E-Learning and resource sharing using a chemical process simulator applied in engineering education – a feedback

Viêt-Hai NGUYEN, Cécile NARCE, Konrad SZAFNICKI*.
*Corresponding author
Ecole Nationale Supérieure des Mines de Saint-Etienne,
158, cours Fauriel
F-42023 Saint-Etienne Cedex 2, (France).
Tel. +33.477.42.02.24, Fax: +33.477.42.66.33 E-mail: konrad@emse.fr

Abstract - **The aim of this paper is to describe the feedback of a course using an e-Learning simulation tool at the Ecole Nationale Supérieure des Mines de Saint-Etienne (ENSM-SE, France). It deals with the accelerated-time simulation of a chemical process (series of CFSTRs). The research project concerns the modelling of the functioning and the optimization of an industrial continuous wastewater detoxication process (WWDP). It also takes an interest in their applications in different fields, such as education and training. In the engineering education, a simulation tool is usually an interesting and efficient utility for familiarizing students with real industrial context. The pH regulation during the detoxication process of the wastewater from metal finishing workshops was first investigated, modelled and simulated. The simulator presently offers a model of the pH regulation, which intervenes in almost every WWDP stages. The e-Learning environment used was e-Mersion with its eJournal. This tool has been used in the frame of "Discrete Simulation of an Industrial Process" course in October 2006 for the first time. The goal of this course will be presented, as well as its conduct, results and feedback from students. We will also discuss about difficulties that we met during this project and some improvements that we will carry out for the next year.**

Key Words- simulation tool, e-learning, chemical process and control teaching, engineering formation

INTRODUCTION

I. *Pedagogical context*

During the second year of the engineering formation cycle at ENSM-SE, students may choose the credit entitled: "Process and Industrial Systems (P&IS)" (total: 120 h). The pedagogical approach of this credit tends to familiarize students with control tools for process and industrial systems. Through different courses, the following themes are reached:

- Modelling
- Simulation
- Automatic Control
- Optimizing
- Subjecting to risks and safety.

The 18-hours course on "Discrete Simulation of an Industrial Process" included in this credit, presents to students the following aspects:

- Discrete simulation of an industrial process which is **continuous and strongly non linear**: the pH control in a perfectly mixed reactor.
- Handover of a **simulator**
- Multiple constraints process **optimizations** (efficiency, safety, costs, environmental aspects…).

II. *Industrial & scientific contexts*

Industrial wastewater from the plating shops contains lots of toxic elements. The most common elements are cyanide and chromium, particularly its hexavalent form. These effluents must be treated before being rejected in the nature in order to meet the more and more strict legal requirements. The detoxication process contains different stages such as decyanidation, dechromation, neutralization and flocculation. The acidic effluent which contains hexavalent chromium pours into the dechromation tank in which Cr^{VI} is reduced to Cr^{III}. The cyanided effluent flows into the decyanidation tank in which the oxidation of cyanides into cyanates occurs. At the overflow of these two tanks, the both effluents are mixed in the neutralization tank where the pH is regulated so as to enable the heavy metals precipitation into metal hydroxides. The latter are then coagulated and flocculated to aggregate them into particles, large enough to be settled.
The efficiency of each of these treatment stages strongly depends on the pH parameter. For example:

- The reduction of chromium by bisulphite is optimal for pH at 3.
- The optimal condition for oxidation of cyanides with bleach is at pH 11.5.
- The metal hydroxides precipitation depends on pH value. For the majority of metals, the optimal pH value varies between 7 and 10.5. When several heavy metals coexist in the solution, the pH value has to be chosen as the best compromise between the different metal hydroxides to precipitate.

