# Embedding ICT in Real-Time Measurements for Versatile Applications in Modern Life Sciences Education

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***Abstract*—Involving undergraduates and high school students to play a more active role in science lessons has been an objective in many educational research programmes. ICT is a perfect tool to meet this goal. Particularly, in this paper the processing of experimental biochemical – biotechnological data in the science classroom is highlighted.**

**Additionally, the paper focuses on the interdisciplinary approach 'from scientific experiment to a mathematical model' in biochemistry courses. Indeed, bridging the gap between experimental data and mathematical functions is not evident at the level of secondary and undergraduate education.**

***Index Terms*—Biochemistry, biotechnology, chemistry, data acquisition, data analysis, educational technology.**

## I. INTRODUCTION

Children nowadays are overwhelmed by theversatility of multimedia, the latter having a profound and deep impact on the maturing brain[1].From an educational point of view this known fact is an opportunity to use digital tools for the processing of e.g. experimental biochemical data.

Developing educational material with both ICT and interdisciplinary mathematics and science aspects [2] is a major challenge at Hasselt University[3].

## II. THE MULTIPLE USE OF GRAPHIC CALCULATORS

The presented paper introduces an educational method to encourage high school students and undergraduates with basic ICT knowledge to develop a mathematical model starting from biochemistry - biotechnology data collected in students' experiments. These experiments are performed by Texas Instruments™ (TI)graphic calculators [4] used as measurement devices. The used TI technology goes beyond graphing to help students getting a new and different view on mathematics and sciences.

With a dedicated sensor [5-8] for each chemical parameter linked via an interface, experimental data are gathered and transferred to the graphic calculator or/and to the computer screen (see figs. 1 and 2).

Due to this multiple combination of devices, the audience gets the opportunity to model experimental data. Moreover, the integration into spreadsheets and text documents becomes possible through commonly used application software.

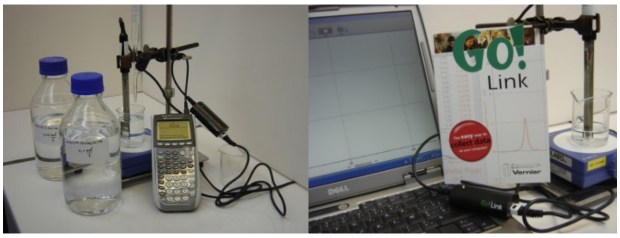



Figure 1. TI-84Plus™ + peripherals EasyLink™(left) + Go!Link™ (right)

Figure 2. TI-Nspire cx CAS™+ lab cradle™ (left) in combination with computer (right)

This paper focuses on a potentiometric titration: the pH is measured as a function of the volume of an appropriate solution added by a 'classical' burette to a reagent in a conical flask [9].

A potentiometric acid-base titration is ideal to start with as a result of the well-balanced mixture of traditional laboratory skills and modern ICT technology.

The TI-84Plus™ graphic calculator connected to its peripherals in particular the EasyLink™ and related pH sensor(figure 1) measures the evolution of the pH during the titration.Digital pH signals are transferred to and displayed by the graphic calculator.The stepwise added volumes of the solution are read from the burette and manually entered into the calculator.

Instead of using the TI-84Plus, the TI-Nspire cx CAS™ connected to a lab cradle™, has more than one advantage. The TI-Nspire cx CAS, the latest generation of its kind, not only has a colour screen but also its compatibility with computers has been improved by the introduction of maps and documents, commonly used by the operating system of latter. In addition, more than one sensor can be connected to the lab cradle, a peripheral of the TI-Nspire cx CAS (figure 2). For example, if required, both temperature and pH can be measured simultaneously during a single experiment by connecting a temperature sensor and a pH sensor to the cradle.

Last but not least, in contrast to the TI84-Plus where the EasyLink needs to be replaced byaGo!Link™ to make the connection to a computer, the TI-Nspire+ lab cradlecan be directly connected without switching any peripherals.

## III. TITRATION OF MALEIC ACID WITH SODIUM HYDROXIDE

Analytical information concerning the concentration of a maleic acid (cis-butenedioic acid) solution initiates the study of the stereo chemistry of butenedioic acid e.g. fumaric acid (trans-butenedioic acid) in the citric acid cycle. Another example is the use of maleic acid as an excipient in cosmetics formula. A potentiometric acid-base titration is a first step to study the applications of maleic acid. The titration data have been collected by measuring the pH of a maleic acid solution as a function of the added volume of sodium hydroxide (NaOH) solution with a known concentration. The titration endpoint can be numerically pinpointed by processing the experimental data with the graphic calculator. The first and second numerical derivatives need to be calculated. At the endpoint of the titration these derivatives show extremes. If these extremes are known the endpoint simultaneously can be used for the calculation of the unknown concentration of maleic acid solution.

