

Food Microbiology—Design and Testing of a Virtual Laboratory Exercise

Steve Flint and Terry Stewart

Abstract: A web-based virtual laboratory exercise in identifying an unknown microorganism was designed for use with a cohort of 3rd-year university food-technology students. They were presented with a food-contamination case, and then walked through a number of diagnostic steps to identify the microorganism. At each step, the students were asked to select 1 of 4 tests. All tests had an associated cost. Feedback was given on selection and once the right test was selected, students were shown the results and could progress. At the end of the exercise, students had determined a number of characteristics of the microorganism. They were then required to identify the organism using a variety of reference material and present a report on the significance of the microorganism identified. A student survey showed they enjoyed the exercise and felt it fulfilled the aims and objectives of the lesson. There was a positive response to its flexible nature and the inclusion of test costs. This virtual laboratory was less expensive and 10 times faster than a traditional laboratory exercise yet achieved the same learning outcomes for students who were already familiar with laboratory techniques. The virtual lab was developed with a generic template that could be used for future lessons.

Introduction

Practical laboratories for university studies require a great deal of preparation, must be run with students at one point in time, and require all students to be physically present. They are demanding on manpower and materials, and lack flexibility in a teaching schedule.

In many cases, actual- or physical laboratory exercises are essential. Laboratory technical skills, such as how to prepare media or use laboratory equipment, are best learnt at the bench (McLandsborough 2005). In other cases, however, the lesson focus might be more on process and the interpretation of results and analysis rather than technical skills. If the educational objectives are focused on the latter, then virtual-laboratory exercises (that is, web-based simulations) may suffice and, in fact, may offer several advantages over their real-world counterparts (Raineri 2001; Nickerson and Ma 2006). Once constructed, virtual laboratory exercise can be accessed at any point in time, anywhere in the world. No physical preparation is required and the exercise can be reused from year to year at minimum cost. Furthermore, if the initial framework is generic, similar exercises could be easily produced using this template.

Scenario-based learning interactive (SBLi) is an authoring and delivery suite for SBL (Stewart 2007; CBIT 2009). The authoring tool allows a problem-based scenario to be easily constructed, with representations of sequenced activities, tests, and test results

presented in an intuitive 4-pane interface. The activities within scenarios can be sequenced, partially sequenced, or students can have complete freedom over what they do and when.

A virtual diagnostic exercise using SBLi was developed as a trial with distance students in Singapore for a 3rd-year degree paper in food microbiology and safety. It partly mirrors a real laboratory exercise that is used for on-campus students at Massey Univ. For the virtual laboratory exercise, 1 unknown microorganism was the focus whereas in the actual laboratory, each student has 2 different microorganisms to identify. All students had the same organism in the laboratory simulation whereas in the traditional laboratory class, each student has a different mix of 2 organisms. The desired learning objectives were for the students to be able to make decisions on the type of testing required in a sequential stepwise manner and to interpret the results from each test, deciding on the next course of action and interpreting the significance of their findings. Note that all students had already had prior experience with the laboratory methods involved. Students were required to write a full report containing an introduction to the contamination issue, details of the experiments chosen with appropriate reasons followed by the interpretation of results, conclusions, and recommendations. After the exercise was completed, students were surveyed for their feedback.

Description

The lesson was introduced to the students mid way through the laboratory course, once they had performed most of the tests involved in the simulation. This was introduced as a special exercise that had been designed for them to complement their other laboratory exercises and enable the work to be done within the

MS 20100374 Submitted 4/6/2010, Accepted 6/9/2010. Authors are with Massey Univ., Private Bag 11222, Palmerston North, New Zealand. Direct inquiries to author Flint (E-mail: s.h.flint@massey.ac.nz).



Figure 1—Setting the scene at the start of the exercise.

time allocated for their course. Students were given 1 h to work through the exercise in class and the opportunity to continue in their own time if required. The results from this exercise required interpretation outside this class setting and students had free access to all the information they needed to interpret their results and devise recommendations.

At the beginning of the web exercise, the students were presented with the scenario, in this case a foodstuff with an unknown contaminant (Figure 1). The students were not told that they each had an identical exercise.

They were then guided through a series of diagnostic steps indicated as stages in the program. At each stage, they were shown a selection of 4 common tests likely to be appropriate for this diagnostic step. They were asked to select the most appropriate

test. By clicking on each test option, students could see some basic information about them. They were also given the option of actually running the tests. Each test had a monetary value attached. Students could read about all tests available before committing to running any of them.

