Digital Labcoat:
An Active Learning Tool for Teaching the
Scientific Method in the Social Sciences

by

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for the degree of Master of Arts
Department of Psychology
University of Toronto

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Abstract

Active learning methods have established themselves as the “gold standard” of teaching, and are recommended as part of good teaching practice. In high-enrollment university courses, incorporating active learning activities can be difficult, as they are often a resource-intensive undertaking, requiring large time commitments on the part of the instructor. By turning to online technologies, it may be possible to introduce low-cost implementations of active learning activities. To this end, we have created a web application called Digital Labcoat -- a tool for introductory social sciences courses that implements active learning methodology to engage students in the scientific method and improve scientific literacy. The present study examines the use the Digital Labcoat software in large university courses, and assesses its success at achieving its educational goals. The results establish Digital Labcoat as a feasible assessment tool that is associated with increased student understanding of the scientific method.
Acknowledgments

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Chapter 1

Digital Labcoat

1 Introduction

The use of online technology in the teaching of postsecondary courses has become mainstream practice, with learning management systems like Blackboard and D2L serving as the major delivery mechanism for course administration (Quarless, 2007). These systems aim to enhance the traditional classroom experience, by providing features like calendars, centralized grading, and discussion forums. Often, these online tools are used in a supplementary role, as an adjunct to a classroom-based course where lectures are delivered in person. It is becoming increasingly common, however, for courses to be delivered entirely online, with both the delivery of content and assessment of learning taking place over the internet (Young & Duncan, 2014). In these “eLearning” environments, recorded videos and online examinations are akin to classroom-based lectures and paper tests, but the parallels are less clear when we look at the sorts of enrichment activities that can be conducted in classrooms, like group activities, role-playing, and laboratory work. The efficacy of these “active learning” activities has been well established, with gains in both academic performance and student engagement being observed (Brown & Cocking, 2000; Bonwell & Eison, 1991; Price & Kirkwood, 2011). To provide students with an optimal eLearning experience that is comparable to what they would receive in a traditional classroom, online active learning activities need to be developed. To this end, we have created a web application called Digital Labcoat -- a tool that implements active learning methodology to engage students in the scientific method. In this paper, we explore the motivations behind the
development of Digital Labcoat, describe the application itself, and discuss preliminary results on the use of Digital Labcoat in large introductory psychology courses.

1.1 What is Active Learning?

Active learning encompasses a range of instructional techniques that place the student at the center of their learning. Although definitions vary, it is generally understood that active learning is when students engage in learning activities that require them to think about what they are doing (Bonwell & Eison, 1991). This is in contrast to the usual “passive” learning that takes place in a lecture, where there is one-way communication between the instructor and students, with the instructor delivering information and students absorbing it. Active learning activities can take many forms, such as group discussions, collaborative assignments, role-playing, simulations, and laboratory experiments. With such a broad range of techniques falling under the heading of “active learning,” it is difficult to make claims on the overall effectiveness of active learning in general (Prince, 2004), however, a multitude of evidence exists supporting specific teaching strategies.

Hands-on activity and peer collaboration are two of the active-learning strategies that have been well established as effective teaching practices. In a meta-analysis by Hake (1998), it was found that conceptual understanding of physics concepts was significantly higher in classes using hands-on activities and peer/instructor discussion, compared with strictly lecture-based courses. In courses that have been restructured to include active learning components like group activities and in-lecture checks of understanding, students report higher overall satisfaction with the course and perform better on academic outcome measures, particularly those assessing the more advanced “Application” and “Analysis” levels of Bloom’s taxonomy (Armbruster, Patel, Johnson, & Weiss, 2009). High performance on these levels indicate a deeper understanding of
course content and an ability to apply the acquired knowledge, not just recite it (Bloom & Krathwohl, 1956). From this sort of evidence, active learning methods have established themselves as the “gold standard” of teaching, and are highly recommended as part of good teaching practice (Chickering & Gamson, 1987).

As the support for active learning methodology continues to accumulate, the task of incorporating these practices into teaching falls to the instructors. Adopting active learning may be a straightforward undertaking in a traditional, small-sized classroom, but for those instructing high-enrollment online courses the path is not so simple. In these instances, turning to technology to provide active learning activities may be the answer.