By using the GO!Link™ interface and the pH sensor of Vernier™ connected to a laptop, students can independently titrate a maleic acid solution with0,1 mol.liter$^{-1}$NaOH solution via the included programme Logger Pro™.

The measurements appear in a ($V_{NaOH}$, pH) table. While the titration curve grows as the titration progresses, the measurements can be stored at the end of the titration. The huge advantage of this method is the fact that it is possible copying the ($V_{NaOH}$, pH) table in an Excel file in order to compute the titration endpoints.

Figures 3-6 illustrate the comparison between the results of a set of the experimental data gathered by the TI-84 Plus and GO!Link with this of the data collection done with the TI-84 Plus and the EasyLink. On the TI-84 Plus screen, the tables and graphics can only be displayed separately. While on the computer screen when using the GO!Link both are shown simultaneously. The GO!Link and the EasyLink need different software. The first only works when the programme LoggerPro is active on the computer. The last operates on EasyData™ a software programme provided for the TI-84 Plus.

These programmes transfer signals from the Vernier™ pH sensor to the computer or to the TI-84Plus.Logger Pro stores the collected data into lists as well does EasyData. Since LoggerPro has more opportunities, it is more suitable for demonstrations in the classroom.

The calculator provides enough information for the student to perform further calculations. The TI-84Plus screen displays the PH(VOL)-graph showing the two endpoints of the titration. VOL is the list of volume data of the added NaOH solution. PH is the list of the corresponding pH data.

Mathematical analyses of the second endpoint – the most explicit slope of the titration curve – show the first and second derivative using respectively the formulae: DList(PH)/DList(VOL) = List(DC) and DList(DC)/DList(VOL) = List(DDC)

At this level, the TI-Nspire cx CAS has an additional advantage in the exploration of measurement results. Both, table and associated graphic can be transferred by TI-Nspire CAS and corresponding Teacher Software™ to the computer screen. The first numeric derivative in each measuring point can be marked by moving the tangent line over the curve as shown in figure 7 by the red line. The slope of the tangent line reaches its maximum at the end-point of the titration and is therefore a good indication of the equivalence point of the titration.

| | Latest V(NaOH) (ml) | Latest pH | | Latest V(NaOH) (ml) | Latest pH |
|---|---|---|---|---|---|
| 1 | 0,0 | 1,91 | 21 | 23,5 | 6,99 |
| 2 | 2,0 | 1,99 | 22 | 24,0 | 7,11 |
| 3 | 4,0 | 2,12 | 23 | 24,5 | 7,45 |
| 4 | 6,0 | 2,32 | 24 | 25,0 | 8,80 |
| 5 | 8,0 | 2,51 | 25 | 25,5 | 10,86 |
| 6 | 9,0 | 2,60 | 26 | 26,0 | 11,17 |
| 7 | 10,0 | 2,77 | 27 | 26,5 | 11,39 |
| 8 | 11,0 | 3,05 | 28 | 27,0 | 11,47 |
| 9 | 11,5 | 3,20 | 29 | 27,5 | 11,56 |
| 10 | 12,0 | 3,50 | 30 | 28,0 | 11,66 |
| 11 | 12,5 | 4,12 | 31 | 29,0 | 11,74 |
| 12 | 13,0 | 4,76 | 32 | 30,0 | 11,87 |
| 13 | 13,5 | 5,09 | 33 | 32,0 | 11,95 |
| 14 | 14,0 | 5,24 | 34 | 34,0 | 12,05 |
| 15 | 15,0 | 5,50 | 35 | 36,0 | 12,12 |
| 16 | 16,0 | 5,67 | 36 | 39,0 | 12,20 |
| 17 | 18,0 | 6,02 | 37 | 42,0 | 12,27 |
| 18 | 20,0 | 6,30 | 38 | 45,0 | 12,33 |
| 19 | 22,0 | 6,61 | 39 | 47,5 | 12,37 |
| 20 | 23,0 | 6,84 | 40 | 50,0 | 12,42 |

