE OR MASS FRACTIONS FOR EACH STREAM
eq{9}=;
eq{10}=;

```

Figure 1. Image of the template provide to the students.

When the information of a problem has been introduced in the template and executed (Figure 2), it is when the second file (*steady_state_balances_solver.m*) is used. In this file, the *solve* function of the Toolbox is in charge of simultaneously solving the equations. The "*solver*" file is designed to ask the student for the name of the file to be resolved (without the *.m* extension).

Next sentence shows an example of the question required, when in bold characters appears sentence that must to be written by the students.

Steady-state balance file name (without extension): **problem_example**

Then, a second question appears in the *steady_state_balances_solver.m* file. The type of the solution desired is asked, having two different options: (1) numerical solution and (2) analytical solution.

Which type of solution do you prefer, numerical (1) or analytical (2)?: **1**

```

% Take into account all the independent material balance equations, the
% specified variables, the additional relations and the summation of the
% mole or mass fractions for each stream

%% SPECIFIED VARIABLES
eq{1}=F1==1000;
eq{2}=xM1==0.2;
eq{3}=xE1==0.25;
eq{4}=xP1==0.4;
eq{5}=xP2==0.03;
eq{6}=xM4==0.995;
eq{7}=xM7==0.01;
eq{8}=xE7==0.89;
eq{9}=xB8==0.002;
eq{10}=xP9==0.7;
eq{11}=xP10==0.98;

%% ADDITIONAL RELATIONS
eq{12}=F6==0.5*F5;
eq{13}=xM6==xM7;
eq{14}=xE6==xE7;

%% INDEPENDENT MATERIAL BALANCE EQUATIONS
eq{15}=F1*xM1+F6*xM6-F2*xM2==0;
eq{16}=F1*xE1+F6*xE6-F2*xE2-F3*xE3==0;
eq{17}=F1*xP1+F6*xP6-F2*xP2-F3*xP3==0;
eq{18}=F1*xB1-F3*xB3==0;
...

```

Figure 2. Example to introduction of parameters corresponding to material balances.

Once the numerical option (1) has been chosen, the program returns in a txt file the mathematical solutions of the variables of the problem. Figure 3 shows an example of the resolution of material balance composed by 5 streams and 14 mass fractions:

```

Physical Solution:
[ F1, 1.0000e+03]
[ F2, 1.7500e+03]
[ F3, 7.0000e+02]
[ F4, 1.0500e+03]
[ F5, 3.0000e+02]
[ xA1, 6.1900e-01]
[ xA2, 8.8000e-01]
[ xA3, 8.8000e-01]
[ xA4, 8.8000e-01]
[ xA5, 1.0000e-02]
[ xH1, 3.1100e-01]
[ xH2, 2.0000e-02]
[ xH3, 2.0000e-02]
[ xH4, 2.0000e-02]
[ xH5, 9.9000e-01]
[ xP1, 7.0000e-02]
[ xP2, 1.0000e-01]
[ xP3, 1.0000e-01]
[ xP4, 1.0000e-01]

```

Figure 3. Mathematical solutions obtained by the steady_state_balances_solver.m file.

Once the methodology for using the templates has been explained, the surveys carried out are detailed. The resolution of material balances is carried out in a core subject of the second year of the Degree in Chemical Engineering. Completely anonymously and during three academic years (2017-2018, 2018-2019 and 2019-2020, with a total of 85 students surveyed), the survey showed in Figure 4 has been carried out.

SATISFACTION SURVEY ON TEACHING MATERIAL IN THE BASIS OF CHEMICAL ENGINEERING SUBJECT.					
MARK THE CORRESPONDING BOX WITH AN X					
1. Of the following didactic materials used in the course, how do you consider its level of ease of use?					
	VERY EASY	EASY	DIFICULT	VERY DIFICULT	I HAVE NOT USED THEM
Matlab guide template and Steady State					
2. Of the following teaching materials used in the subject, how do you consider their usefulness?					
	VERY USEFUL	USEFUL	LITTLE USEFUL	NOTHING USEFUL	I HAVE NOT USED THEM
Matlab guide template and Steady State					
3. Regarding the use of the Matlab template and the Steady State “solver”, do you consider its use suitable for solving material balances?					
	VERY APPROPRIATE	APPROPRIATE	LITTLE APPROPRIATE	NOTHING APPROPRIATE	I HAVE NOT USED THEM
Matlab guide template and Steady State					
4. Do you consider that the Matlab template and the Steady State “solver” help to understand material balance problems?					
	TOTALLY AGREE	AGREE	LITTLE AGREE	NOTHING AGREE	I HAVE NOT USED THEM
Matlab guide template and Steady State					
5. Regarding the Matlab template and the Steady State “solver”, would you recommend its use to other classmates or even in other subjects?					
	TOTALLY AGREE	AGREE	LITTLE AGREE	NOTHING AGREE	I HAVE NOT USED THEM
Matlab guide template and Steady State					
6. Do you think the teacher has correctly explained the approach to the material balance problems?					
	TOTALLY AGREE	AGREE	LITTLE AGREE	NOTHING AGREE	I HAVE NOT USED THEM
Matlab guide template and Steady State					
7. Do you think the teacher has correctly explained the use of Matlab templates and the Steady State “solver” for solving matter balances?					
	TOTALLY AGREE	AGREE	LITTLE AGREE	NOTHING AGREE	I HAVE NOT USED THEM
Matlab guide template and Steady State					
8. After using the Matlab template and the Steady State “solver” in the course, what is the general level of satisfaction with the solving of matter balances?					
	VERY SATISFACTORY	SATISFACTORY	UNSATISFACTORY	NOT SATISFACTORY	
Solving Material Balance Problems					

Figure 4. Survey provided to students of Degree in Chemical Engineering.

The main objective of the survey was to know the degree of acceptance of the methodology, since it allows them to solve complex algebraic systems, and it is the first time they used them during their chemical engineering studies.

The survey questions are divided into 4 aspects to study:

- 1 First two related questions about the ease of use and usefulness of Matlab guide files.
- 2 Second, questions about the adequacy of the guides to the resolution and understanding of the material balances.
- 3 Thirdly, the performance of the teachers themselves in the implementation of the new methodology with Matlab guide templates is studied. The students are asked about the correct explanation from the teachers about the resolution of material balances and the use of Matlab files.
- 4 Finally, two aspects related to the general opinion of the students: if they would recommend the use of this methodology to other classmates, even subjects, and the general satisfaction of the learning process.

