

Chapter 6

Acquisition of Laboratory Skills by On-Campus and Distance Education Students

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Introduction

Teaching biological sciences by distance

Teaching experimental sciences by distance education is acknowledged to be difficult (Dalgarno, Bishop & Bedgood, 2003). Although computer simulations can be used to illustrate scientific concepts and to introduce students to experimental techniques, only “hands-on” sessions can ensure that students acquire appropriate laboratory skills. For this reason, many distance education providers avoid experimental sciences (for a discussion see Trindade, Carmo & Bidarra, 2000). Remote, online, access to instrumentation can provide a real experience in areas such as chromatography and spectrometry, where instruments are often computer-controlled (Kennepohl et al., 2005), but there is evidence that many distant students lack relevant expertise, so the requirement to work in an online environment can be a major barrier (Galusha, 1997; Hara & Kling, 2000).

Studying by distance education is challenging; it is important that first year studies stimulate students and maintain their interest. Practical work engages and enthuses students (Handelsman et al.,

2004; Ford, Prudente & Newton, 2008) and has been shown to significantly improve retention of first year students (Hoit & Ohland, 1998; Aziz, 2003). However, a compulsory on-campus laboratory program can be problematic for those distant students who have chosen to study in distance education mode because of difficulties associated with university attendance. A recent study considered factors leading to students' decisions to withdraw from a Bachelor of Science program at Indira Gandhi National Open University, where students are required to attend full-time lab sessions of at least seven days' duration. The dropout rate in this program is very high, with approximately 50% of students failing to move on to second year and 63% of students failing to complete their degree program. In this study, 53% of students cited "difficulty in attending lab sessions" as a reason for withdrawal (Fozdar, Kumar & Kannan, 2006).

At the School of Applied Sciences and Engineering (SASE), Monash University (Gippsland campus), it is certainly our experience that the first year of distance education is a difficult one, as students make the transition to university study. Laboratory kits, which allow experiments to be conducted at home, enable first year students to become involved with unit material and to develop technical skills, yet postpones the requirement for on-campus attendance until the second year of the program. By this time, students are well committed to their degree studies and more prepared to accommodate this requirement, as are their families and/or employers.

Teaching staff at SASE have extensive experience in delivering experimental science programs by distance education. During the 1970s and 1980s, the school was part of the Gippsland Institute of Advanced Education (GIAE) and the student population comprised students in local regional areas and students from metropolitan Melbourne studying for diplomas and degrees in the applied sciences. Courses were first made available by distance education to students who were employed in local industries and therefore unable to attend classes during business hours. While the basis of the

theory course was delivered in print form, supplementary tutorials and laboratory classes were held on weekends. Students attended what came to be known as “Weekend Schools” three to four times per semester.

In the late 1980s, the GIAE became part of Monash University. Distance education courses became attractive to people further afield, and gradually the geographical range of the student population expanded. It became clear that the weekend school model was unsuitable for many of the students, since the costs associated with travel to the campus (from interstate and sometimes overseas) were considerable. It was at this time that laboratory kits for first year units were introduced. Second and third year laboratory programs were also blocked into concentrated residential schools, held once per semester, so that travel to the campus was minimized.

Given the strong focus on applied sciences, all courses emphasize hands-on, practical work. We feel that this training is essential from the beginning of the course, as it has a dual role: allowing students to develop skills and competencies, and encouraging them to apply their theoretical knowledge to practical situations, which enhances their understanding and facilitates learning. Learning objectives for laboratory classes, which are provided to the students in written form, relate to the development of both generic laboratory skills and skills which are discipline-specific.

While the student demographic varies from year to year, the on campus cohort is comprised mainly of students who have taken up university studies directly after completing their secondary school education, so this cohort consists predominantly of full-time students in their late teens or early twenties. Distance education students are typically older than students in the on-campus cohort and their personal circumstances are extremely varied. Many work full-time (in science-related jobs or in other fields), some are parents who are caring for young children at home, and some travel frequently, for example elite athletes and members of the defence forces.

Programs in biological sciences at SASE

First year units

Two first-year biology units, Human Biology and Cell Biology, are available in both on-campus and distance education study modes. Students complete their laboratory requirements in weekly laboratory sessions (on campus) or by distance education using portable experimental kits.

