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Technology Report

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Using ChemDuino, Excel, and PowerPoint as Tools for Real-Time Measurement Representation in Class

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Supporting Information

ABSTRACT: To easily implement digital data collection methods in class, devices like the low-cost solution "Chemduino" have been proposed earlier in this *Journal*. In this paper, we demonstrate how to apply the Excel spreadsheet PLX-DAQ in order to visualize the process of data collection with the help of "Chemduino". With the use of different kinds of sensors, relationships between different variables like temperature, conductivity, and pH are made possible. Furthermore, the real-time data collection can be visualized with media tools like video projectors or interactive whiteboards. In this way, real-time measurement representations can easily be implemented in chemistry classes.

KEYWORDS: *High School/Introductory Chemistry, Laboratory Instruction, Hands-On Learning/Manipulatives, Laboratory Equipment, Apparatus, Inquiry-Based/Discovery Learning*

INTRODUCTION

To support students during hands-on activities, Kubínová and Šlegr suggested a low-cost device called "Chemduino".[1] During hands-on activities that involve analog data acquisition, data recording can be a sophisticated and time-consuming task for students. For example, during titration students face the challenge of getting a sufficient set of measuring points in order to take continuous measurements.

Against this background, there are several advantages of digital data acquisition. The application of computer-based data logging is quite common to the everyday experiences of the students with digital media. It opens new opportunities during the process of scientific inquiry. There is a range of different sensors for all kinds of physical or chemical quantities as pH, conductivity, or temperature. These can be combined when more than one variable is recorded. Furthermore, "working with data" is an important part of scientific inquiry. With the help of computer-based data acquisition, more time in class can be spent on working with data, interpreting results, and reflecting upon the investigation. Technical support brings chemistry education closer to the process of science.

In this technical report, we demonstrate the incorporation of the widely used program Excel to record data via serial communications with devices like "Chemduino"[1] and PLX-DAQ[2] Excel spreadsheet to support the experimental work with data.

EXPERIMENTAL SETTINGS AND THE PROBLEM OF DISPLAYING DIGITAL DATA

As Kubínová and Šlegr pointed out, chemical phenomena can be investigated in class using demonstrations and student experiments. "In the first case, teachers can use a measuring device, whether in connection with a computer (...) or without, in which case it is necessary to have a demonstration device with a large enough display: for example, a pH meter or thermometer. In the case of student experiments, pupils carry out experiments independently. In this case, the use of electronic measuring devices for measuring is also possible" (p 1751).[1] Apart from using large displays, we suggest using already installed projectors and interactive whiteboards for displaying the process of data collection and data representation in charts during demonstrations.

This is possible because all Arduino-based devices are able to send data via serial communication to computers. Arduino IDE[3] already has an implemented serial monitor, which displays recorded measurements. Unfortunately, it is not quite useful for working with data. By implementing the PLX-DAQ source code, the serial communication between the "Chemduino" can be sent directly to Excel and PowerPoint. This enables teachers to easily visualize the process of data collection and to represent the collected data.

REAL-TIME DATA ACQUISITION WITH EXCEL AND DISPLAY WITH POWERPOINT

The free Excel spreadsheet PLX-DAQ[2] works in MS Windows. If the serial communication is implemented in Arduino[3] source code and combined with a few lines of source code needed for the PLX-DAQ spreadsheet, the measurements are printed in ordinary Excel columns and cells. The Supporting Information explains how PLX-DAQ source code is working. Although the Arduino board is connected to computer via USB port, in PLX-DAQ the properties of serial port are set. Arduino board uses USB to Serial Converter to act as standard serial device to make communication with software easier. Figure 1 shows Excel with the starting window of the PLX-DAQ Excel spreadsheet.

There are three advantages of using this kind of data logging. First, there is the possibility to record live data in charts during experiments. During demonstrations in particular, this tool allows one to spend time on the description and explanation of

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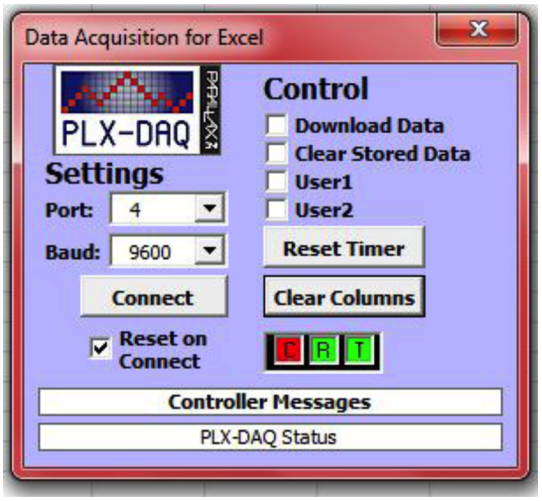

Figure 1. PLX-DAQ interface.

the phenomena by plotting the generated data in real time in Excel charts.

