Purdue University

NOMINATION FORM FOR

HELPING STUDENTS LEARN AWARD

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Title of Innovation

Improving student hands-on lab skills in Chemistry 11100 by earning a pipetting badge

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Improving Student Hands-On Lab Skills In Chemistry 11100 By Earning a Pipetting Badge

Rationale for the Pipetting Badge

Based upon Fall 2012 survey data, 30% of the nearly 1,000 students in Chemistry 11100 have carried out five or fewer chemistry laboratories in high school. Students come to our chemistry laboratory without significant hands-on laboratory skills, thus they need opportunities to become proficient at them to be successful in the course.

Pipetting is a fundamental skill in which a solution is suctioned into a calibrated glass tube that is drawn down to a fine bore at one end. It is an essential technique used to measure precise volumes of solutions and it is used routinely in all general chemistry courses nationwide. In order to pipet you need two pieces of equipment—a pipet and a pipet bulb. According to our preparations laboratory which prepares all chemicals and manages equipment for the laboratories, the chemistry department purchases 200-250 pipet bulbs each semester at a cost of $14 each. Thus, the department spends $2800-$3500 each semester on a single type of equipment. Through improper use the students render the many of the bulbs useless (although we could list the ways in which this happens it is easier to acknowledge that it happens). Although each laboratory textbook contains an appendix describing in detail how to properly fill and deliver a sample of liquid using a pipet and pipet bulb, students continue to misuse the equipment and as a result the department still loses equipment.

In addition to the damage caused to equipment, improper pipetting impacts experimental results through incorrect volume measurements. When students draw more or less than the precise calibrated amount into the pipet and use that incorrect volume in experiments their measurements and subsequent calculations become less precise, less accurate, and more random. Students use pipetting in six of 10 laboratories during the semester and they need to learn this technique to carry out experiments precisely and accurately.

In spring 2014 we partnered with the IT staff (Alex Kingman and Jason Fish) associated with Purdue's Passport[1] system to develop and implement a pipetting badge activity. The Passport system allows students to visually display their work as a product of their procedural knowledge. It's a powerful match to an authentic assessment[2] of a hands-on laboratory technique. Further, it is a new and novel way for students to demonstrate their learning that provides meaningful, educative feedback. There are no reports of such a learning activity in the chemistry education literature.

The Innovation: The pipetting badge

In our laboratory curriculum the students learn how to pipet liquids during the second lab. In Fall 2014, each student was charged with creating a video at the end of the lab in which they would explain how to pipet a sample of liquid, thus allowing each student to create a product of their learning. Most, if not all, students have a device such as a smartphone, iPad, or computer that can be used to film a video. We created a set of 10 steps for students to follow in creating the video. After students uploaded their videos to the Passport system, instructors reviewed them and provided each student with feedback on his or her technique and accepted or denied the submitted video. If the video was denied then students were able to make use of the feedback and upload a new submission. We piloted the pipetting badge in Summer 2014, which allowed us to refine our instructions to the student and address issues with uploading the video across platforms.

We modified a questionnaire from the research literature to measure a student's perception of his/her knowledge, experience, and confidence pipetting[3]. The items were designed to measure the impact of the pipetting experience on the students' knowledge, confidence, and psychomotor skills. The seven items included two identification statements and five process statements. For each item the student was asked to respond separately on a five-point Likert scale for knowledge (cognitive dimension), experience (behavioral/psychomotor dimension), and confidence (affective dimension).

Through consultation with Dr. Brooke Robertshaw at Purdue's Office of Institutional Assessment we decided to administer the survey shown in Table 1 three times as part of the badge activity. The first was a pre-test to be completed prior to the second laboratory. After submitting a video a student then completed a "retrospective" pre-lab survey[4] which allowed a student to think back to before they had completed the lab to reconsider what he or she did and didn't know about pipetting. The theory behind this survey was that students might not really know what they didn't know until after they had completed the video portion of the badge activity. Then the students completed the post lab survey. This research design allowed us to measure student knowledge, experience, and confidence before and after the laboratory.

Table 1: Seven statements to measure student's knowledge, experience, and confidence pipetting. 35 is the maximum score.

Statement	knowledge					experience					confidence				
	low				high	low				high	low				high
1) Identify a pipet from among pieces of glassware.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2) Identify a pipet bulb from among pieces of equipment	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3) Use a pipet and pipet bulb to deliver a sample of liquid to a flask.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4) Connect a pipet and pipet bulb properly.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5) Draw liquid into a pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6) Get liquid to the proper level in the pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
7) Dispense liquid from the pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

Implementation

The pipetting badge was implemented in Fall 2014 in Chemistry 11100 with 965 students, 874 of whom submitted videos and 843 of whom completed all surveys and submitted a video. Dr. Brooke Robertshaw analyzed the survey data and it is her report that is used in this section to discuss student performance on the survey. Additionally we could statistically analyze the differences in results among all three surveys.