The Human Biology laboratory program includes practical exercises in which students investigate various aspects of human physiology from a systems-based approach. Distance education students receive a laboratory kit containing glassware; basic chemicals; histological specimens; equipment including a spirometer, sphygmomanometer, and a dissection kit; and a preserved rat. There is an option to request either a “full” or a “half” kit. The “half” kit contains equipment for only three of the five practical exercises, and students who choose half kits must complete the other two exercises at a single weekend school; approximately 50% of students choose this option. Students who do not attend may live interstate (typically 20% of the distance education cohort) or have work or family commitments.

The practical exercises in the Cell Biology program are arguably more complex, particularly for distance education students. Again, the laboratory kit contains glassware and chemicals, but there is also a significant requirement for students to source their own materials, such as fresh plant materials and chicken hearts. There is no weekend school option for this unit.

The first year distance education and on campus programs are similar, but not identical; however, they are designed to provide an equivalent educational experience for both groups of students. Certainly, the time commitment required by distant students is greater, as they have to prepare many reagents and source experimental materials. However, this is outweighed by the flexibility provided by the kits, which enables distant students to choose where and when they complete their experimental work.

Second and third year units

The first year biology program provides a background for students who may then extend their studies into the ecology and/or biotechnology discipline areas.

About two thirds of the first year biology cohort proceed to second and third year biotechnology units, primarily biochemistry and microbiology. In these units, laboratory work is performed in concentrated periods (residential laboratory schools) of four or five days per unit per semester. During this time, students are trained in specialized skills and the use of instrumentation appropriate to the discipline; the practical work undertaken by on-campus and distance education students is identical. In many ways the residential school mimics the workplace, providing opportunities for students to dovetail activities and perform experiments that are not easily accommodated in weekly lab sessions. As a consequence, this concentrated “block laboratory” model has been extended to many on-campus biotechnology units at third year.

Table 1: Summary of laboratory programs for on campus and distance education students in biological sciences at SASE, Monash University (Gippsland campus).

Year level	On campus	Distance education
First year	Practical exercises conducted throughout the semester.	Practical exercises using home-based experimental kit; option to complete some labs at weekend school for the first semester unit
Second year	Weekly practical exercises (3–4 hrs) conducted throughout semester.	Practical exercises conducted at compulsory residential schools (4–5 day block)
Third year	Practical exercises conducted either weekly (~4 hrs) throughout semester or in a block (~5 days)	Practical exercises conducted at compulsory residential schools (~5 day block)

Comparing the student experience

The diversity of the on- and off-campus student populations, and the variety of modes in which the laboratory components of the units are delivered, raise the question of parity of experience for students in the distance education and on-campus cohorts. It is essential that both on- and off-campus students acquire the skills and competencies required in the workplace or for higher level studies. It is difficult to assess student competence, particularly prior to their participation in laboratory classes. In this study, students were asked to rate their confidence in performing particular tasks related to the unit learning objectives.

While the link between confidence and competence is tenuous (Haun et al., 2000; Morgan & Cleave-Hogg, 2002), there is some evidence for a link between confidence and performance as measured by grade point average (GPA) (Lotkowski, Robbins & Noeth, 2004), and there is significant evidence supporting a link between student confidence and subsequent student retention (Felder, Felder & Dietz, 1998; Irizarry, 2002; Lotkowski, Robbins & Noeth, 2004; Rickinson & Rutherford, 1995). Therefore, we contend that confidence is a meaningful parameter to measure, especially for practical skills, since students' confidence is reflected in how they approach a task and how, as graduates, they make career choices (Betz & Borgen, 2000) and present themselves to potential employers.

Methods

Surveys

While it would have been ideal to track students throughout their studies, the extended time frame of off-campus studies (most distance education students study part-time, so take six years or more to complete their degree) was prohibitive. This study involved two 'snapshots' of students' perceptions about their laboratory skills: On-campus and distance education students enrolled in first

year biology units, and in second and third year biotechnology units, were surveyed at the beginning and end of a single teaching semester.

Questionnaires were distributed to 95 on-campus students during first, second and third year laboratory classes; 72% of these surveys were returned. Eighty-three questionnaires were also distributed by mail to first year distance education students; 40% of these questionnaires were returned. Fifty-six distance education students received questionnaires during second and third year residential schools; 52% of these were returned. In total, 234 questionnaires were distributed and the overall response rate was 57%.