The rate of data collection is only limited by the baud rate implemented in Arduino source code and the response time of the data-generating sensor. Enough measuring points and a continuous measurement are guaranteed. Second, MS Office programs from the version of 2007 onward can be connected with each other. If a chart in PLX-DAQ Excel spreadsheet is changing, it will be adjusted also in PowerPoint. With the use of a projector or interactive whiteboard, the chart is brought into focus just by using a simple PowerPoint slide. The chart in PowerPoint is adjusted if a new data event is recorded in Excel (see Figure 2).

This allows for direct links between the phenomena and the intended representation without losing time for data collection and creating charts. In addition, the user can add other measurements in order to compare data in one chart (e.g., comparison of titration between hydrochloric, sulfuric, and phosphoric acid). Third, there is also the opportunity to record more than one data stream because of the ability of PLX-DAQ to record up to 24 different data streams at the same time. In fact, Excel allows more than one million measuring points per column. So, there are practically no limitations for data acquisition during a chemistry lesson. For example, this allows one to combine the measurement of pH and temperature in order to investigate the changes of neutralization heat during the changes of the pH value (see Figure 3).

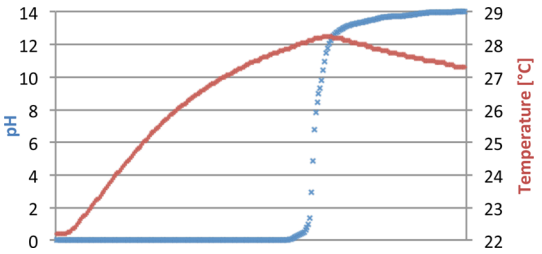

Figure 3. Titration of HCl with NaOH recorded by PLX-DAQ.

By combining the measurements of pH and temperature, students are enabled to understand that neutralization, as an example for a chemical reaction, begins right from the start. As Figure 3 shows, neutralization heat increases temperature until pH 7 is passed because titration proceeds exothermally.

In addition, the PLX-DAQ Excel spreadsheet records the time of every measurement since the data acquisition started, so the measured data develop over time. Several articles are already emphasizing Arduino and its possibilities.[1,4−8] As shown in this article, using PLX-DAQ enhances measuring processes[4,7] with one or more parameters.[9] With PLX-DAQ, no Internet connection or Ethernet shields are required which effects costs and complexity of circuits.

Apart from articles, a lot of projects and helpful guides are available on the Internet just by searching for specific parameters or sensors.[10]

CONCLUSION

As we have shown, teachers and educators can easily implement these technical tools like Chemduino with such widely used computer programs as Excel or Power Point.

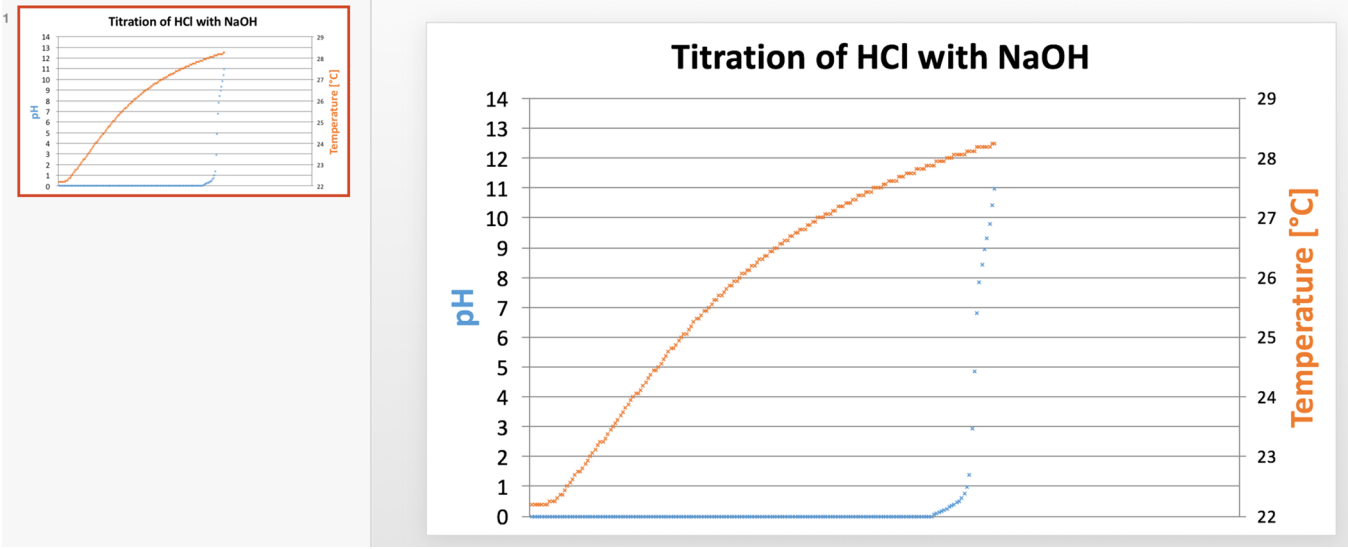

Figure 2. A chart developing on a PowerPoint slide.

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■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00923.

The source code for PLX-DAQ and its explanation. For using PLX-DAQ, just add in the source code in the right function (void setup or loop) and replace the placeholders with your current declarations (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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