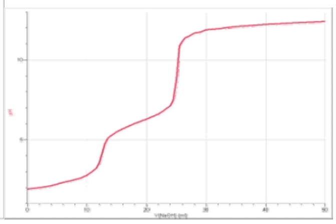


Figure 3. Collected pH(V) data by using TI-84Plus and the GO!Link

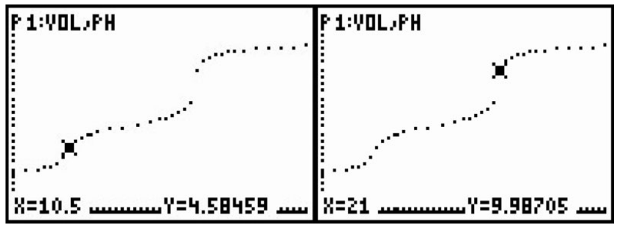



Figure 4. VOL,PH graphic showing two endpoints by using TI-84Plus and the EasyLink

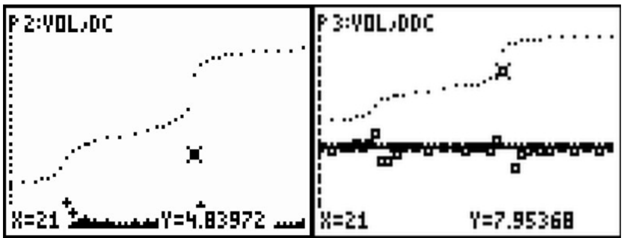
| VOL | PH | DC 1 |
|---|---|---|
| 9 | 3.2527 | .33766 |
| 9.5 | 3.4966 | .48772 |
| 10 | 3.8342 | .6753 |
| 10.5 | 4.5846 | 1.5007 |
| 11 | 5.0536 | .93792 |
| 11.5 | 5.2224 | .33764 |
| 12 | 5.4475 | .45022 |

VOL(8)=10.5

| VOL | PH | DC 1 |
|---|---|---|
| 19.5 | 6.9482 | .4502 |
| 20 | 7.1358 | .37518 |
| 20.5 | 7.5672 | .86288 |
| 21 | 9.9871 | 4.8397 |
| 21.5 | 10.7 | 1.4257 |
| 22 | 10.925 | .4502 |
| 22.5 | 11.056 | .2626 |

VOL(24) =21

Figure 5. VOL,PH and VOL,DC data for two endpoints by using TI-84Plus + EasyLink




| VOL | PH | DDC 1 |
|---|---|---|
| 19.5 | 6.9482 | .30012 |
| 20 | 7.1358 | -.15 |
| 20.5 | 7.5672 | .9754 |
| 21 | 9.9871 | 7.9537 |
| 21.5 | 10.7 | -6.828 |
| 22 | 10.925 | -1.951 |
| 22.5 | 11.056 | -.3752 |

VOL(24) =21

Figure 6. VOL,PH and VOL,DDC data for the second endpoint by using TI-84Plus + EasyLink

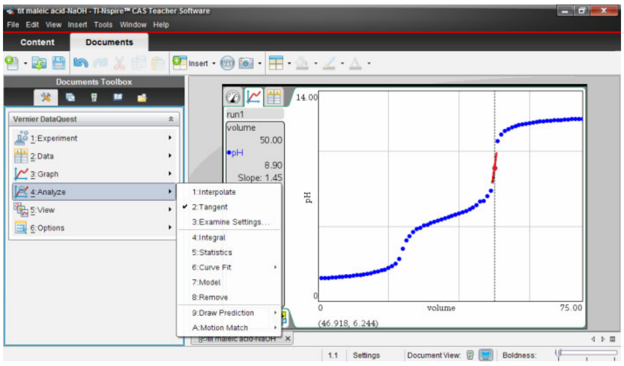



Figure 7. pH(volume)-graphic and tangent at second endpoint by TI-Nspire cx CAS

For verifying measurement results, the TI-84Plus is more suitable. On the other hand, the TI-Nspire cx CAS is more convenient for demonstration purposes.

## IV. EXPERIENCES WITH THE EDUCATIONAL METHOD AND CONCLUSIONS

The use of a graphic calculator and its peripherals in science lessons and corresponding practice sessions opens a new world for students and their teachers. The presented educational method provides a new approach in teaching life sciences to students which, from early childhood on, have grown up with ICT. The teacher is no longer the central person in the classroom, but students explore their collected data independently and at their own pace. As shown in this paper, interdisciplinary projects are accessible by the integration of mathematics into science education through software provided by the graphic calculator. The latter hereby proves to be a perfect tool to lower the threshold between theory and practice. Furthermore, due to the growing compatibility of latest generation of graphic calculators and computers, demonstrations have an increasingly educational relevance for large audiences. Applications of the graphic calculator whether or not in combination with computers are legion for classroom use and can be considered worthwhile to introduce in modern life science education.

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