After a test was selected, the cost was added to the student's total and they were shown 1 of the 2 results. If the choice was incorrect, the student was alerted to this fact and told why (Figure 2). They could then select another test (but accrue the cost of doing so). If they were correct, they were informed of this and told why (Figure 3). A results report was then available under an icon that appeared in the top right-hand window, an area called the Environment Window in SBLi. Clicking on the results report icon in the Environment Window then showed what

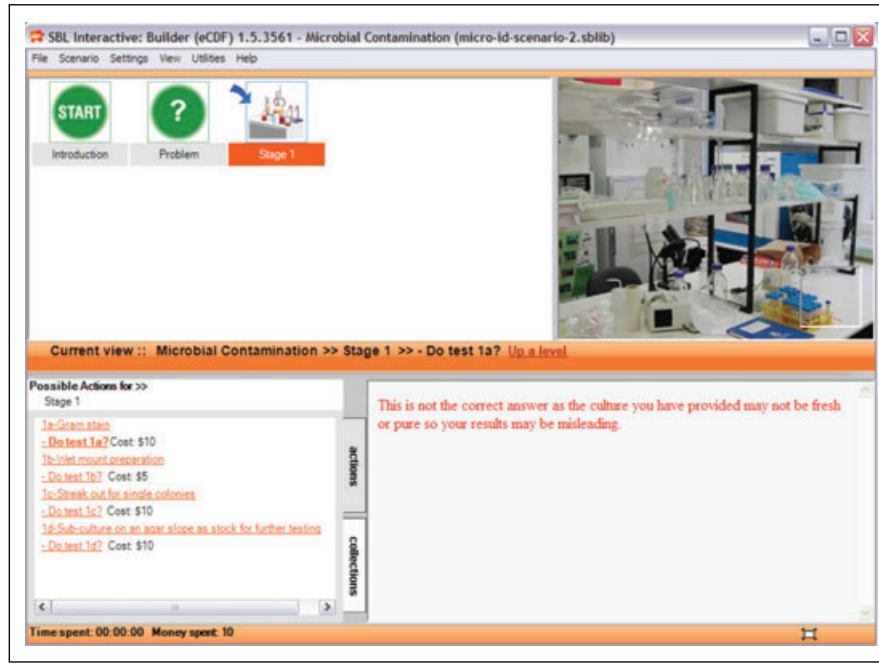


Figure 2—Result of an incorrect test selection, where student has selected a gram strain.

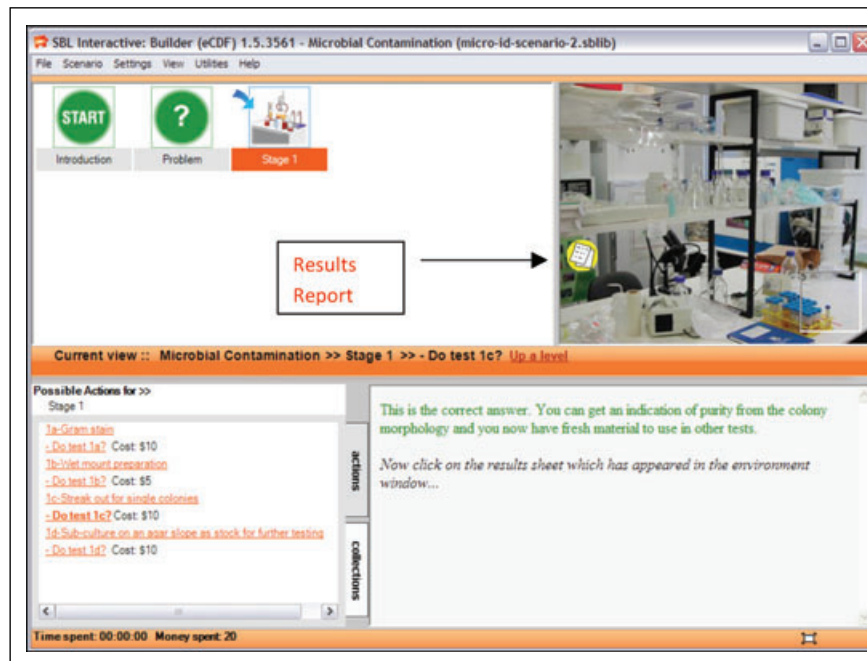


Figure 3—Result of a correct test selection, in this case streaking out for single colonies.

