The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)

Volume 1, Pages 201-207

ICONTES2017: International Conference on Technology, Engineering and Science

ROLE OF PRACTICAL ACTIVITIES IN IMPROVING COLLEGE STUDENTS SKILLS IN STOICHIOMETRY AND BETTER UNDERSTANDING OF THE UNITS OF MEASUREMENTS

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Abstract: This paper presents results on improvement of college students' knowledge of "units of measurements" understanding and their inter-conversions, and improving their skills in manipulating and understanding chemical calculations through practical experiments on corrosion of four different steel alloys. The experiments constitute a practical part (1 hour/week) of a course on materials and corrosion for second year diploma program in chemical processing. The course includes 3 hours theory as the major part.
The course introduced learners to the physical and mechanical properties of materials commonly used in the chemical processing industries. One part of the course examines the factors that promote the corrosion of these materials when used in industrial processes. Learners also examine a variety of means of controlling and monitoring of corrosion and corrosion processes in chemical industries.

During the academic term winter 2017, 20 students were enrolled in this course. Due to the limited time allotted to practical session, the practical part of the course was focusing on a long single experiment of monitoring corrosion rate of four bars of different steel alloys having the same surface area, placed in a solution of 3.5 % sodium chloride solution, over 8 weeks, by measuring weekly weight loss of each specimen. Students' development of knowledge was monitored by three different theoretical tests, over the period, that involve similar calculations (but not identical) on rust and rate of corrosion. The first two tests were undertaken independent of the final results of the practical part with similar questions (but not identical) were given. The third test was undertaken after the students have submitted reports of their results and calculation.
In the first test, two students only were able to score over 80% of the mark in the calculation part of the test which consists of two problems; four were able to solve one problem only scoring about 50%. Fourteen students were unable to solve any of the two problems. In the second test, four students scored over 80% of the mark in the calculation part and 7 students scored around 50%. The rest failed to solve any problem. In the third test 19 students scored over 80% and 1 student scored 50%.

On the units of measurement that required 3 conversions, 2 students were able to manipulate all the conversion calculation correctly, 5 with two correct conversions, 13 with no correct conversion. In the second test 8 students were able to manipulate all conversions correctly (although some included few calculation error), 4 with two correct conversions and 8 with no correct conversions. In the third test 18 students were able to manipulate all conversions correctly, 2 students with two correct conversions.

Keywords: Practical, corrosion, units, stoichiometry, weight loss

Introduction

According to Novak's theory of meaningful learning (Novak, 2011*)* *"Human beings think, feel, and act. Every learning event involves, to a greater or lesser degree, all three of these actions. In rote learning, there is often little emotional commitment other than to recall the information, and the extrinsic motivation that comes with*

- Selection and peer-review under responsibility of the Organizing Committee of the conference
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getting the right answer. In meaningful learning, the recognition of how the new information integrates with prior knowledge "makes sense" provides much more rewarding intrinsic motivation. Moreover, when the learning is integral to some activity and helps to guide and clarify the activity, there is usually a higher level of positive affect resulting" (p.2).

Galloway and Bretz (2015) explained that for meaningful learning to occur based on this theory, it should integrate the three domains i.e. cognitive (thinking), affective (feeling) and the psychomotor (doing) domains and for this learning to occur in the undergraduate chemistry laboratory, students must actively integrate both the cognitive and the affective domains into the "doing" of their laboratory work.

It is well known that students, as other humans, tend to experience the greatest enjoyment when they are involved in activities that require some investment of skill or effort (Harter 2009) According to Shumow and Schmidt (2014) "*If given the choice many students will opt for an activity that presents a moderate challenge over one that is mindless, because the challenging one is actually more enjoyable. Thus if students experience challenge in science, they may be more likely to choose to become involved in science tasks. Challenging activities are not just enjoyable, they also require that students focus their attention and energy in engaging more deeply in the task at hand. Thus practical activities are the best challenging tasks in learning science"* (p.12).

