Labshare for Schools

Report on School Trialling in Western Australia
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1. Summary

Trials were conducted by students in four Western Australian high schools in the period August to November 2011, with the co-operation of Science teachers in these institutions. There were two Perth-based schools and two regional schools. Participating students used one of three Labshare apparatus located at the University of Technology, Sydney.

Students completed a 4-page post-experimental survey after their session with their assigned apparatus. Analysis of the completed student surveys presents a reasonably consistent description of their reactions to the remote lab experience, especially focussed on its comparison with their experience of in-class hands-on practical work.

The students in this small sample perceive that the interaction with this remote access experiment is a valid practical experience that yields readily-obtainable, reliable, authentic, reproducible (and very readily recapitulate able) experimental data. They have a high level of trust in the data that the apparatus yields. They identify positive learning outcomes for both conceptual understanding and skills acquisition.

They recognise, however, on balance, that online, remote-access, pre-constructed experimental apparatus is less engaging than hands-on practical work in school learning spaces, such as laboratories. Also, on balance, they identify that the remote laboratory experience involves less interpersonal, less performance-focussed and less interactive, in all senses, practical activity, and encompasses a narrower selection of Science-oriented skills than does hands-on experimentation. Again, the sample group, as a whole, perceives the similarities and obvious differences between the two approaches and, consequently, prefers the experiential and learning opportunities presented by hands-on apparatus, compared to those offered by the remote laboratory experiential environment. With clarity about the comparison and contrast, the group, overall, assesses each treatment as valid and capable of constituting a worthwhile element of its collective practical learning experience.

A small sample of Science teachers provided survey data. Their assessments echo those of students consistently.

When the Western Australia data are considered against the New South Wales data from 2010, despite specific differences in responses to specific survey items, there are many more close similarities than differences across the survey items. In none of the 26 survey items is it that the case that the present data present a contrast to the NSW data. Any general statement of student opinions about a given survey item is mirrored to a moderate or high in the two sets of data. There may be some minor regional differences but the characteristic strengths and weaknesses of the remote lab methodology (compared particularly to hands-on practical work) is highly consistent, lending verisimilitude to the conclusions made previously and to the statistical outcomes of the limited WA sample.

2. Context of Trialling

The *Labshare* project is a joint initiative of five Universities [University of Technology Sydney (UTS), Curtin University, University of South Australia, RMIT and Queensland University of Technology] and is partially supported by the Australian Government's Department of Education, Employment and Workplace Relations through the Diversity and Structural Adjustment Fund. The mission of *Labshare* is, in part, to support greater student flexibility and improved educational outcomes through the creation of a nationally shared network of remotely-accessible laboratories. A number of remote experiments has been provided to tertiary engineering students as part of their laboratory-based learning in various courses.

The James N. Kirby Foundation (http://www.kirbyfoundation.com.au/) has provided funding to UTS to explore ways in which selected experimental apparatus can be adapted or developed for use in schools as remote laboratory experiences and this has resulted in the offshoot, *Labshare for Schools*. Because many universities' remote labs are only required by tertiary students during a few focussed weeks of the academic year, there is ample opportunity to provide access to schools for most of the school year. In addition, it may be feasible to develop remote laboratory apparatus that are specifically tailored to the curriculum and learning needs of primary and/or secondary school students.

It was considered essential to conduct studies of the feasibility of remote laboratory experiences for school students and to ascertain the attitudes of educators, especially classroom teachers, to such a learning resource. The objective of these studies was to assess students' responses to the context of a laboratory experience which lacked direct, hands-on contact with experimental equipment. It was hoped that the results of the trialling studies would be sufficiently clear to inform both *Labshare,* and those who have a prime responsibility for the delivery of primary and secondary education across Australia, about the viability of remote laboratories for the school contexts.

A key objective was to assess students' views of the strengths and weaknesses of this remote-access practical experience, especially compared to their familiar experience of hands-on experiments conducted in the school classroom. As a result, the trialling which is the subject of this report was undertaken.

Three apparatus were used variously, as assigned by co-operating teachers, to the subject group of 27 students in 4 schools (see Table 1).

- shake table (activities involving the relationship between earthquake frequency and the degree of displacement of vibrating buildings)
- hydroelectric apparatus (activities involving the relationships between water flow rate, water pressure, rotation rate of a Pelton wheel and the voltage, current and power output of a hydroelectric generator)
- inclined (activities focussing on the displacement, velocity, acceleration, force and energy changes with time of an object sliding down an inclined plane of adjustable tilt angle to the horizontal)

Documentation (experimental activity guides and background notes) were available to students, as required.