Students enrolled in first, second and third year units received different questionnaires, but all survey questions related to students' confidence in their laboratory skills. Questions were of two types: general questions and questions specific to each year level. General questions were common to all questionnaires and related to generic laboratory skills. For example, some of these general questions asked students to rate their confidence in:

- Handling biological samples safely
- Coordinating work with that of other students
- Managing several experimental tasks concurrently
- Drawing a reasonable conclusion from experimental data
- Writing a scientific report

Questions specific to each year level related directly to skills described by one or more learning objectives for the unit in which they were enrolled. For each question, students were asked to rate their confidence level for a particular laboratory skill on a 5-point scale, where 1 represented "lacking in confidence," 3 represented "confident," and 5 represented "very confident." Full questions from each of the questionnaires are provided in Table 2.

It is important to stress that these surveys assessed *confidence* rather than *competence*, and that the students reported their own confidence levels.

Analyses

Survey results were analysed according to mode of offering (distance education versus on campus) and year level (first, second, third year). An average confidence ranking was determined for each question by taking the mean of all student responses to that question. The standard error (a measure of the variance of the mean) was also calculated for each mean. Results that differed by at least two standard errors were considered to be significantly different (95% CI).

Table 2: See pages 117–118. Mean confidence rankings (with standard errors in brackets) for on-campus and distance education students at four time points: start of semester 1, year 1 (new students); end of semester 1, year 1; end of semester 1, year 2; and end of semester 1, year 3. Questions 1–8 were common to multiple year levels. Questions 11–15, 21–25 and 31–35 were restricted to students in year levels 1, 2 and 3 respectively. Results that differ by two standard errors are indicated as follows:

Means in bold represent significant differences between students at the beginning and end of first year studies.

Means underlined represent significant differences between on campus and distance education cohorts at the same year level.

Significant differences between students at different year levels within a single cohort are indicated by superscripts († #).

	Indicate your ability to perform the following tasks	On campus cohort						Distance education cohort							
		Sem 1, Year 1		Sem 1, Year 2		Sem 1, Year 3		New students		Sem 1, Year 1		Sem 1, Year 2		Sem 1, Year 3	
		New students													
1	Handle Biological samples safely	3.2 (0.2)	4.4 (0.3)	3.9 (0.4)	4.1 (0.4)	4.1 (0.4)	4.1 (0.4)	4.1 (0.4)	4.6 (0.3)	4.5 (0.3)	4.1 (0.3)	4.1 (0.3)	4.1 (0.3)	4.1 (0.3)	
2	Draw a reasonable conclusion from experimental data	2.6 (0.2)	3.4 (0.3)	3.5 (0.4)	3.9 (0.4)	3.9 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	3.8 (0.4)	
3	Write a scientific report	2.6 (0.2)	3.5 (0.3)	3.4 (0.3)	3.4 (0.3)	3.4 (0.3)	3.5 (0.5)	3.5 (0.5)	3.6 (0.4)	3.6 (0.4)	3.6 (0.4)	3.6 (0.4)	3.6 (0.4)	3.6 (0.4)	
4	Working independently, perform an experiment using written instructions, such as those provided in a lab manual	3.0 (0.3)	3.6(0.4)	3.5 [#] (0.4)	4.3 [#] (0.4)	4.3 [#] (0.4)	3.3 (0.5)	3.3 (0.5)	3.6 (0.4)	3.4 [#] (0.4)	4.1 [#] (0.3)	4.1 [#] (0.3)	4.1 [#] (0.3)	4.1 [#] (0.3)	
5	Coordinate your work with that of other students working in the laboratory	3.5 (0.2)	4.3 [†] (0.2)	3.9 [#] (0.4)	4.8 [#] (0.3)	4.8 [#] (0.3)	3.0 (0.4)	3.0 (0.4)	3.3 [†] (0.5)	3.8 (0.3)	4.1 [†] (0.4)	4.1 [†] (0.4)	4.1 [†] (0.4)	4.1 [†] (0.4)	
6	Manage several experimental tasks concurrently			3.0 [#] (0.3)	4.2 [#] (0.3)	4.2 [#] (0.3)				3.3 [#] (0.4)	4.2 [#] (0.3)	4.2 [#] (0.3)	4.2 [#] (0.3)	4.2 [#] (0.3)	
7	Accurately measure pH	3.1 (0.2)	4.0 (0.3)	3.5 (0.3)			3.5 (0.3)	3.5 (0.3)	3.7 (0.3)	4.1 (0.3)	4.1 (0.3)	4.1 (0.3)	4.1 (0.3)	4.1 (0.3)	
8	Calculate the rate of an enzyme catalysed reaction	1.8 (0.2)	2.9 (0.4)	2.4 (0.3)			2.0 (0.3)	2.0 (0.3)	2.5 (0.3)	3.1 (0.4)	3.1 (0.4)	3.1 (0.4)	3.1 (0.4)	3.1 (0.4)	
11	Accurately measure 20mL of liquid	4.5 (0.2)	4.5 (0.3)				4.8 (0.2)	4.8 (0.2)	4.9 (0.2)						
12	Accurately pipette a 1mL sample of liquid	3.6 (0.3)	4.4 (0.2)				3.8 (0.4)	3.8 (0.4)	4.7 (0.2)						
13	Use a microscope to identify features in a tissue section	2.6 (0.2)	2.9 (0.4)				3.1 (0.4)	3.1 (0.4)	3.9 (0.3)						
14	Prepare biological samples (e.g. enzymes or chloroplasts) from raw materials	1.7 (0.2)	2.2 (0.3)				2.3 (0.3)	2.3 (0.3)	3.4 (0.3)						

