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Analyzing a virtual-lab based contextualized activity from action logs

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Abstract

In this paper, we present and analyze a virtual-lab based activity oriented as an application of the stoichiometry concepts that appear in the first year of the Spanish Bachillerato (16-17 year old). The activity was brought to class and was used by more than hundred Catalan high school students. The task was worked in pairs and each action they did in the virtual lab was anonymously recorded to a log file. The analyses of these log file allow us to affirm that this type of activities provide a significant support for a focused and active learning experience.

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Keywords: chemistry; simulation; chemical education; log; educational data mining

1. Introduction

Despite the existence and availability of simulations and virtual laboratories for chemistry education (see for example, Cuadros, 2014; Greenbowe, 2014; University of Colorado, 2013; Yaron et al., 2005 or The ChemCollective, 2014), their presence in the Catalan high school classes is not common. Given its acknowledged educational value (Honey & Hilton, 2010) and in order to make it easier for the chemistry professors to consider its inclusion in the curriculum, our group (Artigas, Cuadros, & Guitart, 2012; Artigas, Cuadros, & Guitart, 2013) has been developing several activities sharing the following features: (1) they are based on the ChemCollective virtual

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lab (The ChemCollective, 2014), (2) they provide a relevant context for the students, (3) a worksheet for the students is made available and (4) and connections to the Catalan standards are indicated.

In order to better understand to what extend these resources are useful for improving learning, one of these activities has been brought to several high school classes in Catalonia and action logs from student problem solving have been collected and analyzed. This is the work presented in this communication.

2. Activity description

The activity *Water hardness determination and removal* is intended as an application of the stoichiometry concepts that appear in the first year of the Spanish Bachillerato (16-17 year old) curriculum. It consists in the chemical determination of water hardness by means of a complexometric titration with ethylenediaminetetraacetic acid (EDTA) and Eriochrome Black T (NET for its initials in Catalan) as indicator. The students are then asked to the study the possibility of removing hardness through carbonate precipitation.

As explained above, the activity is based on a virtual lab problem (Fig. 1) that the students must use to gather the data required to complete the activity and to work out their resolution to the questions on the corresponding worksheet.

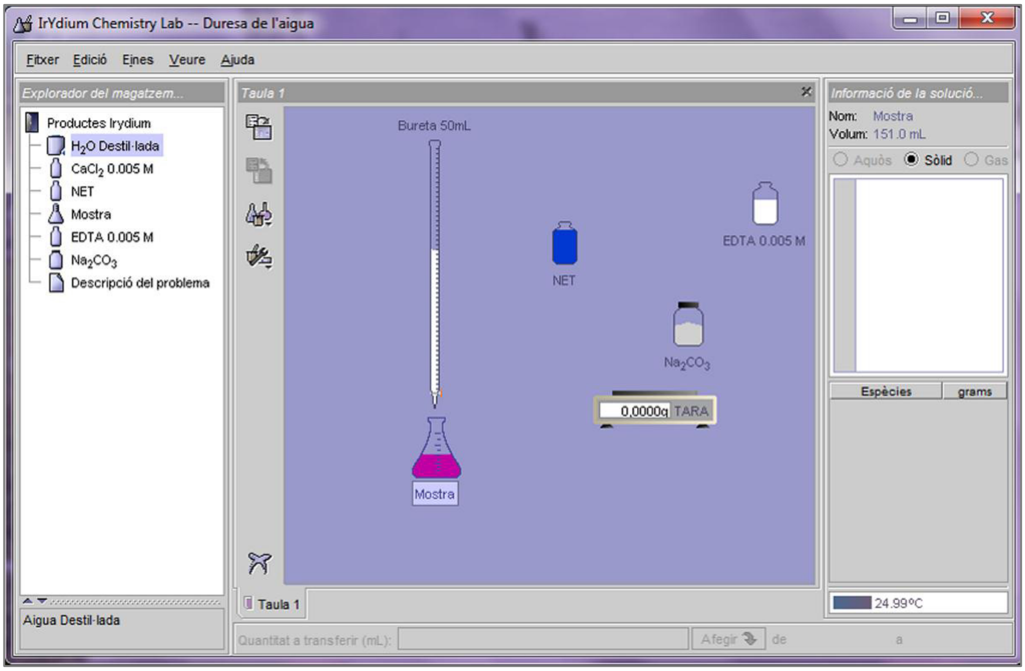

Fig. 1. Water hardness determination and removal activity in the ChemCollective virtual lab.