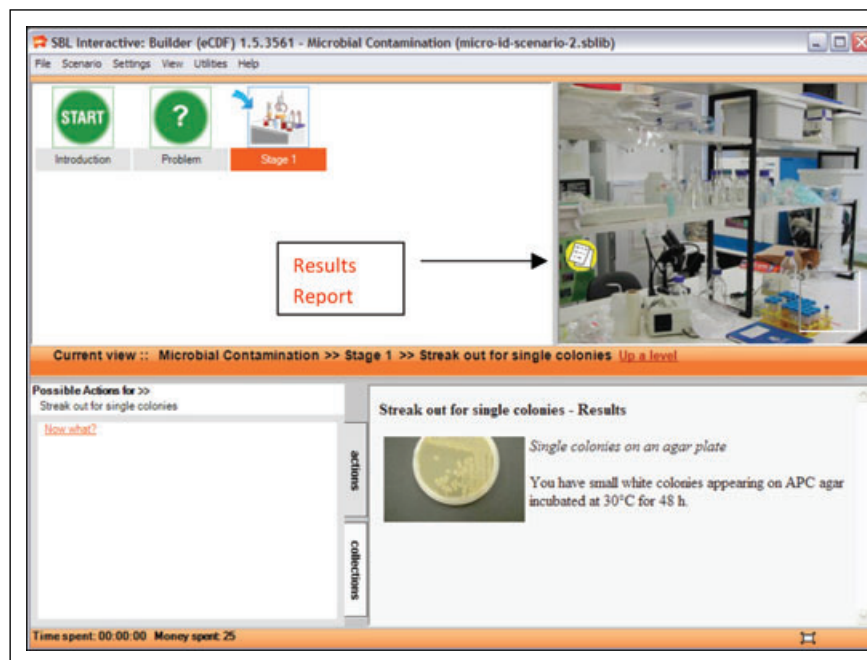


Figure 4—The result of a test, seen by clicking on their results icon.

happened as a result of the procedure (Figure 4). Students could note this or drag the report icon into a “collection box” (the transparent box on the lower right of the Environment Window) where the report would be available for referral anywhere in the exercise (by clicking the collections tab in the bottom left-hand window).

After checking the result and collecting the report, students were then instructed to return to the listed tests by clicking on the “stage” icon representing a diagnostic step in the window on the upper left-hand part of the screen. The tests once again appeared in the bottom left-hand window. If more tests needed to be done at this “stage,” students could select them. If all the necessary tests for this stage had been done, a “Where to from here. . .” action appeared. Clicking on this gave students a short summary of this phase of the diagnostic process and opened up a

new icon in the top-left window representing the next diagnostic step.

This sequence repeated until all steps of the diagnostic process were complete. At the end of the exercise, students were expected to gather together all the information discovered about the unknown organisms (from their reports) and identify it using resources outside the scenario. They would then be asked to provide a diagnostic report that would include an identification of the organism, its significance to human health, and control recommendations (Figure 5).

Lesson design efficiencies: A template approach

The exercise above is a fairly straightforward step by step approach that involves choice at every step. At each stage, only 1 test is the correct one. Although SBLi offers a coherent interface for

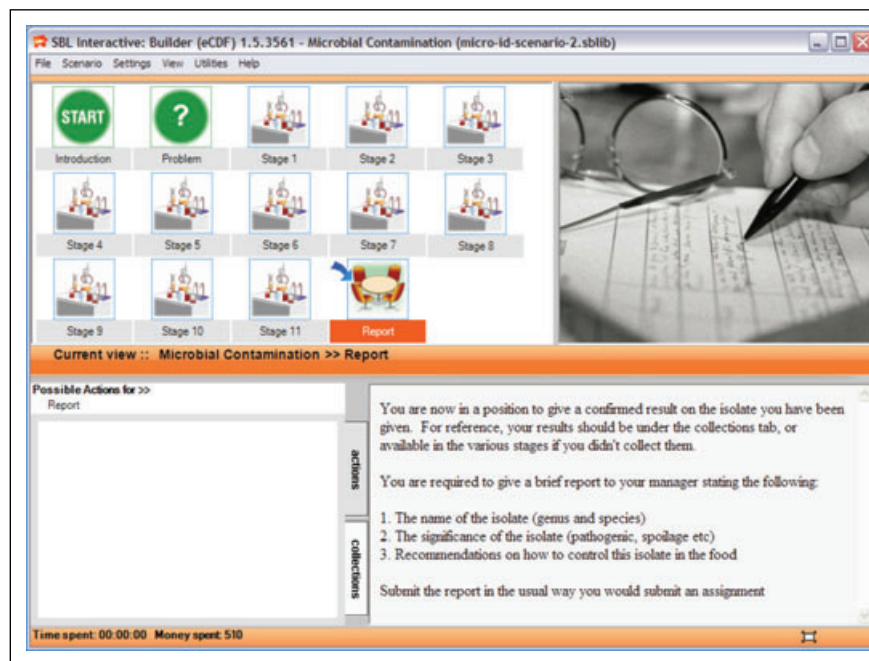


Figure 5—SBLi screen after all tests have been completed.