Importance of Practical Activities

There is no doubt that practical work in science at schools, is widely accepted as a vital component of teaching and learning. It is an effective way to enhance students' motivation and extend their knowledge in understanding theories and ideas about natural world. It is also a well-known fact that students prefer practical work to any other learning activities. However, students do not always learn from a practical task the things their teachers want them to learn. According to Millar and Abrahams (2009) *" A few weeks after carrying out a practical task most students recall only specific surface details of the task and many are unable to say what they learned from it, or what they were doing it for"* (p. 59). Practical work is essential only when it is used effectively. The above authors considered the effective practical as the one that is designed to link the objectives of what students are intended to learn and what they are intended to do; to what students actually learn and what they actually do in a process that involves both learning and assessment (p.60). Abrahams and Miller (2008), developed a model which suggests processes of design and evaluation of the practical tasks. It considers the effectiveness of the specific practical tasks at two interrelated levels that combine both learning and doing. It is based on the belief that *"the fundamental purpose of practical work in science is to help students make links between the real world of objects, materials and events, and the abstract world of thought and ideas" (pp.1948-49).*

However, despite these interdependencies, the instructor aim plays the role in directing the main focus of the activity as suggested by this model. This argument may lead to the conclusion that the degree of this interdependence, is dependent on what the instructor focuses on. If the instructor's aim is that students should develop their understanding of a scientific model or idea then his assessment is based on what the students have learned. If on the other hand the teacher focuses on students' ability to verify an observable phenomenon or process, then assessment is mainly based on students' understanding of how to deal with real data based on actual observation.

These selected requirements are the domains of what instructors and educators call "Practical Activities" Millar 2009) and Dillon 2008.

Hofstein, Mamlook and Naman (2007) wrote that "inquiry-type laboratories have the potential to develop students' abilities and skills such as: posing scientifically oriented questions, forming hypotheses, designing and conducting scientific investigations, formulating and revising scientific explanations, and communicating and defending scientific arguments " (p.106). In previous investigations, by the author, on science education in the state of Qatar the school teachers and science coordinators attributed students' limited science achievement primarily to a lack of student motivation to learn science. That deficiencies in other factors, such as practical activities, are important because these deficiencies can individually and collectively undermine students' motivation (Said & Friesen 2013, Said, Friesen and El-Ezzeh 2014, Said, 2016)

The principle author of this paper was the instructor of a course "materials and corrosion" for second year diploma program in chemical processing. This course, which spans over 12 weeks, introduces students to the physical and mechanical properties of materials commonly used in the chemical processing industries. It examines the factors that promote the corrosion of these materials when used in industrial processes. Learners also examine a variety of means of controlling and monitoring corrosion and corrosion processes in chemical industries. It consists of 3hours/week theory and 1hour/week practical part. The prerequisite for the course is General Chemistry II.

This paper presents results on improvement of, this course-enrolled, students' skills in manipulating and understanding chemical calculations through practical experiments on corrosion of four different steel alloys and also testing their knowledge and understanding of "units of measurements" and their inter-conversions.

Methods

The weight loss method was used to calculate the amount and rate of corrosion, the procedure followed was taken from A.S. Krisher [11].

Metal Samples Preparation and Cleaning

Four specimens of different steel alloys were used coded as in table-1 below. They are all steel cylindrical rods with the size of 1cm diameter and 5 cm length. In the first week of the lab period, they were first polished with sandpaper and cleaned with analar grade acetone for about 3 minutes and dried with filter papers and then left for 5 minutes in the oven to dry completely. Each metal coupon was accurately weighed and immersed in 75 ml 3.5 % NaCl solution contained in a glass jar, covered with a cellophane that contains few pin holes, kept in a cabinet at room temperature (22^{o}C) and left for the next week lab period.

Table.1 Description of alloys specimens

Alloy		Density (g/cm^3)
AISI 1018 Mild Carbon Steel	(MLCST)	7.85
AISI 1045 Medium Carbon Steel	(MDCST)	7.85
AISI 4140 Alloy Steel	(ALST)	7.91
ASTM A36 Stainless Steel	(SST)	7.98

In the second week, the specimens were removed from the jars, cleaned by brushing under running tap water to remove the corrosion products, dried and found out the weight loss. The weighing on an electronic balance were carried out in triplicate to ensure reproducibility. The mean value of weight loss was calculated. From the weight loss values the amount and rate of corrosion were calculated using the equation below. This procedure was followed in each of the subsequent seven weeks. However, due to the slow corrosion rate at the beginning, and two weeks interruption due to holidays that coincided with the lab date, the weight loss was determined 5 times as shown in tables 1 and 2 in the results sections.

Students were asked to submit one report only after 8 weeks following the procedure of calculation shown below.