The activity is conceptually divided in three parts. In the first part, students have the opportunity to familiarize themselves with the laboratory instruments, the change of the colors and the titration process. Still in this first part, the activity asks students to determine the concentration of calcium in the water sample and to calculate the hardness of this sample.

The second part is the precipitation of calcium with carbonate to decrease the hardness. In this part, students first have to do several calculations and then need to use the virtual lab to determine the mass of calcium carbonate precipitated.

The last part consists in repeating the titration with EDTA to analyze for the remaining concentration of calcium after the precipitation with carbonate.

The resolution process as detailed in the worksheet provided to the students is shown in Table 1.

Table 1. Resolution process for the activity following the guidance of the worksheet.

	Steps in the activity worksheet
1	Test for the color change of Eriochrome Black T (EBT, NET in Spanish) with earth alkaline ions.
2	Test the titrating reaction by adding excess EDTA.
3	Titration (or determination of the minimal volume required for color change)
4	Calculation of water hardness (as Ca)
5	Calculation of water hardness (as CaCO3)
6	Calculation of the maximal amount of sodium that can be added
7	Calculation of the amount of calcium precipitated
8	Test for calcium presence in solution
9	Filtration and calcium determination
10	Calculation of water hardness after removal
11	Mass conservation check for calcium

3. Methodology

The activity was brought to 9 different volunteered Catalan high schools in the province of Barcelone (Spain) in the academic year 2011-2012. 212 Catalan students of 1º Bachillerato (11th grade) in 12 classgroups took part on the experience.

The activity was led by a researcher in our team and scheduled in a regular Chemistry class. Students were organized in workgroups of 2 or people and anonymously identified through a code provided to them. The session started with a pre-test which was followed by the activity, as presented above, and a post-test. The time allotted was in most cases of about an hour which allowed for about half for solving the virtual lab based activity. Observation notes were also collected along the session.

All data was collected anonymously and consent forms were included in the tests. Only the workgroups were all the members agreed to participate are included in the study.

While working with the virtual lab, the actions done by the students were automatically and anonymously recorded to a log file (Fig. 2).

The results from analyzing the 60 log files collected from consenting students are presented here.

4. Results and discussion

The analysis of the 60 log files was done with the R statistics environment (R Core Team, 2014). In summary, 37791 actions were recorded and analyzed to get a sense on the value of the activity for learning chemistry.

Time-on-lab (time using the virtual lab) was computed as the difference between the time of the last and the first action collected. This measure provides us a conservative estimate of the time the students were working on the activity.