Most of the responses were answered on a scale of values ranging from: *totally agree, agree, little agreement, nothing agree* or an option to detect when students have not used the guide templates provided, indicating a poor implication.

3 RESULTS

In this section, the results obtained during the last three academic course have been summarized.

The first question has been asked in order to determine the students' interpretation of the ease of use of the Matlab templates. This question is considered necessary, since the Matlab programming environment, as well as the deficit of the students in programming tasks, cause a general rejection of its use, compared to other calculation programs with a much more graphic environment, as they can be the *Excel worksheets*.

Regarding the question: "Of the following didactic materials used in the course, how do you consider its level of ease of use?", It should be noted that, contrary to expectations, more than a third (35.3%) of the surveyed students consider its "very easy" to use. It also stands out that the vast majority consider its use "easy" with 41.2% of the responses. Therefore, the Matlab templates and the use of *steady state solver* are interpreted as "easy or very easy" to use by more than 76% of the surveyed students. Authors highlights that almost 6% of the students admit not having used the tools provided, a high number of students being in agreement with the degree of abandonment of the students in some subjects of the degree of chemical engineering.

About the question asked to determine the opinion about the usefulness of the Matlab files provided for the resolution of complex algebraic systems present in balance material, more than 73% of the students consider it "very useful". Less than 10% of the students consider its use "little or not at all useful".

Therefore, analyzing the results of these first two questions, it can be concluded that students assume the use of the Matlab file templates and the steady state solver as an easy-to-use and very useful tool for solving complex algebraic systems, which would be very difficult to solve without this software. Results obtained are summarized in Figure 5.

The following questions were asked to determine if the students considered appropriate the use of the guides provided for the resolution of balance material, as well as, if they helped the interpretation and understanding of the problems raised.

Regarding the adequacy of the templates for solving problems, almost 60% of the students consider it "very adequate" and 23.5% "adequate", adding together more than 82% of the students surveyed. On the other hand, 8% of students stand out, who admit not to use the tools provided, indicating the degree of students with very poor involvement in the subject.

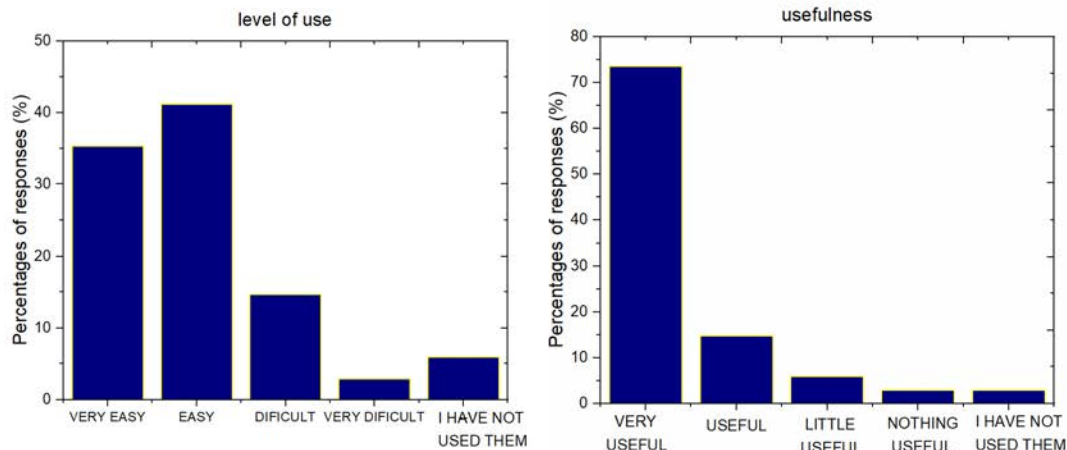


Figure 5. Results obtained in questions about the ease of use and the usefulness of the Matlab templates provided

Because the authors feared that the use of templates data entry and the steady state solver, as resolver, were, interpreted by students as a system of "black box", where a numerical result is obtained but without interpretation, the teacher asked about the contribution of the files to the understanding of the problems and proposed processes. In this case, 32.4% of the students consider that they "totally agree" on the contribution to the understanding of the problems raised. For their part, almost 50% considered it simply "adequate".

The results obtained in this block of questions (Figure 6) confirm to teachers that the new methodology for solving matter balances through the use of Matlab templates is interpreted by students as a very appropriate process and that it helps in understanding the processes and problems raised.

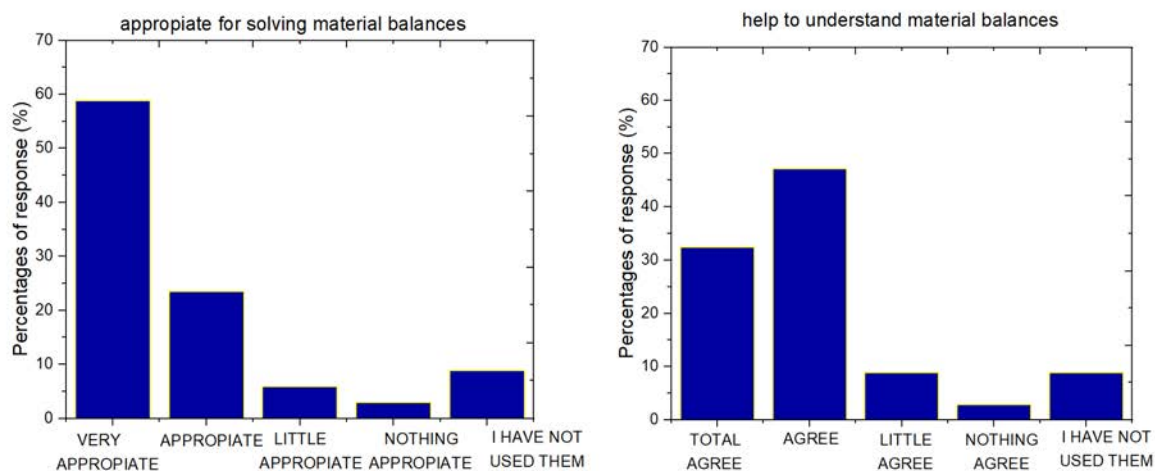