the exercise, a similar exercise could have been constructed using a series of webpages where students would be required to copy results to a file for future reference. However, in constructing the scenario, thought was given to more complex exercises that could build on the basic components. In future exercises, a larger selection of tests may be available, the sequencing might be controlled more by the student (and could be assessed accordingly), and they may be required to answer questions along the way or select more than 1 test to progress. This type of scenario is more difficult to construct simply with a series of linked web pages. However, now that a template of basic tests exists successive, more complex, exercises using different organisms can be produced quickly and simply by altering the template and tweaking a few of the options.

The subject expert took 8 h to plan the lesson and provide the content (text and images). These were supplied to the SBLi designer in an MS Word document using a series of repeating headings that corresponded to the components of each phase, for example, Stage1, test1, result1, test2, result2, and so on. The construction of the exercise (and so the template) in the SBLi authoring tool took approximately 10 h. Hence, a total of 18 person-h was used to develop this new lesson. An introduction to the session took 1 h compared with 10 h of teaching time for the traditional laboratory. In addition, 1 wk of technician time was saved by offering this exercise over the web, rather than in a physical laboratory.

Student opinion

After the exercise was completed, but before their reports were marked, students were surveyed for their views on the exercise. There were 33 students in the class. Thirty-one (94%) participated in the survey, and of those, 1 student did not answer the 1st question. The results appear in Figure 6 and Table 1 to 3.

Level of agreement

Students were asked to indicate their level of agreement to the questions indicated where 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree (Figure 6).

All students who responded enjoyed the exercise (Q2). Twenty-three students found the interface intuitive and easy to use (Q1).

However, 8 felt there was room for improvement. Students detailed these improvements in the comments section of the survey (see later). Most students felt they improved their knowledge of the process involved (Q3). Two students were unsure regarding this question with only 1 individual disagreeing. The full question for the response shown in question 4 was: "Real 'hands on' labs are best for teaching practical skills, such as pipetting, isolating, and so on. However, regarding the diagnostic process (that is, thinking about and selecting the necessary steps to take based on test results), this virtual lab taught me as much as a real lab would have." This question has been shortened in the figure title. Twenty-three of the students agreed with the above statement with 3 strongly agreeing. Six were unsure and 2 disagreed. An overwhelming majority of students (29 from 31) felt having a financial penalty when selecting tests made them more careful about test selection. Some were keen to turn this into a competition with their colleagues to see who could obtain a result for the least cost. This has some bearing on the real world in a cost-competitive environment. Graduates from this degree course quickly find management positions in which cost will be a key concern.

Short questions

Students were asked what they liked most about the exercise, what they like least about it, and how the lesson could be improved (Table 1 to 3). On analysis, their comments regarding what they liked most could be distilled down into 6 key ingredients: The design of the lesson, the convenience of the web-based exercise, the imagery that was used, the inclusion of costs, ease of use, and "engagement" (Table 1). It is appreciated that the last factor is a very qualitative one, and could be a product of the 1st 5. A number of students mentioned more than just 1 factor in the response to the question. Each factor was counted that is why the total count is greater than the number of students surveyed.

Student performance

All students correctly identified the unknown microorganism from the laboratory simulation. This suggests that they gained