1.2 Active Learning in Large Courses

Large instructor-to-student ratios and limited resources are the plight of high-enrollment courses. As a result, the instruction in these courses is often strictly lecture-based, using multiple-choice assessments that allow for automatic grading. The idea of incorporating active learning into this sort of environment can seem overwhelming, given that most methods require substantial time commitment on the part of the instructor and expert graders. Considering this, we conclude that a feasible active learning tool for large classes needs to be easy for the instructor to set up, and include assessments to produce grades that require little to no input from human markers.

Attempts to create such tools have produced things like Audience Response Systems, which involve students purchasing a handheld electronic “clicker” device, and using them to respond to multiple choice questions proposed by the instructor during classes. Responses can be viewed immediately for the class to see and discuss. These devices have been shown to improve retention, test scores, and student attitudes toward the class (Caldwell, 2007). Although this technology is effective at engaging students who are attending physical classrooms, it is not
viable for use in an online learning environment where lectures are viewed at different times, in multiple locations. To create an active learning tool with further utility, development of web applications allowing for asynchronous participation is needed.

Online simulations, such as “virtual laboratories,” have been developed to address this need. Primarily existent in the physical sciences, these virtual laboratories allow students to participate in a simulation of an experiment, record data, and answer questions. Compared to lecture-based teaching, this approach yields benefits such as improved student engagement and academic achievement (Rutten, van Joilingen & van der Veen, 2012). The downside of this approach is that each simulation is focused on teaching a very specific topic, such as the mechanics of oscilloscopes or computer networks, and the creation of any single simulation requires substantial time investment. Imagining a virtual laboratory for the social sciences is even more difficult, considering that the logistics of simulating a human participant are much more complex than something like an oscilloscope. Rather than attempting to create a suite of individual simulations for specific concepts, a more useful tool might be one that teaches the broader skills of scientific and numeric literacy, and is flexible in its content.

1.3 Digital Labcoat

For university students in the social sciences, introductory level psychology courses may be their only exposure to research design methodologies and qualitative reasoning (Lutsky, 2006). The ability to be a competent consumer of scientific data is central to the university experience, and so engaging students in an active learning task designed to develop scientific and numeric literacy is important. As part of the transformation of the University of Toronto Scarborough’s “Introduction to Psychology” course into fully online class, we developed a web application called “Digital Labcoat,” which aims to teach students about the scientific method, and improve
their numeric and scientific literacy in the process. Students go through the phases of data collection, hypothesis generation, statistical analysis, experimental replication, and theorizing about results. In line with recommendations of Paré and Joordens (2009) on the construction of educational technologies, the high-level design of Digital Labcoat was informed by pedagogical research supporting active learning, with the educational goal of improving student understanding of the scientific method. Lower-level implementation decisions were guided by intuition. Details of the Digital Labcoat application are discussed in the following sections.

1.3.1 Setup

On the side of the instructor, the time to set up an activity is minimal. The instructor specifies the start and end dates and times for each of the four phases of Digital Labcoat, and constructs the initial survey. Survey questions can be of three formats: multiple choice, likert scale, or numeric entry (with the option of specifying upper and lower bounds). In the past, Digital Labcoat has been used with both general interest questionnaires designed to give the students enjoyable data to explore, and with more targeted questionnaires related to course content. Instructors have the option of specifying whether students are allowed to skip questions, or if responses are always required.

1.3.2 Phase 1: Survey

In this data collection phase, the students complete the survey that has been created by the course instructor. Responses are stored anonymously, but a completion grade is stored for each student.
1.3.3 Phase 2: Analyze

In this phase, students complete statistical analyses on the dataset acquired in Phase 1. Digital Labcoat facilitates both Pearson correlations and Student’s t-tests. After selecting the type of analysis to run, students select which two survey questions will serve as the variables of interest (Figure 1), and in the case of a t-test, define levels of the independent variable (Figure 2). Next, students are asked to state their hypothesis on the predicted relationship between the two variables. A random sample of 200 student responses is selected, and the specified correlation or t-test is run. Results of the statistical analysis are then presented (Figure 3), and the student is asked to make a statement indicating whether or not their hypothesis was confirmed.