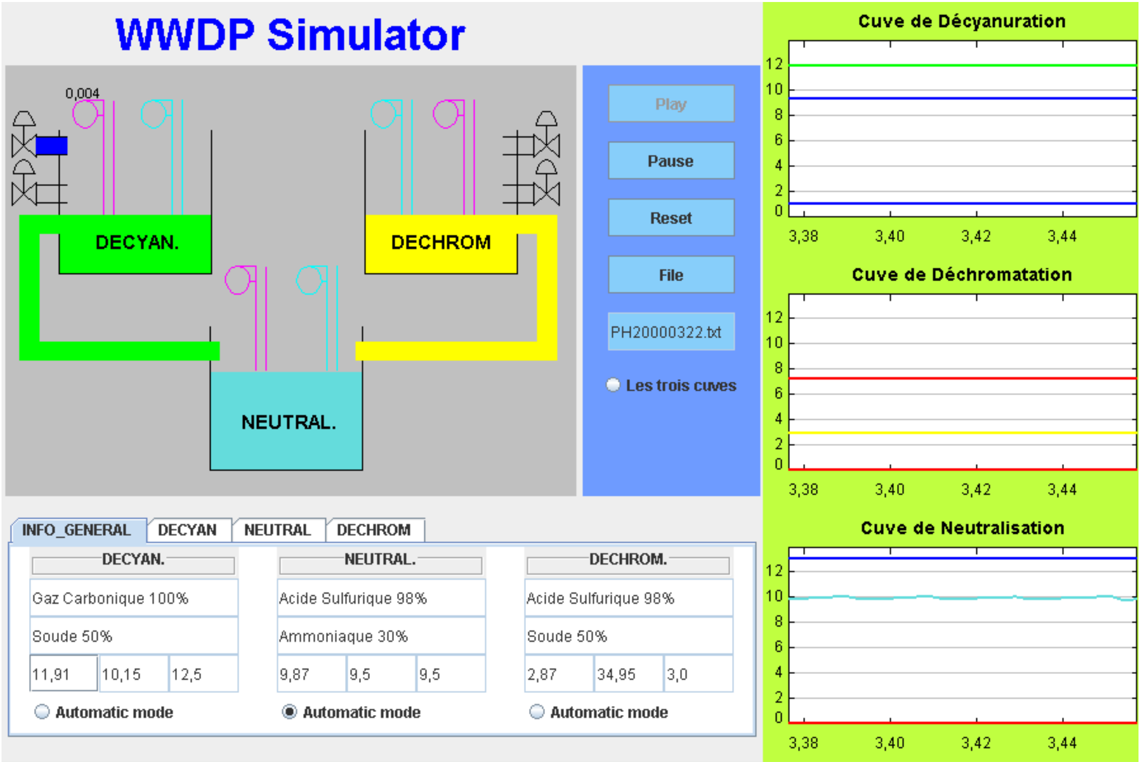

FIGURE 1
SIMULATOR INTERFACE UNDER E-MERSION PLATFORM

TABLE 1
PREDEFINED INTERVAL FOR THREE STAGES

Stage	optimal pH value	Interval	QN limit (%)
Dechromation	3	2.5 - 3.5	16.66
Decyanidation	11.5	11 - 12	4.3 →10
Neutralization	9.5	9 - 10	5.2 →10

From automatic control point of view, the pH is a strongly nonlinear system which is difficult to regulate at one defined value. Thus it is routine to define an interval around the optimum, in which the pH value should stay, following two criterions: control quality and cost. The control quality is expressed by the quadratic norm (QN) which computes the deviation between the optimum and the real values. The control cost is calculated according to the used up quantity of reagent. The intervals defined this way, for each detoxication stage, are presented in the Table 1.

A mathematical model for the pH simulation and control has been built by Narce [3]. The validation of this model was carried out on an industrial database from a real wastewater detoxication plant.

III. Simulation tool

In these pedagogical and industrial contexts, the development of an integrated simulation tool has been decided. This tool permits to simulate the pH control during a three stages detoxication process: decyanidation, dechromation and neutralization. Such a simulator may answer to different needs from pedagogical and industrial fields as exposed in [7]. In the frame of "Discrete Simulation of an Industrial Process" course, this simulator can be useful for different reasons:

- First, the pH control is ubiquitous in various industrial processes. Moreover, in case of detoxication process, it is subjected to many constraints such as the cost of reagents used for controlling and the necessity to meet regulations. Thus it represents a very interesting case study which enables students to familiarize themselves with industrial constraints.
- Then, in the control point of view, the pH is a strongly non linear system, it is both complex and interesting to implement.