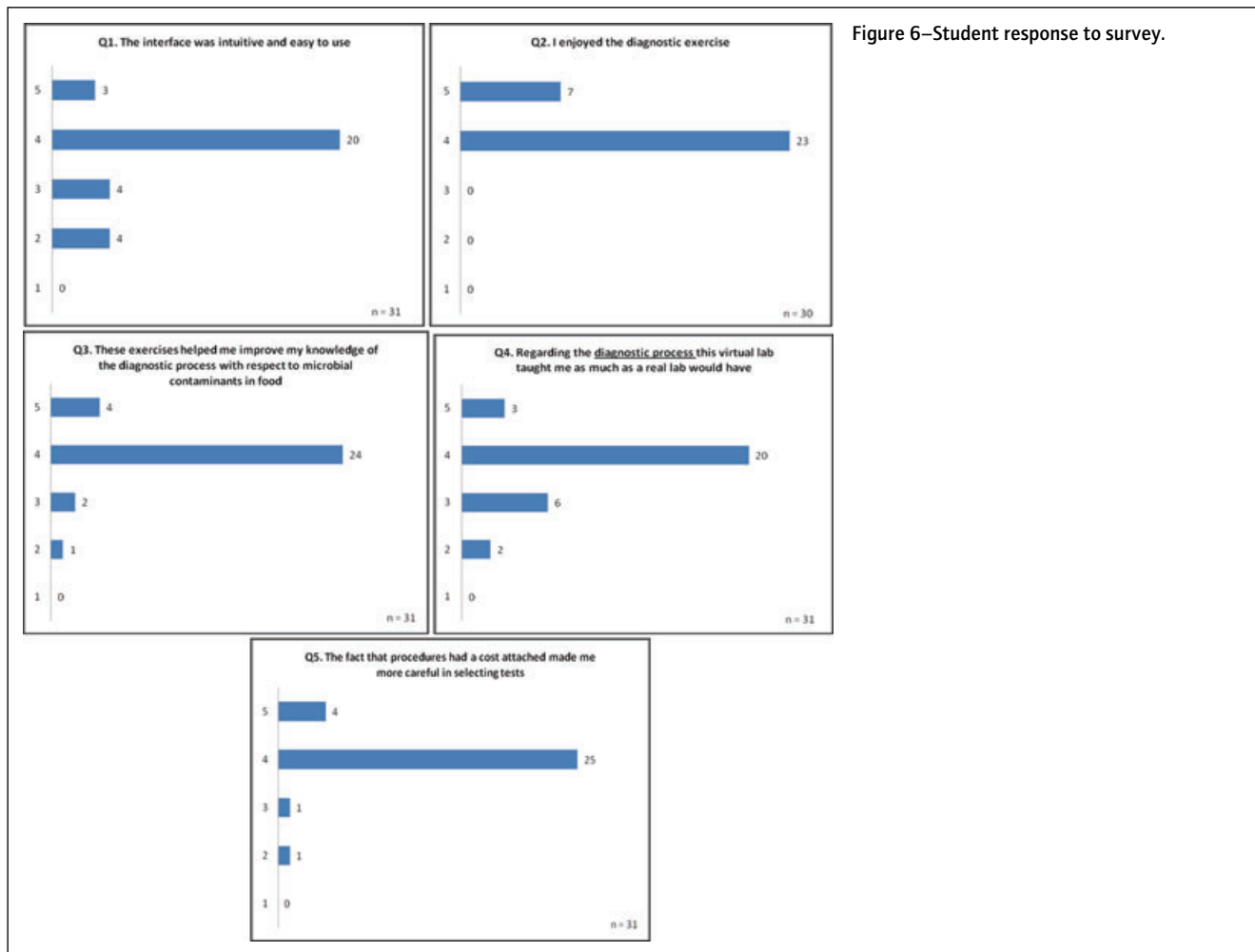


Figure 6—Student response to survey.

Table 1—What students liked most about the exercise.

Feature	Nr of students who mentioned this as "most liked"
<i>The way the lesson was organized</i> —That is, a systematic step by step procedure run as a realistic simulation which explained the function of the common tests and gave students the opportunity to apply them (and get it wrong), see the result, and then move to the next phase.	15
<i>Convenient</i> —Students could do the exercise in their own time, it was immediate and they could see results without having to physically conduct a test.	8
<i>Imagery</i> —The fact that photos of the test results were available.	4
<i>The inclusion of costs</i>	3
<i>Interesting and exciting ("engagement")</i>	3
<i>Ease of use</i>	2

Note: Two students left their forms blank for the "most liked" question.

Table 2—What students liked least about the exercise.

Feature	Nr of students who mentioned this as "least liked"
<i>Difficulty with navigation and screen layout</i> —that is they had difficulty navigating and collecting results.	6
<i>Difficulty in identifying which test was which, from the collection of test results.</i>	5
<i>Difficulty with the content</i> —that is, not knowing which test to choose, not enough information on the procedures.	4
<i>No summary report generated at the end</i>	4
<i>System error</i> —Program hung	3
<i>It was easy to click "do test" resulting in an unwanted cost</i>	1

Note: Three students left their forms blank for the "least liked" question. Four students stated there was nothing they did not like.

enough information from the exercise to achieve 1 key objective, of identifying an unknown contaminant in a food.