At the conclusion of the interaction time, each student was requested to complete a survey pro forma (Appendix 6.1A). The foci of the survey form were to elicit views about the perceived qualities of remote labs and to promote reflection by students on the potential place of remote labs in their learning of concepts via practical experience.

In a separate, but sometimes overlapping, study teacher educators of the students were asked to conduct the experiments and complete a survey pro forma (Appendix 6.1B). While the teacher survey covered most of the same ground as the student survey, teachers were also asked to reflect on specific curriculum and teaching-learning issues associated with this method of delivery of first-hand practical experiences.

The intention is to allow the collected survey data to inform future development of the *Labshare for Schools* project. In this report, the WA data outcomes are compared with the survey of the NSW trial conducted nearly a year earlier, in order to compare and contrast students' and teachers' expressed experiences.

3. Method

A. General Approach

Students

1. The trialling process involved the use of one of the rigs hosted at the University of Technology, Sydney: shake table rig (4 off); hydroelectric energy conversion rig (1 off); inclined plane rig (one off).
2. A co-operating teacher at each school identified student participants and facilitated the trial sessions.
3. Each student carried out testing of the assigned rig, either at school or at home (because of educational systems' firewall provisions), and either individually or in a small group, with or without some teacher support. This diversity of treatment may have influenced student responses to the survey pro forma but this effect, if any, is not known.
4. Students engaged with the apparatus for variable amounts of time but each student was afforded to interact with the remote laboratory at length and complete one or more activities.
5. The data from the survey forms was collated using Microsoft Excel (see Sections 4 and 6.2 for analysis and statistics respectively).

Educators

1. One of the authors liaised with teacher educators, as required, in order to facilitate their participation in this trial, and that of their students. Educators were provided with relevant documentation for specific rigs, among them:
   - a *Teacher Guide*, which provides a discussion of strategies for providing students with practical experiences related to the experiment
   - a set of *Background Notes*, targeted at both students and teachers, which discusses key conceptual issues related to the experiment
   - an *Experiments Guide*, provided as a possible resource for teachers and a direct aid to students, which contains worksheets and instructions for each of the six experiments detailed in the Guide
2. Each teacher participant was provided with an individual logon. He or she was then asked to perform experiments of choice in order to assess adequately the characteristics of the remote lab environment for teaching and learning.
3. After interacting with the apparatus, educators were requested to complete the Teacher Survey form. This required approximately 20 minutes to complete.

B. Trial Schools and Participants

Four schools in Western Australia facilitated the participation of their students in this trial. Table 1 summarises the characteristics of these schools. The schools described briefly and their straight line distance, in kilometres, from central Perth and from the experimental apparatus at UTS, Broadway, central Sydney, is estimated.

Table 1. Participating Trial Schools in WA

School	School profile Ind = independent Govt = WA government high school				Approximate straight line distance from central Perth and from apparatus in Sydney (km)	Number of participating students, grade level (n_{total} = 27)
1	Ind	boys	Non-selective	Inner metropolitan	9 3 300	10 Year 9
2	Govt	co-ed	competitive entry	Inner metropolitan	11 3 300	5 Year 11
3	Govt	co-ed	Non-selective	Regional	155 3 400	3 Year 10
4	Catholic	co-ed	Non-selective	Regional	370 3 500	9 Year 9

4. Survey Data – Findings

Important Considerations

1. In consequence of the small sample size (27 students from 4 schools) in this initial survey in Western Australia, caution must be exercised in drawing conclusions. It is acknowledged that unknown biasing factors may be relevant in students' responses to one or more of the 26 survey items.

2. As a result of consideration 1, and in light of the existence of a report of the in-schools trialling with 85 students framing this analysis, emphasis is placed on a comparison of these WA data with those NSW data. It is of interest to note areas of high similarity and considerable difference between the two sets of data and to assess, in an overall sense, whether students' experiences have been quite similar, or otherwise, across the range of survey questions. In analysing the data for each survey question, reference is made to the previous NSW survey data. In addition, Appendix 6.2 indicates percentage data from NSW triallees, for comparison purposes.

3. The treatment regimes in the WA and NSW trials were different; e.g. all of the NSW data were compiled with the Labshare for Schools conducting trials personally within schools, principally with small groups; all of the WA data were obtained with the Labshare for Schools liaising with contact teachers, who then arranged for trialling with their students, individually (at home or at school) or in small groups (at school). It is not known whether these two differences in treatment are significant or insignificant in accounting for statistically significant differences between the two sets of data.

A full account of the survey data is located in Appendix 6.2. There were 27 students, ranging from Year 9 to Year 11, who participated in the trials. The percentage of participants at each grade level is indicated below.

Year 9	19	70%

Year 10	3	11%

Year 11	5	19%

Whether or not the age of participants affected their experience and their survey responses was not considered in this analysis.