Since this software was designed for an introductory psychology class containing no mathematical component, the statistical calculations are computed for the student. The goal here is to “demystify” the role that statistics plays in the scientific process. Students see the calculations, and it is explained how the results are used to determine the significance of a result. Students are able to conduct as many analyses as they wish, and are tasked with picking their “most interesting” result to submit forward to the next phase. For the finding they choose to submit, the student must come up with a title for their result, as if they were publishing a paper on the topic. This phase is graded as a completion mark, awarded once the student submits their most interesting result.

1.3.4 Phase 3: Replicate

During the replicate phase, students see a list of fifty analyses submitted by their peers. Of these, students select ten of them to replicate. In a replication, a new random sample (n = 200) of the dataset is chosen, and the analysis is run again. Students see the results of the new analysis
alongside their peer’s original analysis, and are asked to apply their knowledge of statistical significance learned from Phase 2 to assess the statistical significance of the new result, and determine whether or not there was a successful replication of the original result. Correctness of their responses is used to compute a grade for this phase. Students are also asked to rate the how interesting each result was, on a scale of 1 to 10.

1.3.5 Phase 4: Theorize

Here, a “top ten” list is compiled, containing the ten most interesting results that replicated at least 80% of the time, and were chosen for replication at least 5 times. Students are given the option of completing one of two tasks: (1.) Provide a theoretical explanation for one of the findings, or (2.) For each of the ten findings, vote on the best theoretical explanation that has been posted. A completion mark is recorded.

At the end of this whole process, we are left with the perceived most interesting results, and a list of the most endorsed theories to explain the results. Here, attention is drawn to fundamental misconceptions like third variable contributions and the difference between correlation and causation. This sort of learning is crucial, as addressing misconceptions is recognized as an essential element of effective teaching (Brown & Cocking, 2000).

Digital Labcoat has been piloted in the University of Toronto Scarborough’s Introductory Psychology and Social Science courses, and used in Coursera’s 2013 offering of an Introduction to Psychology MOOC (massive open online course). The studies presented here examine the feasibility of using Digital Labcoat in large social science courses, and assess the tool’s success in meeting educational goals (Experiment 1). Experiment 2 begins to explore variations of the software’s interface, with the long-term of achieving an optimal implantation of the system.
2 Experiment 1

Digital Labcoat was used first piloted as an active learning activity and assessment tool in a large introductory psychology class at the University of Toronto Scarborough in the 2012-2013 academic year. The inclusion of Digital Labcoat coincided with the implementation of other online learning activities in the course, as part of an initiative to create so-called “fully online” courses at the university, in which all aspects of the course were delivered in an electronic format, with the exception of a final cumulative exam. Students completed all four phases of Digital Labcoat as an activity worth 7% of their final course grade.

This pilot of the Digital Labcoat software was designed to assess user interface issues, examine student engagement with the software, and uncover student perceptions toward the Digital Labcoat activity. It was expected that students would demonstrate engagement with the software by completing more than the minimum amount of work required to receive perfect marks on the activity. In terms of subjective reports, it was expected that students would express that they enjoyed the activity, and report a better understanding of the scientific method after completing Digital Labcoat.

2.1 Methods

2.1.1 Participants

Undergraduate students (n = 1803) from the University of Toronto Scarborough completed the Digital Labcoat activity as part of their required coursework for Introductory Psychology: Part II (PSYA02) during the Winter 2013 session. The activity was worth 7% of their final course grade.
2.1.2 Apparatus

Students accessed Digital Labcoat over the internet, from either their home computers or via the many computer terminals freely available on the campus. Digital Labcoat was implemented in Python using the Pyramid Web Framework, allowing for compatibility with all major internet browsers.

2.1.3 Design and Procedure

Students were instructed to complete the Digital Labcoat activity as part of their coursework for Introductory Psychology: Part II (PSYA02). Before each phase, students were told to watch an online video explaining how to complete the phase. Of the 1803 enrolled students, 1733 students completed at least one phase of the activity, and 1266 students completed all four phases. While completing the activity, students were asked to report any technical or conceptual issues to the supervising teaching assistant via email or discussion forum.

As each student completed the activity, the following information was recorded by the software:

Phase 1 (Survey): - Whether or not the student completed the questionnaire

Phase 2 (Analyze): - The number of t-tests the student completed

- The number of correlations the student completed

- Whether or not the student submitted their most interesting experiment

Phase 3 (Replicate): - The number of replications the student completed

- For each replication, the student’s assessment of
  (a.) the significance of the result
  (b.) whether or not the original result was replicated
Phase 4 (Theorize): - The number of theories the student completed
- The number of votes the student cast

A grade for each participating student was computed automatically by the Digital Labcoat system, based on completion of the phases and correctness of responses. Phases were graded independently, and any missed phase was assigned a grade of zero.