The first simulator, called RESPECTS, has been developed in Java and its "one tank" version has been tested in the frame of the "Discrete Simulation of an Industrial Process" course in 2004 and 2005. The choice of integrating this simulation tool on the e-Mersion E-Learning platform has been motivated by the reasons previously described in [7]. With this aim, it has been settled that it is more judicious to develop a new version in EasyJava because the EasyJava's libraries provide a lot of functions which make the integration easier. Its interface is shown in the Figure 1 and its main functions have been described in [7]. In 2006, for the first time, this new version has been used in the P&IS curriculum.

PROJECT'S DESCRIPTION AND CONDUCT

To initiate the course, a 3-hours introduction is organized to inform students about:

TABLE 2
EVALUATION'S RESULTS

Questions	1/4	2/4	3/4	4/4	Average
1 – Has this course been interesting?	0	9	4	2	2.5
2 – Have the course's goals been well defined?	3	7	3	2	2.3
3 – Has the paper support been useful?	6	3	2	4	2.3
4 – Do you think that the simulator is a good teaching aid?	0	6	7	2	2.7
5 – Have you found the teacher's presence useful?	1	8	4	2	2.5
6 – Is the simulator's interface user-friendly?	1	4	9	1	2.7
7 – Has the using simulator been natural for you?	2	2	9	2	2.7
8 – Does the simulator have a good performance	5	4	6	0	2.1
9 – Has the e-Mersion platform been useful?	3	6	4	2	2.3

- Metal finishing industry and its environmental problematic,
- Necessity and obligation for metal finishers to treat wastewater,
- Goals and conduct of the e-learning project,
- Simulator's presentation.

The continuation of the course is divided into three stages, in which the students work as little groups (2-3 students' teams):

- In the first workshop, students experiment the simulator and the e-Mersion platform. They test different sets of parameters (reagent's choice, control's parameters) to study the role of each parameter. At the end of this first workshop, students keep between 1 and 3 sets of parameters for the second stage.
- The second workshop aims at testing the set(s) of parameters on industrial data. According to these tests and other criterions (such as economic and/or environmental performances), an "optimal setting" may be suggested. It is worth noting that there is not a single solution; each group may justify its choice.
- In the last stage, each team writes a report, in which may be presented :
  - the approach,
  - the results of tests with various parameters,
  - the analyses of the parameter's impacts,
  - the "optimal setting" as well as the logical reasoning leading to its choice.

The course's conduct and the goal of each workshop have been itemized in a paper support, distributed to students at the beginning of the course.

EXPERIENCE FEEDBACK

This first experience has permitted to collect a lot of conclusions about reports' quality, as well as the way that our pedagogical method has been perceived by students.

I. Report's evaluation

The mark's repartition of the 11 teams is shown in Figure 2. The majority of reports is satisfactory; the group's average is 13.54/20 for a deviation of 2.50. Students have understood the course's scientific objective and have chosen a good approach. Through the tests with different parameters, good quality analyses have been done. The economic and environmental constraints have been understood and well integrated in the logical reasoning which leads to the optimal solution. The two reports, marked 17/20 and 18/20, were the closest to the goals that we have been looking for.