Calculation of Corrosion Rate

The weight loss is converted to a corrosion rate (CR) or metal loss (ML), as follows:

$$Corrosion\ Rate\ (CR) = \frac{Weight\ loss\ (g) * K}{Alloy\ Density\ \left(\frac{g}{cm^3}\right) * \ ExposedArea\ (A) * Exposure\ Time\ (hr)} \text{-------------(1)}$$

The constant can be varied to calculate the corrosion rate in various units:

Desired Corrosion Rate Unit (CR)	Area Unit (A)	K-Factor
mils/year (mpy)	in^2	5.34 x 10^5
mils/year (mpy)	cm^2	3.45 x 10^6
millimeters/year (mmy)	cm^2	8.76 x 10^4

Theoretical Tests

In the first test performed one week after the start of the practical session on course material that includes corrosion part and, before students have performed any calculation, only instructed theoretically the following two questions were given in the test;

1. Calculate the amount of rust (in kg) produced when 15 kg iron tank is completely corroded.

2. After 30 days of immersion of a 50g steel alloy 25.0 cm2area, in sea water, the weight was reduced to 49.85g. Calculate the corrosion rate (CR) in millimeters/year (mmy) using the formula:
   CR = (Weight loss (g) x 8.75x104) / DAT
   D= density = 7.76 g/cm^3, A = Area, T = time in hours.
   If 1 mil = 0.001 inch, calculate the rate in mils/year, Inch = 2.54

In the second test, written after 3 weeks, one calculation question similar to question 2 above was included. The question is as below:

- After 60 days of immersion of a 70g steel alloy 25.0 cm^{2}area, in sea water, the weight was reduced to 69.34g. Calculate the corrosion rate (CR) in millimeters/year (mmy) and in mils/ year.

The third test was written after submission of the final practical report. This was part of the final exam of the course. The two questions were similar to questions in the first test with small changes. The questions were as below:

1. Calculate the approximate amount of rust (in kg) produced when 10 kg iron piece is completely corroded.
2. After 50 days of immersion of a 70g steel alloy 20.0 cm2area, in 3.5% electrolyte solution, the weight was reduced to 49.70g. Calculate the corrosion rate (CR) in Millimeters/year (mmy) and in mils/ year.

Results and Findings

First we have to state that the purpose of the paper, as the title shows, is not intended to study and discuss corrosion phenomenon; the aim is to explore the impact of practical activities on improving students' knowledge and skills when they are involved in practical activities linked to course curriculum. Therefore discussion of results is directed in this context. However, some of these results are required to help explaining that impact.

Figure -1 shows photos attached to one of students' report. This photo shows the progress of corrosion of the four samples in 3.5% sodium chloride solution over a period of 8 weeks. During that period students were developing knowledge on the process of corrosion similar to metal corrosion caused by sea environment (3.5% NaCl concentration is an average of sea water content of salt). At the same time, students were also practicing stoichiometric practice on calculation rate of corrosion and units of measurement conversions.

Table-2 shows the amount of weight loss of each of the four alloys over a total of eight weeks (1344 hrs.) The results are depicted in figure-2.

Table. 2 Weight loss of metal alloys compared to week 1(g)

Exposed Time			**Weight loss of each metal (steel) compared to week 1 (g)**			
Week	**Hrs**	**Days**	**AISI 1018**	**AISI 1045**	**AISI 4140**	**ASTM A36**
2	168	7	0.02	0.02	0.01	0.01
3	336	14	0.03	0.04	0.04	0.03
5	672	28	0.05	0.06	0.07	0.06
6	840	35	0.06	0.08	0.08	0.07
9	1344	56	0.11	0.21	0.23	0.22

Figure 1. Photographs of steel alloys specimens during (a) week 1, (b) week 2, (c) week 5, and (d) week 8.

Table-3 shows the results of converting weight loss into rate of corrosion as calculated by equation (1). In the questions given in the three mentioned tests, students were asked to perform similar conversions. The impact from the practical results is clear as shown from their scores in table-4. Before performing this long practical activity, only 2 students (representing 10% of the total) were able to perform correct calculation while after completing the activity 19 students (90% of students) have performed calculation correctly and none scored below 50%.