Engagement was operationalized as the amount of work that a student completed above what was required to obtain a perfect mark on the activity. This was computed from the Phase 2 data, where students were required to complete just one analysis to receive their completion mark. Any additional analyses completed were considered to be a demonstration of interest in the activity, and engagement in learning.

At the end of the course, students were asked to complete an online questionnaire regarding their experience in the “fully online” course. 1249 of the 1803 enrolled students completed the survey, and were compensated for their time with course credit (0.5%) and a chance to win movie tickets. The questionnaire contained a total of 51 questions, with 6 questions pertaining to the use of Digital Labcoat. These questions asked respondents to report on their enjoyment of the activity, and the perceived learning outcomes of participating. For each question, respondents rated their agreement with a given statement on a 7-point likert scale, ranging from “Strongly Disagree” to “Strongly Agree.”
2.2 Results

2.2.1 Feasibility

No major technical issues were encountered during the Digital Labcoat activity. All phases of the activity were executed successfully, in line with the design outlined in the introduction of this paper.

A common error made by students during the activity was a failure to identify and submit their most interesting analysis during the Analyze phase. This requirement was articulated in the instructional video, suggesting that students may not have watched the video in its entirety. Students reported that it was not clear from the interface that this was a required step.

The entire Digital Labcoat activity required approximately 30 hours of instructor time. This included researching topics and constructing questions for the Phase 1 questionnaire, entering the questions into the Digital Labcoat system, entering the student information into the system, responding to student emails and discussion forum enquiries, and uploading the Digital Labcoat grades into Blackboard.

2.2.2 Engagement and Grades

On average, students completed 11.1 analyses during Phase 2 of the activity (SD = 11.23). A one-sample t-test determined that this was significantly higher than the number of analyses required to receive full marks for the phase (i.e. one analysis) (t(1802) = 38.13, p < 0.0001). Students completed significantly more correlation-type analyses than they did t-tests (t(1802) = 24.94, p < 0.0001, see Figure 4). A Pearson correlation revealed a significant positive correlation between overall course grade and the number of analyses completed in Phase 2 of
Digital Labcoat ($r(1801) = 0.32$, $p < 0.0001$, see Figure 5). This is considered to be a medium effect size, according to Cohen (1988).

### 2.2.3 Survey Responses

Results from the end-of-term questionnaire expressed an overall acceptance of the Digital Labcoat activity. Table 1 shows the complete response data from the Digital Labcoat portion of the questionnaire. A large majority of the students endorsed the statement “I actually enjoyed looking for and learning about the interesting results in our class's data ... it was actually a lot of fun,” with 856 responses (70.8%) indicating agreement, and 145 (12.0%) indicating disagreement. Only 312 students (25.8%) recorded that they had done the minimum amount of work required to complete the activity.

706 respondents (58.2%) agreed that the Digital Labcoat activity inspired them to think about data and relations among variables. When compared with learning about research methods from a textbook, 814 respondents (67.4%) indicated that statistical concepts like sampling, replication, hypotheses, and third variables made more sense after completing Digital Labcoat. 829 respondents (69.5%) endorsed that using Digital Labcoat allowed them to gain a clearer understanding of the role of statistics in the scientific process. Finally, 438 respondents (36.1%) agreed that the Digital Labcoat activity had made them less worried about taking a course in statistics.

### 2.3 Discussion

The results establish Digital Labcoat as a feasible active learning tool to incorporate into introductory level social sciences classes. The activity met its educational goals by delivering an
opportunity to both increase student understanding of the scientific method, and assesses that understanding. Digital Labcoat was successful in incorporating a graded activity into a large online social science course, without requiring human markers. This offered obvious financial benefit to the educational institution, since it was not necessary to employ additional teaching assistants to compute grades. There were also logistical benefits to the course administrators, seeing as the involvement of the instructor was minimal, requiring only the construction of the Phase 1 questionnaire and selection of deadlines for each phase.