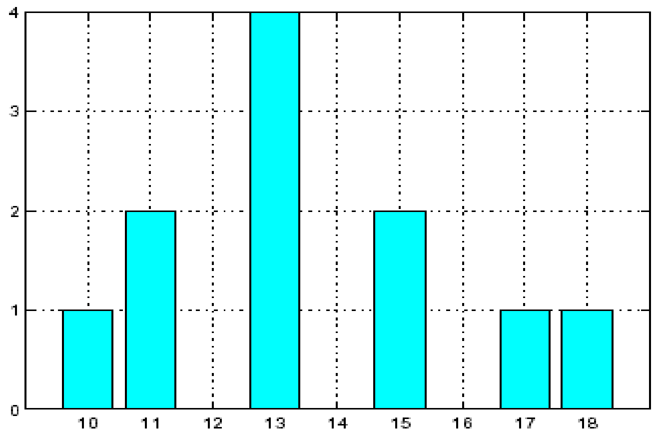

FIGURE 2
MARKS' REPARTITION OF THE 11 TEAMS, AVERAGE 13.54/20

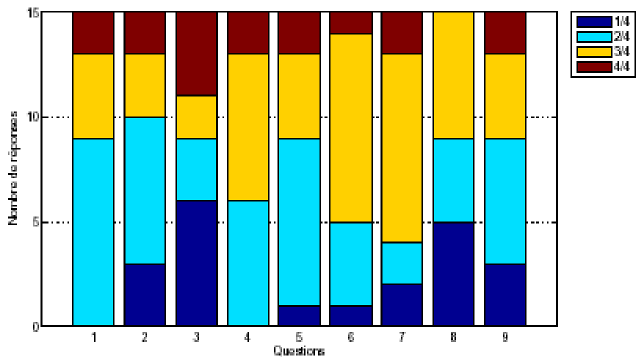

FIGURE 3
RESULTS OF THE EVALUATION

II. Pedagogical wrap-up

At the end of the project, the students have accepted to fill out an individual evaluation form out of the course. For each question, students give a note from 1 to 4[1]. This feedback is presented in the Table 2 and Figure 3.

[1] 1: completely disagree, 2: disagree, 3: agree, 4: completely agree.