The students were asked to use this information from the laboratory simulation to prepare a laboratory report formatted as a scientific paper. All students followed the requested format and the detail contained in the report showed that the students understood the background to the work and how this related to a potential real situation in food manufacture. Any issues students

had in preparing their reports were typical of most students doing this type of exercise. The "abstract," in many cases, failed to give a complete summary of the work. The "introduction" was clear and the "methods" were clearly described. The results were particularly well-handled. The "discussion" section was the most challenging and carried the most marks (30%). This required some background reading and the class had clearly done this well. Students varied in the way in which they determined the identification of the microorganism, in terms of which tests they regarded as most significant. This is exactly how results are interpreted in

Table 3—Student response to “How could this lesson be improved?”

Improvement	Nr of students who suggested this as an improvement
<i>An easier way to see all the results at the end (that is, Having a summary page, labeling tests better or at least being able to view them in order when collected)</i>	10
<i>Have practice diagnostic exercises available</i>	1
<i>Having different scenarios available (that is, other microbes and tests)</i>	2
<i>Have an embedded flowchart</i>	1
<i>Showing tests in more detail</i>	2
<i>Reduce the number of steps to get to a result</i>	1
<i>A wider screen for the content so no scrolling is required</i>	1
<i>Do not accrue costs for an incorrect test</i>	1
<i>A more stable program</i>	1

Note: Seven students left their forms blank for the “How could this lesson be improved” question. Two students stated there were no improvements they could think of.

the laboratory and it was pleasing to see the individuals in the class taking the initiative to think this through for themselves, coming up with the correct answer. All students understood the significance of the isolate in terms of a food-poisoning microorganism and the 2 types of toxin produced were well-explained by most students. Some students considered the likely source of the problem—an important consideration but not key to the recommendations. The recommendations, which formed part of the discussion, were particularly important. Here we were looking for specific recommendations that were appropriate for the organism they had identified. Factors, such as heating, holding, and cooling, and some specific guidelines around these by suggesting specific temperatures gained the extra marks. This required the students to make use of the information on the organism that was available from various reference sources and to devise appropriate recommendations for the control of this microorganism.

The scores students received for this project ranged from 77% to 97% with a mean score of 90%. Clearly, this is an excellent result, but we cannot attribute this to the way in which the class was taught as we do not have a control group of Singapore students to use for comparison.

Discussion

The lesson was generally well-received by students. They enjoyed working through it and appreciated the logical way it had been set out. By far, the majority of students thought it was a worthwhile exercise, easy to navigate through and well-mapped to the objectives of the lesson. One interesting finding was student opinion regarding attaching a cost to each test. This really seemed to “focus the mind” and made students consider their selection carefully as opposed to simply clicking through the options. The amount the students spent was not taken into account in the assess-

ment in this particular case, but could be included for other lessons in the future where students are expected to be more experienced.

The study survey revealed room for improvement in the exercise (Table 2). A number of students had difficulty when it came to referencing the individual test reports for the final write up. Collected reports, when viewed under the collection tab are shown as a double list of icons. Results can be seen by clicking on the icon and the report’s name can be seen by a mouse-over of the icon. Not all students were aware that a mouse-over would reveal the name. Therefore, faced with an unordered list of a total of 11 reports with no obvious names, some students had trouble deciding which report related to which finding. Some students requested that a test summary be available at the end. This, or instructions to the students to compile their own raw-test summary (perhaps by cutting and pasting individual tests sequentially into a Word document as they are revealed) would be a way to overcome this issue. A few students also had issue with the navigation. A short training exercise to get students familiar with the interface before the exercise might be worthwhile considering. Three students reported a system error. A newer version of the SBLi server is now available that is more stable, so this issue should not be repeated. Authoring tools specifically to support the creation of virtual-laboratory exercises are starting to appear (Cherner and Taraskina 2009). These developments are likely to accelerate the use of these types of lessons within a curriculum.

This virtual-laboratory exercise fulfilled the learning objectives, was positively received by students, and was substantially less expensive in time and materials than a physical-laboratory exercise, saving 10 h of teaching time and 1 wk of technical support time. The template-style design means that future exercises will be even quicker to produce, simply by altering the test results depending on the organisms concerned.

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