The analysis of student engagement shows that students were highly engaged in the Digital Labcoat activity, completing more analyses than what was required of them. The fact that students chose to conduct additional analyses demonstrates that they found value in the activity beyond participating to obtain course credit. Engagement has been established as a measure of quality of learning experience (Robinson & Hullinger, 2008), and so the fact that students completed, on average, 11 times more work than necessary is an extremely desirable outcome. Students were likely motivated by the desire to learn information about their peers, and discover relations among variables extracted from the survey that their classmates completed during Phase 1 of the activity. A different dataset containing information that is perceived as less interesting by the students make not result in the same levels of engagement with the activity. Future investigations should examine this possibility.

The results of the end-of-term survey suggest that Digital Labcoat was widely accepted by the class. A large majority of students reported that they enjoyed the activity and did more work than what was required, illustrating that they were intrinsically motivated to engage in the task. Of most importance are the reported positive learning outcomes endorsed by the students. Responses indicated that a majority of students achieved a greater understanding of statistical
concepts after completing the Digital Labcoat activity, when contrasted with learning those same concepts from the course textbook. This finding is consistent with the established literature that has shown gains in academic performance in response to the introduction of active learning activities in the classroom (Brown & Cocking, 2000; Bonwell & Eison, 1991; Price & Kirkwood, 2011).

The subjective nature of self-report data is an obvious limitation of this study. Future investigations should incorporate objective measurements of learning outcomes, testing knowledge of statistical concepts before and after using Digital Labcoat. It would also be beneficial to conduct an experiment using control and experimental groups, where the learning outcomes of traditional book-learning techniques and Digital Labcoat can be compared. After completing Introductory Psychology, student performance in the second-year statistics course may also be examined to assess long-term effects of the activity.

More elaborate assessments of student engagement are also possible. Other researchers have been successful in assessing engagement using of the National Study of Student Engagement (Robinson & Hullinger, 2008; Kuh, 2001). Although originally designed for on-campus education, some of the dimensions are relevant to online learning and could be used to further assess student engagement with the Digital Labcoat activity.

Feedback from students indicated that there was confusion during the Analyze phase over the requirement to choose their most interesting experiment for submission. To address this issue, additional prompts have been incorporated into the system to remind students that this is necessary to obtain full credit for the phase. It is possible that using instructional videos is not most effective method of detailing the assignment requirements. Future iterations of the software should incorporate written instructions into the interface itself, to move away from
reliance on the video explanations. It would also be useful to conduct lab-based experiments to examine the usability of the software and make further improvements to the interface.

3 Experiment 2

After establishing the feasibility and subjective benefits of using Digital Labcoat in large introductory psychology classes, attempts were made to improve the discriminative grading ability of the software. In prior iterations, each phase of the activity was graded as a binary score, indicated as either “complete” or “incomplete.” The replication phase was the only exception to this, with students answering questions about the statistical significance of the new result, and whether or not there was a successful replication of the original result. Since most students did complete all phases of the activity, this likely contributed to the slight grade inflation (an increase of 2% to the mean final grade) that occurred when introductory psychology was converted to a “fully online” course. To counteract this, additional opportunities for assessment were incorporated into Digital Labcoat for the 2013-14 offering of the course.

Specifically, during the Analyze phase, the interface was updated to facilitate the entering of more useful hypothesis and conclusion statements. Previously, for each experiment the students were asked to enter their hypothesis and conclusion into textboxes, allowing for free-form responses. These responses could not be graded for quality without incorporating human markers, and were thus scored only for completion. The system was able to check that textboxes were nonempty but no deeper analysis of the student input was made, meaning that it was possible for students to receive the completion mark even if they submitted poorly formed hypotheses and conclusions, or even nonsense characters. For this experiment, the open-ended hypothesis input box was replaced with a drop-down menu where students selected the predicted
direction and significance of their experimental result. Similarly, the open-ended conclusion input box was replaced with radio buttons where students indicated whether or not the results of the experiment supported their hypothesis. The correctness of their conclusions was assessed, and replaced the completion grade originally used for the Analyze phase.

Under this new interface it was expected that the variability of Digital Labcoat grades would increase, and that the mean Digital Labcoat grade would be lower, when compared to the grades from the previous year.