	On campus cohort				Distance education cohort			
	New students	Sem 1, Year 1	Sem 1, Year 2	Sem 1, Year 3	New students	Sem 1, Year 1	Sem 1, Year 2	Sem 1, Year 3
15	1.8 (0.2)	3.1 (0.3)			2.3 (0.3)	3.3 (0.3)		
21			4.0 (0.4)				4.4 (0.3)	
22			3.5 (0.4)				4.3 (0.4)	
23			3.9 (0.3)				4.0 (0.3)	
24			3.9 (0.3)				3.9 (0.3)	
25			3.1 (0.3)				2.8 (0.4)	
31				4.9 (0.1)				4.2 (0.4)
32				4.4 (0.3)				3.9 (0.4)
33				3.8 (0.4)				3.7 (0.4)
34				2.9 (0.4)				3.0 (0.4)
35				4.3 (0.3)				4.3 (0.3)

Results

Comparisons across year levels

Data was collected at the beginning and end of a single semester. For each time point and each year level, mean responses for on-campus students, distance education students and all students were calculated. Table 2 shows mean responses for on-campus and distance education students at four time points: start of semester 1, year 1 (new students); end of semester 1, year 1; end of semester 1, year 2; and end of semester 1, year 3.

Combined data for all students (data not shown) show that confidence levels generally increase across year levels. Whilst differences in the mean response for individual questions are not always significant between students in consecutive years, there is a significant increase between first and third year students in all cases. This combined data also shows that students beginning semester 1, year 1 (new students) are much less confident than any other group, all of which are much more similar to one another than to the new student cohort.

New **on-campus students** (beginning semester 1, year 1) have significantly lower mean levels of confidence for many questions (Table 2) compared to students completing semester 1, year 1. Interestingly, first year on-campus students tend to be more confident than students beginning years 2 and 3 (data not shown), although these differences are significant only for the question regarding coordinating their work with others in the lab (Q5). In general, confidence levels are similar or increase for on-campus students between years 2 and 3. There are significant increases in confidence between second and third year on-campus students for questions 4, 5 and 6. These questions relate to: working independently (Q4); the coordination of work with that of other students (Q5); and managing several tasks concurrently (Q6)

The tendency for new students (beginning semester 1, year 1) to be less confident than other groups of students is also apparent

for some questions in the **distance education cohort** (Table 2), although the difference is not as great as that seen in the on-campus cohort for many of the questions. Questions 4 and 5 also show clear increases in confidence from first to third year level for this cohort. Third year distance education students also had higher confidence rankings for question 6 compared to second year students from the distance education cohort.

Comparisons between on-campus and distance education cohorts

Responses from **new students** (beginning their first semester) differed significantly between on-campus and distance education students for three of the twelve questions (Table 2). Distance education students are more confident than on-campus students about handling biological materials safely (Q1), preparing biological samples from raw materials (Q14), and monitoring biological processes (Q15).

First year on-campus and distance education students surveyed at the **end of their first semester** generally have similar perceptions of their abilities. However, significant differences occur in the mean rankings for questions 5, 13, and 14 (Table 2). The on-campus cohort is more confident about their ability to coordinate their work with that of other students (Q5). The distance education students are more confident about using a microscope (Q13) and preparing biological samples (Q14).