Fig. 3 shows the time-on-lab distribution. 55 of the 60 groups spend more than 20 minutes on the lab and 75% of the groups worked for more than 29 minutes. The distribution is bimodal according to a Gaussian kernel density estimation. The first mode is around 30 minutes and accounts for sessions allotted in a one-hour timeframe. The second mode, between 55 and 60 minutes, corresponds to sessions allowed to take some additional time.

```
117  user98ad78ecfd  vlab1e4a3b07c6  IRYDIUM_VLAB    2012-03-13 15:33:19 CET WORKBENCH_FLASKS_CONNECT
     text/xml    <tool_message><semantic_event id='200' name='WORKBENCH_FLASKS_CONNECT'><description>The Flascó 100mL
     (ID18) is connected to the Matràs Erlenmeyer 250mL (ID17).</description><workbench_connect_flasks_operation workbench
     ='Taula 1' source_id='18' recipient_id='17' time_ms='1331649199127' />
     </semantic_event><event_descriptor><action></action><selection></selection><input></input></event_descriptor></tool_me
     ssage>
118  user98ad78ecfd  vlab1e4a3b07c6  IRYDIUM_VLAB    2012-03-13 15:33:22 CET SOLUTION_MIX            text/xml
     <tool_message><semantic_event id='201' name='SOLUTION_MIX'><description>30 mL from Flascó 100mL (ID18) that contains
     CaCl2 0.005 M (0E0g of H2O, 1E-7M of H+, 1E-7M of OH-, 5E-3M of Ca+2, 1E-2M of Cl-; V=100 mL, T=298,15K) are poured
     into Matràs Erlenmeyer 250mL (ID17) that contains Matràs Erlenmeyer 250mL (; V=0 mL, T=298,15K). The resulting
     solution is Matràs Erlenmeyer 250mL (0E0g of H2O, 1E-7M of H+, 1E-7M of OH-, 5E-3M of Ca+2, 1E-2M of Cl-; V=30 mL,
     T=298,15K).</description><solution_mix_operation source_id='18' source_temperature='298.15' recipient_id='17'
     recipient_temperature='298.15' volume='0.03' time_ms='1331649202340' />
     </semantic_event><event_descriptor><action></action><selection></selection><input></input></event_descriptor></tool_me
     ssage>
119  user98ad78ecfd  vlab1e4a3b07c6  IRYDIUM_VLAB    2012-03-13 15:33:25 CET WORKBENCH_MOVE_OBJECT           text/xml
     <tool_message><semantic_event id='203' name='WORKBENCH_MOVE_OBJECT'><description>The following component/s: Flascó
     100mL (ID18), is/are moved being the translation: 165,-134.</description><workbench_move_operation workbench=''
     desktop_components_ids='18' x='165' y='-134' time_ms='1331649205835' />
     </semantic_event><event_descriptor><action></action><selection></selection><input></input></event_descriptor></tool_me
     ssage>
120  user98ad78ecfd  vlab1e4a3b07c6  IRYDIUM_VLAB    2012-03-13 15:33:25 CET WORKBENCH_FLASKS_DISCONNECT
     text/xml    <tool_message><semantic_event id='205' name='WORKBENCH_FLASKS_DISCONNECT'><description>The Flascó 100mL
     (ID18) is disconnected to the Matràs Erlenmeyer 250mL (ID17).</description><workbench_disconnect_flasks_operation
     workbench='' time_ms='1331649205866' />
```


Fig. 2. Extract from a log file.

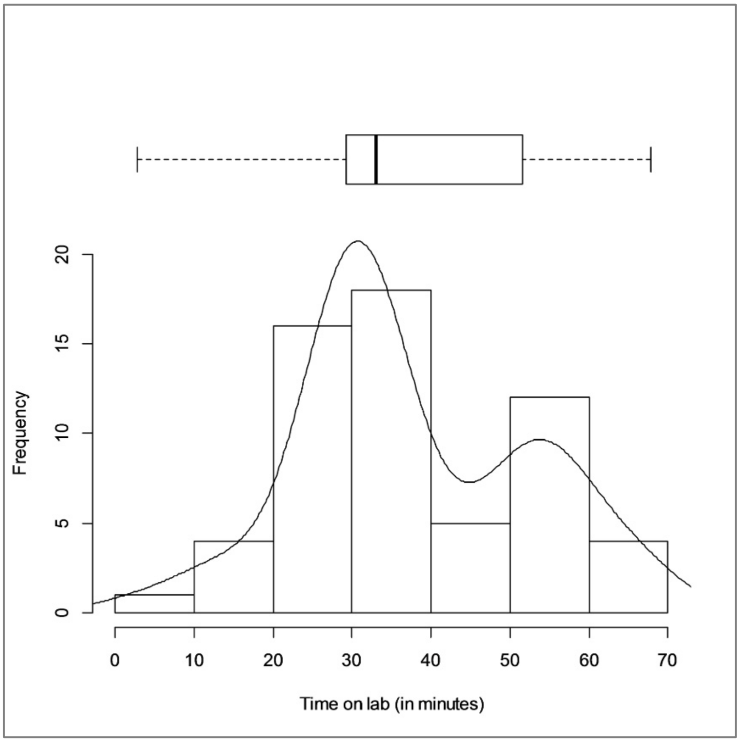

Fig. 3. Boxplot and histogram showing the time-on-lab distribution.