3.1 Methods

3.1.1 Participants

Undergraduate students from the University of Toronto Scarborough completed the Digital Labcoat activity as part of their required coursework for Introductory Psychology: Part I (PSYA01) during Summer 2013 (n = 323) and Summer 2014 (n = 386) sessions. The activity was worth 7% of their final course grade.

3.1.2 Apparatus

Students accessed Digital Labcoat over the internet, from either their home computers or via the many computer terminals freely available on the campus. Digital Labcoat was implemented in Python using the Pyramid Web Framework, allowing for compatibility with all major internet browsers.
3.1.3 Design and Procedure

Students were instructed to complete the Digital Labcoat activity as part of their coursework for Introductory Psychology: Part I (PSYA01). In the Summer 2013 session, 313 of the 323 enrolled students completed the activity, and in the Summer 2014 session, 379 of the 386 students completed the activity. A grade for each participating student was computed automatically by the Digital Labcoat system. Students who did not complete the activity received a grade of 0.

Both the Summer 2013 and Summer 2014 sessions were given identical questionnaires to complete during the data collection phase (Phase 1). Students received identical video instructions for each phase of the activity, with the exception of the Analyze phase, where the method of entering hypotheses and conclusions differed for the two sessions. In this case, a different set of video instructions was given to the two sessions to explain the differing interfaces. Students were encouraged to ask questions on the discussion forum or email the teaching assistants if any instructions were unclear.

The Digital Labcoat activity was graded out of 7 possible marks. In both sections of the course, Phase 1 (Survey) and Phase 4 (Theorize) were graded as completion scores, and Phase 3 (Replication) was graded for correctness in response to the “Is my result significant?” and “Did my result replicate the original finding?” questions. In the Summer 2013 session (using the old interface), Phase 2 (Analyze) was graded for completion. In the Summer 2014 session (new interface), instead of a completion mark the grade for the Analyze phase was replaced with a value indicating the correctness of their responses to the “Did the result support my hypothesis?” questions (computed as number of correct responses divided by number of completed analyses).
Students were required to complete just one analysis for Phase 2, but were encouraged to complete as many as necessary in order to find a result that was interesting.

### 3.2 Results

Contrary to prediction, Levene’s test for equality of variances found no significant difference between the variances of the Summer 2013 and 2014 Digital Labcoat grades, however an independent sample \( t \)-test did find a significant difference between the means of the Summer 2013 and Summer 2014 Digital Labcoat grades \((t(560) = 4.41, p < 0.0001)\). As seen in Table 2, the mean grade for the activity was significantly lower for the Summer 2014 session (mean = 5.63, SD = 1.52) than the Summer 2013 session (mean = 6.21, SD = 1.34).

### 3.3 Discussion

The results suggest that the changes made to the Phase 2 interface resulted in lower grades in the Digital Labcoat activity, but did not change the variance of the grades. Replacing the completion mark with an objective assessment of the students’ understanding was effective in reducing the ceiling effect evident in the Digital Labcoat grades, resulting in a mean deduction of 0.58 out of the possible 7 marks. This is considered to be a positive effect, considering the grade inflation that occurred upon introducing the “fully online” version of Introductory Psychology and its associated online learning activities. The mean final course grade increased from 68% to 70% when the course was modified, and so a deduction in the Digital Labcoat grades resulting from a more objective assessment of learning outcomes is considered ideal.

Although the changes introduced here did bring about improved assessment of students, the mean Digital Labcoat grade (5.63 out of 7, or 80%) is still considered high for an assignment at
the University of Toronto. Future iterations of the software should attempt to introduce even more opportunities for objective assessment, further reducing the ceiling effect evident in the activity’s grades.

4 Conclusions

There is still much to be learned about enhancing the online learning experience to achieve optimal levels of student engagement and facilitate learning outcomes. The results of this pilot study of Digital Labcoat indicate that it is both feasible and beneficial to incorporate internet-based active learning activities into large online courses. Digital Labcoat is a singular example of what can be accomplished using eLearning capabilities. There is great potential for other empirically-supported online learning activities to be created, researched, and improved upon, ultimately contributing to a richer and more engaging online learning experience.