Second year students studying in on-campus and distance education modes have similar perceptions about their laboratory skills (Table 2). Distance education students appear more confident than on-campus students; differences are significant for questions 7, 8 and 22 (Table 2). These questions relate to the accurate measurement of pH (Q7), the calculation of the rate of an enzyme catalysed reaction (Q8), and the accurate use of a pipette at the scale of microlitres (Q22).

On-campus and distance education students surveyed at the end of first semester in their **third year** generally have similar perceptions of their abilities. Significant differences occur in the rankings for questions 5 and 31 (Table 2). On-campus students are more confident in their ability to coordinate their work with that of other students (Q5) and in using an oil immersion lens (Q31).

Discussion

In general, we found that confidence levels of on-campus and distance education students are similar, although on-campus students were generally more confident about coordinating their work with others in the laboratory (Q5). Some differences related to specific skills, rather than to generic skills, were also noted.

First year

The higher confidence levels reported by first year distance education students, especially those reported at the beginning of first semester, may reflect the hands-on experience that some distance education students have obtained in the workplace. Some of these differences persist until the end of the first semester. For example, distance education students remain more confident about preparing biological samples (Q14).

At the end of first semester, first year distance education students report lower levels of confidence in their ability to coordinate their work with others. During first year, distance education students have been working at home, alone, during the semester, while on-campus students have been part of a team, and well supported by demonstrators, in their class-based laboratories. This difference is important, and it is interesting that experiences in second year, where students attend residential schools at second and third year level, increase student confidence in this area. By contrast, the distance education students are significantly more confident in the use of the microscope (Q13). Distance education students must

organize access to a microscope, usually through a local school or hospital, and generally learn to use this apparatus independently. They are, therefore, more self-reliant and more confident with respect to this particular skill.

Second year

Distance education students entering the second year subject have completed their first year laboratory requirements using home experiment kits, or have gained a credit for their first year studies from another institution. Some of these students work either part- or full-time in a related field and have significant workplace laboratory experience; others may have completed laboratory requirements elsewhere, up to ten years previously.

Distance education students surveyed at the beginning of their second year (data not shown) are less confident with respect to coordinating their work with that of others, working independently following written instructions, and performing electrophoretic separations. Distance education students completed their first year laboratory requirements on their own with limited feedback from their classmates and instructors. Their lack of confidence in their ability to follow written instructions may be related to a lack of feedback about their performance during experimental work. Depending on their work environment, they may have had minimal experience working with others in a laboratory situation. The educational laboratory differs in many ways from the professional laboratory; those distance education students with workplace experience perhaps have had laboratory space, equipment, and other resources allocated to them and may be more familiar with oral rather than written instructions.

The lower confidence of distance education students about performing a specialized experimental task (electrophoretic separations) may reflect their lack of knowledge about, and their understanding of, this task. In contrast, first year on-campus students, due to their interactions with later year students and opportunity

to watch others working in the laboratories, gain some familiarity with such experiments. They may be more relaxed about their capabilities because they have had an informal induction into the “mysteries” of this particular technique.

The second year distance education laboratory program requires on-campus attendance; distance education students complete their laboratory requirements at residential schools. By the end of semester, all second year students (on-campus *and* distance education) will have attended some laboratory classes. It seems that this experience is enough to reduce the differences in confidence levels between on-campus and distance education students, although confidence regarding accurate execution of common laboratory tasks and calculations is a little higher for distance education students. Attendance at residential school classes seems to address the problem of distance education students’ perceived abilities to work as a part of a team.

Third year

At the beginning (data not shown) and end (Table 2) of semester 1, year 3, confidence levels are generally high for both on-campus and distance education cohorts. At the beginning of semester, on-campus students feel more confident in coordinating their work with that of others and in their ability to isolate pure cultures of microorganism. At the end of semester their confidence in working with others, and in another specific technique (use of an oil immersion lens), is higher than that of the distance education students (Table 2). Both groups, however, rate themselves as higher than “3” for these skills, i.e., more than “confident,” so the differences may simply reflect a tendency toward conservatism in the distance education population and/or youthful exuberance in the on campus population!

Comments from graduates

Twenty-five recent graduates who had completed a Bachelor of

Science majoring in experimental sciences by distance education were also invited to comment on their experiences. Students who had acquired laboratory skills from sources outside the university were also asked to indicate whether they would have applied for an exemption from laboratory classes if that option had been available.