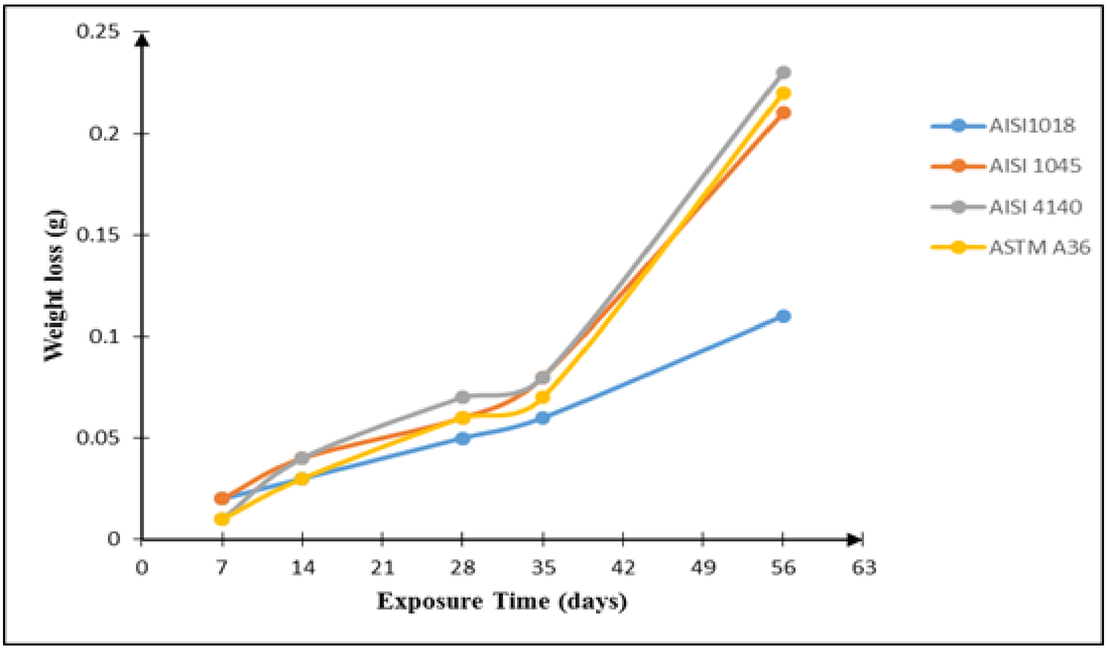

Figure 2. Weight loss vs. exposure time

Most Students concluded that corrosion rate is accelerated with time with an abrupt jump in the rate occurs at week -5 being the highest being in the case of alloy steel(AISI 4140) and lowest with the mild carbon steel (AS1018).

Table 3. Results Calculated from conversion of weight loss into rate of corrosion of the metal alloys

Exposed Time			Rate of Corrosion of each metal (steel) compared to week 1 (mpy)			
Week	**Hrs**	**Days**	**AISI 1018**	**AISI 1045**	**AISI 4140**	**ASTM A36**
2	168	7	3.3941	3.3941	1.7529	1.7079
3	336	14	2.5455	3.3941	3.5057	2.5619
5	672	28	2.1213	2.5455	3.0675	2.5619
6	840	35	2.0364	2.7152	2.8046	2.3911
9	1344	56	2.3334	4.4547	5.0394	4.6967

Table 4. Students' scores in calculation part of the tests (%) n* = 20

Test #	**<50%**	**50% - 79%**	**80-100%**
I	14	4	2
II	9	7	4
III	0	1**	19

* figures in the columns represent number of students who scored the indicated % above each column

** This student scored 67%.

A similar trend was observed in the ability to manipulate units' conversions correctly (table-5) which indicates understanding the importance of units in explaining the meaning of stoichiometric results.

Table 5. Students' Ability in Manipulation Units' Conversion Calculation

Test #	**Students did not do any correct conversion**	**Students did one correct conversion**	**Students did two correct conversions**	**Students did three correct conversions**
1	13	4	1	2
2	6	5	2	7
3	0	0	2	18

Finally in the conclusion part of the submitted reports, most students expressed their interest, enjoyment and understanding of the corrosion phenomenon and stoichiometry and the way this practical contributed to this understanding. Majority of them interpreted the difference in results among the four samples are associated with differences in metal compositions. Finally, Novak's theory of meaningful learning is being embodied since the learning was integral to an activity which resulted in a higher level of positive affect".

Conclusion

In this paper we presented a case on the impact of practical activities in enhancing and promoting better learning when the practical activity is designed to achieve specific learning objectives and its impact can be evaluated both for practical skills and theoretical knowledge. Students were conducting specific investigation to learn how corrosion of metals occurs, how fast it happens, and while enjoying the activity, they practiced and improved their knowledge in understanding certain units of measurements' inter-conversions and manipulating important chemical calculations using the correct units.
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Acknowledgement

We would like to acknowledge and thank Qatar National Research Fund for supporting this research through the National Priority Research Program (award no. NPRP 7-050-5-5001). We are indebted to lab technician Delia Mabulai at the chemical laboratory and Fontino Phillips from the corrosion lab at the College of the North Atlantic for technical assistance and to the twenty students enrolled in the course during winter term 2017.

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