Development of the Digital Labcoat software is ongoing, with plans to incorporate more elements of assessment, and facilitate a deeper understanding of statistical tests. Specifically, instructors will have the option to increase student interaction with the statistical calculations conducted during the Analyze and Replication phases. Learning will be scaffolded by including a “drag-and-drop” option in the interface, where students are required to drag the computed means and sums of squares into the statistical formulae. An even more challenging option would be to have the students compute the statistics themselves, and enter the values into the interface for evaluation.

The inclusion of immediate feedback is also underway, in response to research showing that immediately correcting student errors can inhibit future mistakes (Butler & Roediger, 2008). Confirming correct responses can increase retention and improve students’ confidence in their
responses (Butler, Karpicke & Roediger, 2008). Rather than tallying the students’ marks at the end of each phase, it is expected that students will learn better if they are given immediate feedback on the correctness of their responses.

Finally, efforts are being made to link Digital Labcoat to Blackboard and other learning management systems, in order to automate the tasks of registering students in the activity, and transferring the computed grades back to the LMS.
Table 1. Survey responses indicating reactions to the “fully online” offering of Introductory Psychology: Part II (PSYA02) in the Winter 2013 session.

Survey Statement:
I actually enjoyed looking for and learning about the interesting results in our class's data ... it was actually a lot of fun!

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<th>2</th>
<th>3</th>
<th>4</th>
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Survey Statement:
I did the very least I had to do to complete the steps

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<th>Strongly Disagree</th>
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<th>2</th>
<th>3</th>
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<td></td>
<td>312</td>
</tr>
</tbody>
</table>

Survey Statement:
The Digital Labcoat Activity really got me thinking about data and relations among variables

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td># responses</td>
<td>45</td>
<td>63</td>
<td>59</td>
<td>341</td>
<td>303</td>
<td>230</td>
<td>173</td>
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<tr>
<td>aggregate # responses</td>
<td>167</td>
<td></td>
<td></td>
<td>341</td>
<td></td>
<td></td>
<td>706</td>
</tr>
</tbody>
</table>

Survey Statement:
I gained a much better sense of the scientific process. Concepts like sampling, replication, hypotheses and third variables made a lot more sense than they did after just reading the text

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td># responses</td>
<td>26</td>
<td>37</td>
<td>85</td>
<td>245</td>
<td>338</td>
<td>281</td>
<td>195</td>
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<tr>
<td>aggregate # responses</td>
<td>148</td>
<td></td>
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<td>245</td>
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<td>814</td>
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</table>
Survey Statement:
I gained a clearer understanding of the role statistics plays in the scientific process

<table>
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<tr>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>Neutral</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Agree</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td># responses</td>
<td>17</td>
<td>42</td>
<td>73</td>
<td>237</td>
<td>328</td>
<td>306</td>
<td>205</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.4%)</td>
<td>(3.5%)</td>
<td>(6.0%)</td>
<td>(19.5%)</td>
<td>(27.0%)</td>
<td>(25.2%)</td>
<td>(16.9%)</td>
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<td></td>
</tr>
<tr>
<td>aggregate # responses</td>
<td>132</td>
<td>237</td>
<td>839</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10.9%)</td>
<td>(19.5%)</td>
<td>(69.5%)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey Statement:
I don't feel quite as worried about taking a course in statistics now that I have done the Digital Labcoat Activity

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Neutral</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Agree</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td># responses</td>
<td>80</td>
<td>98</td>
<td>131</td>
<td>466</td>
<td>207</td>
<td>137</td>
<td>94</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.6%)</td>
<td>(8.1%)</td>
<td>(10.8%)</td>
<td>(38.4%)</td>
<td>(17.1%)</td>
<td>(11.3%)</td>
<td>(7.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aggregate # responses</td>
<td>309</td>
<td>466</td>
<td>438</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(25.5%)</td>
<td>(38.4%)</td>
<td>(36.1%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Digital Labcoat grades during the Summer 2013 and Summer 2014 sessions of Introductory Psychology: Part I (PSYA01).

<table>
<thead>
<tr>
<th></th>
<th>Old Interface (Summer 2013 Session)</th>
<th>New Interface (Summer 2014 Session)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>6.21</td>
<td>5.63</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>1.34</td>
<td>1.52</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>323</td>
<td>386</td>
</tr>
</tbody>
</table>
Figure 1. Digital Labcoat Interface: Phase 2 (Analyze), variable selection.
Figure 2. Digital Labcoat Interface: Phase 2 (Analyze), t-test level definition.
Figure 3. Digital Labcoat Interface: Phase 2 (Analyze), results screen.