There was a large improvement in students' self-reported confidence in, experience with, and knowledge of pipetting skills as shown by the increasing means in Table 2. All comparisons between means on pre/post, retrospective pre/post, and pre/retrospective pre surveys for confidence, experience, and knowledge are statistically significant ($p < 0.001$). An effect size was calculated for each comparison because an effect size describes *how different* the groups are rather than just if they are different and is not influenced by sample size. The range for effect sizes is 0-0.30 is considered small, 0.3-0.6 medium, and 0.6 and above is large. As shown in Table 3, every effect size comparison is large. Thus the analysis unequivocally establishes that students improved their knowledge, confidence, and experience in being able to identify a pipet and a pipet bulb, and in the ability to carry out the procedure of pipetting. Among the individual statements shown in Table 1, the largest gain for knowledge, experience, and confidence was on the statement "Connect a pipet and pipet bulb properly." This is a notable result because most pipet bulb losses result from students improperly inserting the pipet into the pipet bulb. There is the potential for significant departmental cost savings if students know how to properly connect a pipet and pipet bulb.

Table 2. Descriptive statistics for each of the subscales for each survey

Scale	Measurement	Mean	Std. Dev.
Confidence	Pre	23.23	6.29
	Retrospective Pre	26.64	4.35
	Post	34.48	2.22
Experience	Pre	20.46	7.14
	Retrospective Pre	29.14	6.58
	Post	33.42	4.24
Knowledge	Pre	22.92	6.46
	Retrospective Pre	31.09	5.34
	Post	34.60	2.06

Table 3. Effect sizes for comparisons between each survey

Subscale	Survey comparison	Effect size for comparison	Small / medium / large effect size
Confidence	Post-Pre	2.38	Large
	Post-Retrospective Pre	2.27	Large
	Pre-Retrospective Pre	0.63	Large
Experience	Post-Pre	2.21	Large
	Post-Retrospective Pre	0.77	Large
	Pre-Retrospective Pre	1.26	Large
Knowledge	Post-Pre	2.44	Large
	Post-Retrospective Pre	0.86	Large
	Pre-Retrospective Pre	1.38	Large

We asked the students a procedural question pertaining to pipetting on the first exam and on the final. The exam 1 item asked students to identify where the liquid in the pipet should be drawn to via a multiple-choice question. To answer this question correctly the student would need to know that a pipet is marked with a calibration line where the liquid (actually the bottom of the curved surface of the liquid, the meniscus) is drawn to. 912 out of 965 students, or 94.5%, answered the question correctly. On the final exam the item contained a picture of a pipet where the liquid had been drawn above the calibration line. The students would need to evaluate the picture, recognize that the liquid was above the calibration line, and that it needed to be lowered in order to accurately deliver 5 mL of sample. 909 out of 928, or 98%, of the students chose the correct answer. The significance is three-fold: the demonstration of correct knowledge about pipetting, the retention of that knowledge, and a concomitant improved accuracy of students' lab results.

Evidence of student learning

There are multiple methods of demonstrating the impact on student learning with this innovation.

- The videos allowed students to receive direct feedback on their pipetting technique. Further, they could improve their technique by re-submitting their video.
- The survey data yielded significant differences between every survey pair (pre/post, retrospective pre/post and pre/retrospective pre) and large effect sizes. These large effect sizes are particularly compelling pieces of evidence that students perceive much greater knowledge, confidence, and experience in identifying a pipet and a pipet bulb, and in their procedural knowledge, confidence, and experience in pipetting a sample of a liquid.
- Exam 1 and Final Exam results demonstrated that 94.5% and 98% of the students could correctly answer a procedural question about pipetting and that the knowledge was retained.

Experienced graduate teaching assistants also commented to us that the students were much more competent in their pipetting technique in subsequent labs. One commented that usually she would have to teach pipetting technique repeatedly during the semester, but this term the students knew what they were doing and didn't ask. We had one unsolicited comment about the pipetting badge experience on the course evaluation: "*At first I thought the pipetting badge assignment was stupid, but later I realized how important being able to pipet efficiently is."*

The analysis of evaluation data and our experiences in the laboratory established that this innovation significantly and positively impacted classroom practices wherein the students learned to pipet more effectively and improved their knowledge, confidence, and experience in pipetting.

Further development

We are continuing to develop this badging activity in Chemistry 111 this spring. We plan to implement a pipetting badge in other general chemistry courses enrolling over 2500 students in the fall of 2015. Development of other badges related to hands-on laboratory experiences is underway.

References:

[1]See http://www.itap.purdue.edu/studio/passport/.

[2] Wiggins, G. P. (1993). *Assessing student performance*. San Francisco: Jossey-Bass Publishers. Wiggins, G. P. (1998). *Educative assessment: Designing assessments to inform and improve student performance.* San Francisco: Jossey-Bass Publishers.

[3]Lee, Y., Kerner, N., & Berger, C. (1998). Student perceptions of collaborative laboratory inquiry, Paper presented at the National Association for Research in Science Teaching meeting, San Diego, CA.

[4]Hill, L. and Betz, D. (2005). Revisiting the Retrospective Pretest. *Am J Eval*, *26(4),* 501-517. Howard, G. S., Ralph, K. M., Gulanick, N. A., Maxwell, S. E., Nance, D. W., & Gerber, S. K. (1979). Internal validity in pretest-posttest self-report evaluations and a re-evaluation of retrospective pretests. *Appl Psychol Meas*, *3,* 1-23.