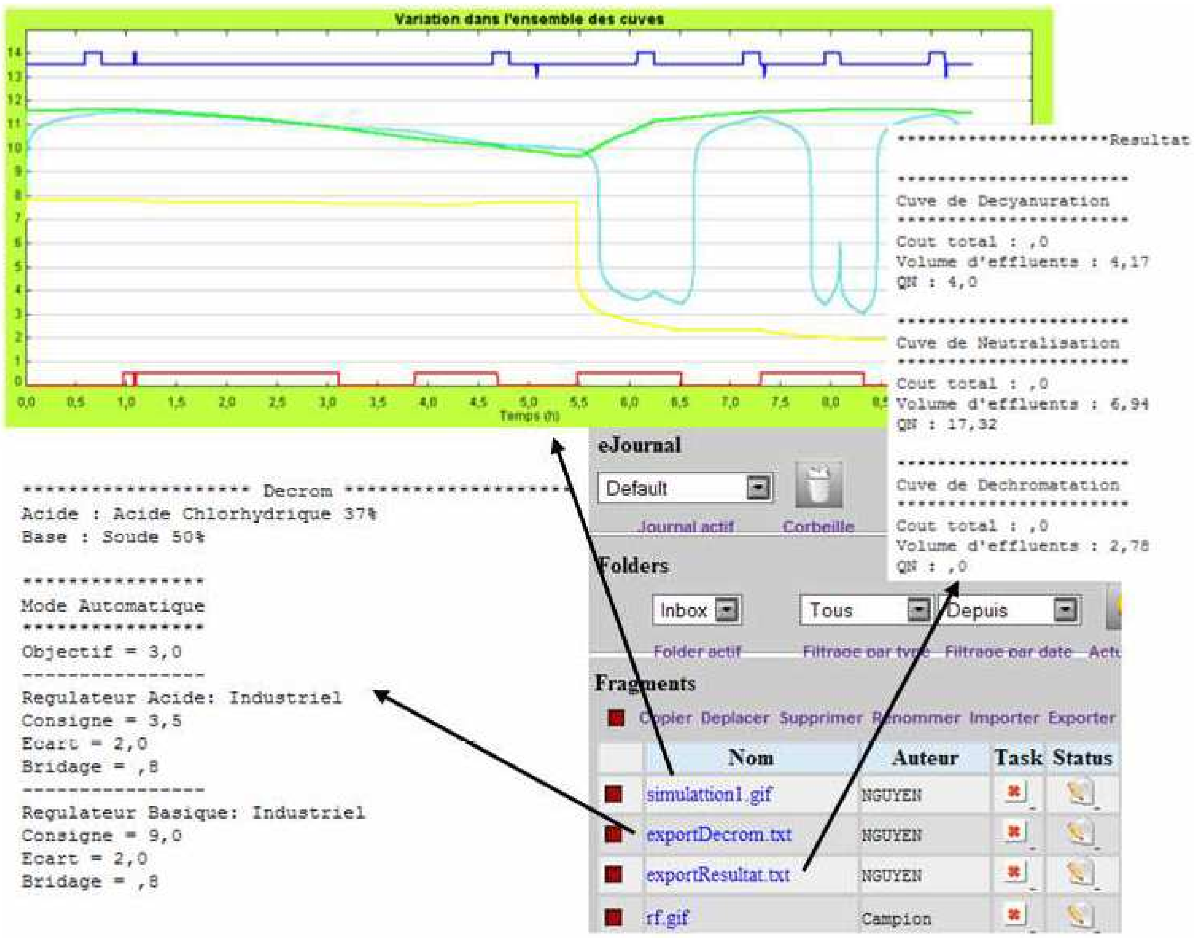

FIGURE 4
AN EXAMPLE OF USING EJOURNAL

For the majority of students, this course has been interesting. However, the 9 answers of 2/4 to the first question and the 10 answers below the average of 2.5/4 to the second one (cf Table 2) show that the suggested role-play has not been understood by more than half the students. It could be explained by the fact that our students are in the habit to attend formal courses, where they have no real active role to play. In this course, the objective is not only to explain how an industrial process runs, but also to familiarize students with the role of an engineer in charge of setting an industrial system subjected to different kinds of constraints.
Forty percent of them have found the paper support useful in spite of the presentation at the beginning of the project. Moreover, it has been observed that teacher's permanent presence during the workshop is not necessary. Thus, by improving the paper support and integrating it into the simulator as a courseware, it is conceivable to carry out this course as cyber course. This idea has been approved by two-third of students.
It also has been confirmed that using simulator as teaching aid is interesting. Students have had no difficulties to use the simulator and the e-Mersion platform. However, a graphical improvement of the simulator's interface would be appreciated.
As shown in the Table 2, the simulation speed performance of the simulator has posed a problem. Twenty minutes were necessary to simulate "24-hours" data. It is due to state variable's display. For example, decreasing the number of points of each curve from 120 to 30 has doubled the simulation speed. Therefore, 11 minutes are now, sufficient to simulate "24-hours" data.
Integrating this simulator on the e-Mersion platform is also a judicious choice. Thanks to its capabilities, it has been easy for students to manage the data: loading/saving configuration files, or saving simulation results for example. An example of using e-Mersion platform is shown in the Figure 4. The file, named "simulattion1.gif", shows the evolution of pH at the exit of the three tanks. The file, named "exportDecrom.txt" indicates all the parameters of the dechromation tank. The file, named "exportResult.txt" groups together the simulation results of the three tanks; for each one, three of the following variables are saved: total cost, total volume of treated effluents and quadratic criterion QN.
However, students are quite reserved about the usefulness of the e-Mersion platform. This could be explained by the fact that many students did only work during the workshops sessions. The parameters have been written down on a notebook and the graphical results have been saved by "print-screen" touch and then, stored on individual USB key. It is due to the lack of habit to work as a group and to data sharing.

PROSPECT

A second course experience is then being considering. First, the students would be entirely autonomous during the major part of the course. A classroom would be allocated to the course during several time windows, with permanent access to the simulator's server. Students might decide themselves when and how long they want to work. In case of difficulty, students may ask for teacher's help by mail. Nevertheless, many compulsory lessons would be maintained, in order to evaluate the project's advance. The results of this second experience would permit to make a comparison with the first course and to evaluate the opportunity to structure the project in a complete cyber course.

CONCLUSION

This first experiment with the simulator was rich in experience. During the preparation phase of the course, a lot of material problems have been detected. Now they are solved, a lot of time will be saved in the future. The feedbacks from students confirm the usefulness of the course and the simulation tool. Thanks to these evaluations, lots of improvements will be done, in the simulator as well as in the course's conduct. In 2007, a second course will be experimented and its results will be compared to the first experiment's ones. The target will be to definitely fix the framework of this course in one year.

ACKNOWLEDGMENTS

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