**T-Test**

**Statistics**

**Variables**

**Independent Variable:** Number of Harry Potter books read
- Level 1: Harry Potter Non-Readers
- Level 2: Harry Potter Readers

**Dependent Variable:** Expected Grade

**Means for Each Level**

<table>
<thead>
<tr>
<th>Level</th>
<th>Mean</th>
<th>Expected Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harry Potter Non-Readers</td>
<td>75</td>
<td>5625</td>
</tr>
<tr>
<td>Harry Potter Readers</td>
<td>82</td>
<td>6724</td>
</tr>
<tr>
<td>Harry Potter Non-Readers</td>
<td>86</td>
<td>7396</td>
</tr>
<tr>
<td>Harry Potter Readers</td>
<td>90</td>
<td>8100</td>
</tr>
<tr>
<td>Harry Potter Non-Readers</td>
<td>95</td>
<td>9025</td>
</tr>
<tr>
<td>Harry Potter Readers</td>
<td>90</td>
<td>8100</td>
</tr>
<tr>
<td>Harry Potter Non-Readers</td>
<td>60</td>
<td>3600</td>
</tr>
<tr>
<td>Harry Potter Readers</td>
<td>80</td>
<td>8400</td>
</tr>
<tr>
<td>Harry Potter Non-Readers</td>
<td>85</td>
<td>7225</td>
</tr>
<tr>
<td>Harry Potter Readers</td>
<td>80</td>
<td>8400</td>
</tr>
</tbody>
</table>

**Hypothesis:**
I predict that the "Expected Grade" scores for the "Harry Potter Non-Readers" group will be lower than the scores for "Harry Potter Readers" group.

**Calculations:**

Null Hypothesis: \( \mu_1 - \mu_2 = 0 \)

**IV Level 1:**
Harry Potter Non-Readers
\( \Sigma X = 16553 \)
\( \Sigma X^2 = 1380633 \)
\( n_1 = 200 \)

**IV Level 2:**
Harry Potter Readers
\( \Sigma Y = 16683 \)
\( \Sigma Y^2 = 1402715 \)
\( n_2 = 200 \)

**Degrees of Freedom**
\( df_1 = n_1 - 1 \)
\( df_1 = 200 - 1 \)
\( df_1 = 199 \)

**Degrees of Freedom**
\( df_2 = n_2 - 1 \)
\( df_2 = 200 - 1 \)
\( df_2 = 199 \)

**Mean**
\( M_1 = \frac{\Sigma X}{n_1} \)
\( M_1 = 82.785 \)
\( M_2 = \frac{\Sigma Y}{n_2} \)
\( M_2 = 83.415 \)

**Sum of Squares**
\( SS_1 = \Sigma X^2 - \left( \frac{\Sigma X}{n_1} \right)^2 \cdot n_1 \)
\( SS_1 = 1380633 - (16553^2 / 200) \)
\( SS_1 = 10623.956 \)

**Sum of Squares**
\( SS_2 = \Sigma Y^2 - \left( \frac{\Sigma Y}{n_2} \right)^2 \cdot n_2 \)
\( SS_2 = 1402715 - (16683^2 / 200) \)
\( SS_2 = 11102.556 \)

\[ t = \frac{(M_1 - M_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \]

**Total Degrees of Freedom**
\( df = df_1 + df_2 \)
\( df = 199 + 199 \)
\( df = 398 \)

**Pooled Variance**
\( s_p^2 = \frac{SS_1 + SS_2}{df} \)
\( s_p^2 = (10623.956 + 11102.556) / 398 \)
\( s_p^2 = 54.59 \)

**Calculate t**
\( t = \frac{0.65 - 0.739}{0.879} \)
\( t = -0.879 \)

\[ t_{crit}(398) = 1.984 \]
\[ |t| < t_{crit} \]

**RESULT IS NOT SIGNIFICANT.**
Figure 4. Mean Number of Analyses Completed per Student, by Type of Analysis, during the Digital Labcoat activity in Introductory Psychology Part II (PSYA02), Winter 2013.
Figure 5. Number of Analyses Completed during the Digital Labcoat activity vs. Final Course Grade in Introductory Psychology Part II (PSYA02), Winter 2013.
References