Figure 6. Results obtained in questions about the appropriate of use of the Matlab templates provided and the contribution to understand concepts and process.

The third block of questions was made to know the opinion about the role of the teachers (Figure 7).

The first of the questions is more generic and the students are asked about whether they consider that the teachers have correctly explained the approach to the balance material problems. This question is important, since negative answers about the use of the Matlab templates could be due to a lack of knowledge about the balance sheet material problems themselves, as well as a lack of communication between teachers and students.

The 76% of the students surveyed consider that the professor has correctly explained the approach to the problems of material balances, and only 6% agree little or nothing with the explanations of the subject. Therefore, it is considered that on the part of the teaching, the approach to the balance material problems has been satisfactory.

The second of the questions was carried out to identify, if once the proposals of the subject balances had been understood, the teachers had correctly explained their execution with the use of the provided Matlab templates. Almost 83% of the students consider that the teachers have carried out this work in a very positive or positive way, being, again, an approximate 6%, the students who do not agree with the explanations given.

Therefore, in view of the results, the teachers consider that their work to disseminate the balance sheet material, as well as their resolution through the Matlab templates, has been favorable.

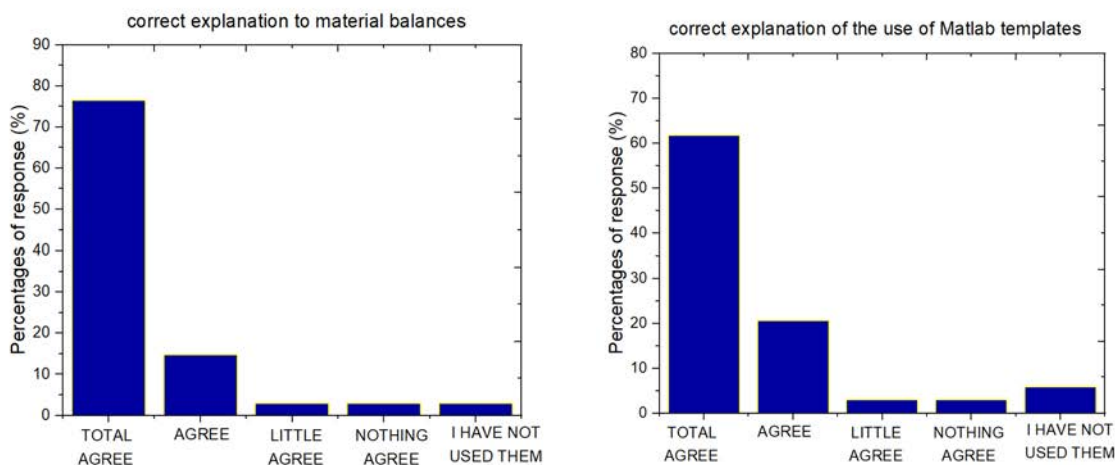


Figure 7. Results obtained in questions about the role of teachers in explaining the material balance and the use of templates of Matlab.

Finally, in the fourth block of questions, general satisfaction with the new methodology for solving complex material balances is evaluated, as well as whether the student would recommend the use of this methodology in other subjects or classmates.

Half of the respondents would "totally agree" in recommending the use of Matlab templates to other classmates and even to other subjects, while almost 40% would "agree". Only 12% of the students would not recommend their use or admit not having used them.

By last, the authors highlight the responses obtained on the general satisfaction of the process. More than 88% of the students surveyed consider the learning process with this methodology based on the use of Matlab templates as very satisfactory or satisfactory. Only 11% of the students consider it little or not at all satisfactory.

Therefore, in view of the results, the use of Matlab templates is seen by the students as a highly recommended learning process and with a high degree of satisfaction.

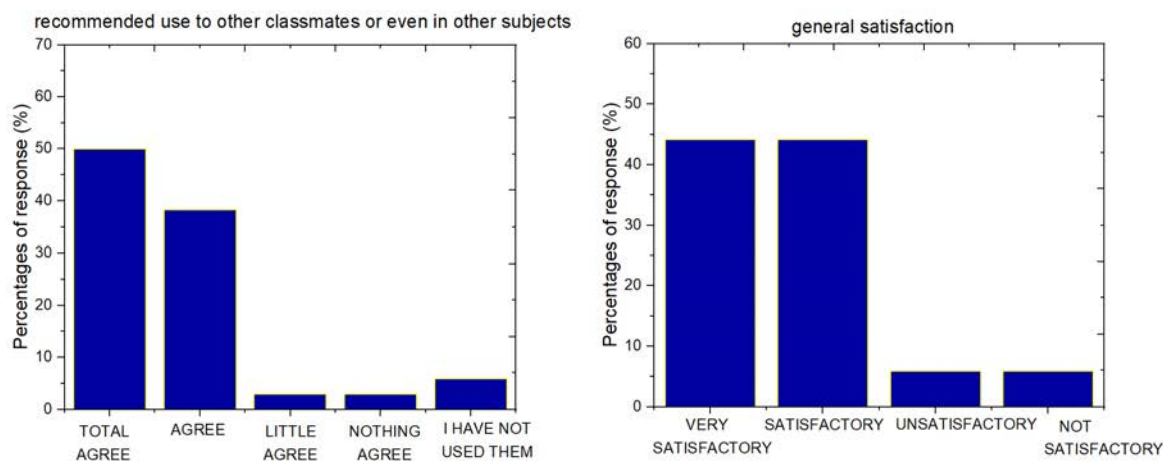


Figure 8. Results obtained in questions about the degree of recommendation and general satisfaction.

4 CONCLUSIONS

The use of Matlab templates to solve the complex algebraic systems resulting from the application of the material balances has been shown to be a very useful and accepted tool by the students. In view of the results obtained, it can be concluded that the student interprets its use as a simple, highly useful process that helps to understand the concepts and processes raised in the problems of material balances. In addition, the teacher's work both in the explanation of the balance sheets and in the application of the Matlab templates is highly valued.

Finally, it stands out that more than 80% of the students consider the learning process through these tools as satisfactory or very satisfactory, showing itself as a widely accepted methodology to be implemented in the resolution of balance sheet material or even in other related subjects.

REFERENCES

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