In order to know whether the students were actively involved when using the virtual lab, working intensity was also analyzed. Fig. 4 shows the histogram corresponding to time differences between consecutive actions. About 75% percent of the actions were performed in 2 seconds or less from the previous one.

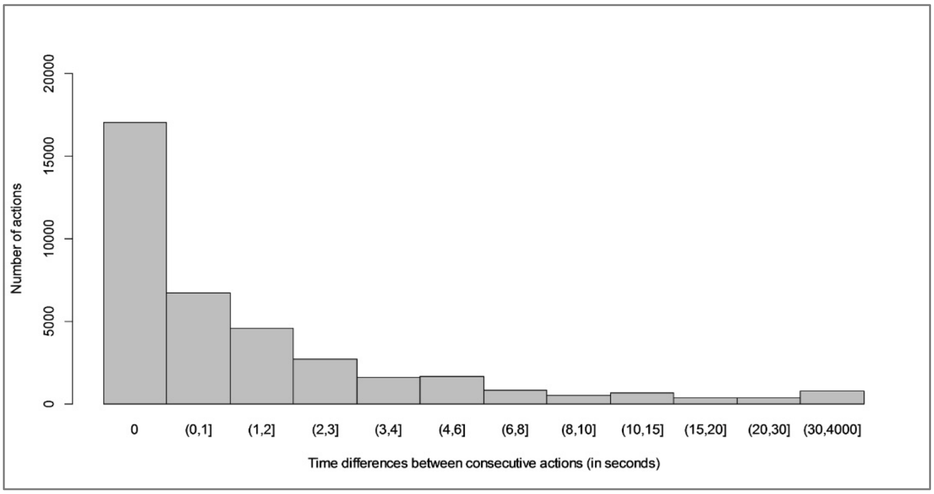

Fig. 4. Bar chart of the time difference from the previous action.

Once proved that the students were actively working when using the activity, different analyses have been performed to evaluate whether the actions completed by the students are meaningful and correspond with the steps required to work through the worksheet.

Fig. 5 shows the use made by each of the groups of each of the solutions present in the virtual lab problem. Since solving the activity requires using the six solutions provided, not using any of them indicates that some of the expected work wasn't done. In specific, group 31 (first in the second part of the hot map) doesn't seem to have been working through the problem.

On the other side, not using the carbonate solution (Na_2CO_3) means that the group didn't reach the second part of the activity (steps 6-7 of Table 1). 12 out of the 60 didn't arrived to start of the activity in the time allotted.

/stockroom/CaCl2 0.005 M	4	8	9	11	4	9	13	14	7	8	12	9	15	9	12	10	19	13	11	16	50	7	5	2	5	2	10	8	4	5
/stockroom/EDTA 0.005 M	3	7	10	12	4	10	14	12	12	6	11	7	10	21	8	13	16	11	9	8	18	9	3	4	3	6	4	7	4	4
/stockroom/H2O Destil·lada	8	3	6	12	4	12	9	10	31	7	11	9	8	6	9	18	13	7	18	6	48	8	3	3	4	3	3	3	4	3
/stockroom/Mostra	3	5	9	11	5	5	11	10	16	3	7	5	6	13	6	10	14	10	7	12	11	10	2	5	3	4	2	5	2	3
/stockroom/Na2CO3	2		8	1		1	3	1	4	1	2	2	5	2	1	4	15	4	6	6	7	4			1	1	1	1	1	2
/stockroom/NET	6	3	7	17	7	9	18	11	13	9	16	10	9	12	8	9	15	15	10	10	12	9	3	3	4	4	5	6	4	5