Twelve responses were received and eight of these graduates indicated that they had been employed in a scientific area while completing their distance education studies. Seven of these eight graduates had developed some laboratory skills in their workplace, but the majority indicated that they would not have applied for a laboratory exemption. Student comments indicated that the majority of their laboratory skill development occurred in residential laboratory programs. Graduates felt that residential programs had an important role in helping them, as students, to develop the “big picture,” as workplace training was often narrowly focused. Student responses indicated that residential laboratory programs provided access to modern equipment and new techniques and exposure to a wider range of techniques than those encountered in the workplace. The opportunity to apply practical skills to a variety of experimental situations was also welcomed.

All students appreciated the networking opportunities provided by residential schools:

“I had various skills but they needed updating as the workplace did, to keep up to date with changes”

“There is often more than one way to perform any task, even laboratory skills”

“There are more to labs than just having laboratory skills — we learnt how and why things worked (or didn’t) ...”

“It was also a great way to meet other DE students and form friendships under pressure.”

“Residential lab blocks were a great reinforcement for centering on my goal (i.e. passing) and touching base with teachers and others in a similar position. Lab classes help develop other skills than just techniques. At the end of the day this gave me a degree of confidence I would otherwise have lacked.”

Conclusion

We contend that our on- and off-campus laboratory programs provide students with a different, but equivalent, experience that facilitates the development of laboratory skills in both student cohorts. Further, we advocate a mix of independent, off-campus laboratory exercises (with some necessary equipment supplied) and on-campus ‘residential school’ laboratory classes to allow distance education students to develop basic laboratory skills without the need for on-campus attendance. This is especially important for students who are new to off-campus study and are combining their studies with a range of extracurricular activities and responsibilities. In later years, residential schools provide support and allow students to make face-to-face contact with their peers and with academics; opportunities that are clearly appreciated by distance education students. Important skills, such as an ability to work in a shared laboratory, are developed during these on-campus sessions. On-campus and distance education students report very similar levels of confidence about their capability in the laboratory on completion of their studies, suggesting equivalent outcomes. Graduate surveys also indicate that this model provides an appropriate preparation for the workplace.

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APPENDIX — QUESTIONS

Students were asked to indicate their level of confidence (from very confident to lacking in confidence) on a scale such as the one shown below. Students' responses were later assigned a value between 1 and 5, depending how the students marked the scale.

Example question and scale:

Using the scale provided, place a cross to indicate your ability to perform the following tasks:

Handle biological samples safely

5	4	3	2	1
very confident		confident		lacking in confidence

Common questions:

Question 1	Common to all years	“Handle biological samples safely”
Question 2	Common to all years	“Draw a reasonable conclusion from experimental data”
Question 3	Common to all years	“Write a scientific report”
Question 4	Common to all years	“Working independently, perform an experiment using written instructions, such as those provided in a lab manual”
Question 5	Common to all years	“Coordinate your work with that of other students working in the laboratory”
Question 6	Common to 2nd and 3rd year	“Manage several experimental tasks concurrently”
Question 7	Common to 1st and 2nd year	“Accurately measure pH”
Question 8	Common to 1st and 2nd year	“Calculate the rate of an enzyme catalysed reaction”

Questions asked only of students in 1st year:

Question 11	“Accurately measure 20ml of liquid”
Question 12	“Accurately pipette a 1ml sample of liquid”
Question 13	“Use a microscope to identify features in a tissue section”
Question 14	“Prepare biological samples (e.g., enzymes or chloroplasts) from raw materials”
Question 15	“Monitor a biological process, such as photosynthesis”

Questions asked only of students in 2nd year:

Question 21	“Accurately measure 0.35ml of liquid”
Question 22	“Accurately pipette a 220 μ L sample of liquid”
Question 23	“Accurately measure the absorbance of a solution using a spectrophotometer”
Question 24	“Determine the concentration of a specific metabolite in a solution using a standard curve”
Question 25	“Perform an electrophoretic separation”

Questions asked only of students in 3rd year:

Question 31	“Use of an oil immersion lens to distinguish stained micro-organisms”
Question 32	“Successfully isolate a pure culture from a mixed microbial population”
Question 33	“Accurately identify a pure bacterial culture using a rapid test kit”
Question 34	“Working independently, prepare microbiological media”
Question 35	“Perform your experimental work in a totally aseptic manner”