/stockroom/CaCl2 0.005 M	3	7	5	11	13	1	7	4	5	5	7	3	3	5	5	4	4	10	5	6	1	4	5	13	6	12	5	3	4	8
/stockroom/EDTA 0.005 M		8	8	10	3	3	7	3	12	8	7	1	4	6	6	5	7	17	6	9	4	8	6	8	6	6	5	10	2	6
/stockroom/H2O Destil·lada	1	24	3	25	5	1	6	2	4	5	6	3	3	6	7	4	4	3	7	5	2	3	5	47	3	54	4	6	3	4
/stockroom/Mostra		4	2	12	2	2	4	3	5	4	5	2	1	5	4	5	4	2	14	7	7	7	6	7	20	5	3	7	4	3
/stockroom/Na2CO3	1	2	2	2	2		1	2		1	2		4	1	2		1		1	1	2	27		5	4	3		3	1	
/stockroom/NET		7	4	10	4	3	4	3	7	7	10	6	5	9	28	5	5	3	6	10	1	4	3	13	8	10	4	5	2	8

Fig. 5. Hot map showing the use of the stockroom solution by each working group.

Last but not least, the actions have been inspected through the use of a regulars expressions to look for the actions required for solving the steps in the worksheets. For example, working through step 1 requires that the student prepares a solution with the indicator (NET) and a second one with the indicator and calcium ions.

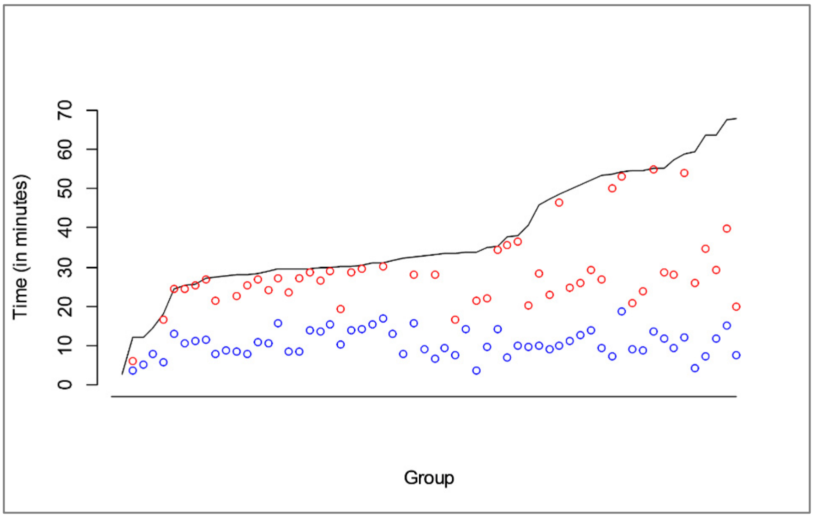

Fig. 6. Plot showing time in minutes when relevant actions for completing step 1 (in blue) and step 3 (in red) are detected.

Fig. 6 shows the time when each of the work groups have completed the relevant tasks corresponding to step 1 (blue data markers) and step 3 (red data markers) of Table 1.

As it reads in this chart, most of the workgroups solve the first step in about 10 minutes from launching the virtual lab. These 10 minutes also account for learning how the virtual lab works and getting acquainted with the activity. Furthermore, although some groups are not able to reach the third step of the activity, many of them are able to solve it in between 20 and 30 minutes from start. In many cases, this leaves no further time for finishing the rest of the activity.

5. Conclusions

The analyses of the log files shown in this contribution have the potential to allow the teachers and education professionals to get meaningful information on the performance of the students when using a computer-based application, even in the case of an open-ended application like a virtual laboratory.

The results that can be obtained can provide relevant insights both on the performance of specific students or groups and on the same educational activity.

In the specific case of the activity tested in this research, a contextualized activity based on a virtual lab, our results allow us to affirm that this type of activities provide a significant support for an active learning experience where the students are really focused on working through it.

Acknowledgements

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