The sex of participants was not considered in this analysis.

The following discussion highlights the major definitive findings from the student and educator surveys.

A. Students

Survey Page 1 -survey items 1 to 6

1. Students reported minimal understanding or pre-existing awareness of remote control applications. It is hypothesised that they did not identify common applications, such as remote control controllers because they were focussed on the notion of remote control robotics. There was a high percentage (67%) of nil responses.

   The WA data and the NSW data are almost identical.

   The common concrete examples that were identified by students included:

   - remote control of equipment in general (using remote controls)
   - remote control of toys

2. Students reported a more limited knowledge of remote control phenomena than was anticipated. It is hypothesised that students interpreted Item 2 of the survey to be a more technical question than was intended. There was a high rate (37%) of nil responses.

   The WA data and the NSW data were similar.

   The common examples that were identified by students included:

   - handling dangerous goods or bombs
   - use in medical procedures

   Some WA students also mentioned mining/engineering applications.

3. Respondents were somewhat content with the clarity of the experiment notes provided with the practical session; 40% of students considered the guides easy or very easy to follow (NSW 73%); 40% were neutral; 19% expressed concerns about adequacy.

   NSW students expressed a significantly higher degree of satisfaction with the background notes and/or experiment guides.

   The most common positive reasons cited were related to the clarity, high level of detail, concision or appropriate language level of the guides (32% of all responses).

   Deficiencies in clarity or detail of explanations were identified in 51% of responses.

   A hypothesis here is that, given the younger average chronological age of WA participants compared to NSW participants, the style, content and language level of the notes and guides revealed different experiences. In addition, differences in treatment conditions (see above) may be significant here.

4. Respondents identified strongly with the advantages of providing an experimental guide with a number and range of experiments. Some77% (NSW 85%) of participants considered experimental choice to be either a good or very good idea.

   The most commonly-cited reasons were that choice:

   1. (44%) can cater for different student learning needs (also choice 1 for NSW sample)
   2. (27%) provide motivation or greater interest for students (also choice 2 for NSW sample)
   3. (19%) is an advantage provided that sufficient student guidance and scaffolding are provided (not noted in NSW sample)

   Choice 3 is a somewhat negative or neutral response, indicated by students who, otherwise, identified difficulty or confusion with written materials supplied and/or with the learning purpose of the apparatus and activity or activities with which they interacted.

5. There was mixed opinion about the qualities of a pre-constructed experimental apparatus (compared to a hands-on, self-constructed experimental apparatus). About half (48%) of students considered the remote lab apparatus about the same or worse in being pre-constructed (NSW 56%). Correspondingly, about half (52%) considered the remote lab format better in this respect (NSW 44%).

   The WA and NSW results are very similar.

   It is hypothesised that some students prefer to handle and have the important experience of building (and, perhaps, operating first-hand) experimental apparatus, while others focus on the advantage of greater proportions of time spent operating the apparatus and obtaining data. Some perceive advantages in both remote lab and hands-on approaches.

6. There was a clear preponderance of opinion that the group work involved in performing a remote lab is less than that which would apply to a hands-on class practical experience. Some 80% of students (NSW 85%) regarded the group interactions for a remote lab. to be the same or less than for a class lab session. Students in both states do not identify remote labs as affording much more intense group processes.

   The WA and NSW results are very similar.

   Item 6, as presented, had the flaw that the two variables of intensity and effectiveness were confounded. It may be the case that participants would have different opinions about the two distinct variables. However, the strength of the neutral and negative responses suggests that the level of tentativeness is minimal in the survey groups.

Survey Page 2 - survey items 7 to 11

7. Students generally identified that the remote lab experience was fun. However, this opinion was not overwhelmingly in favour of the remote lab as a learning experience. Some 63% of participants (NSW 64%) were positive in their assessment of the experience.

   The WA and NSW results are very similar.

   The use of the word "fun", though it is appropriate language for a student survey, allows the possibility for some diversity of interpretation by respondents. The opportunity for follow-up written response suggests that students most often associated "fun" with motivation, interest, acceptance and engagement.

   The most common positive reasons cited for the experience being "fun" were:

   - the efficiency and effectiveness of data collection
   - that the remote lab was something novel and/or could provide variety to the learning experience
   - the excitement, interest or motivation provided by using high technology to learn
   - the interest level and engagement inherent in the experience

   (These 4 reasons constitute 37% of reasons.)

   The first of these reasons is insignificant in the NSW data.

   The most common negative reasons cited for the experience not being "fun" were:

   - the phenomenon is less inherently engaging and motivating than a hands-on experiment
   - pros and cons of remote lab learning compared to a hands-on experiment
   - problems with the camera view or camera view speed affecting student motivation

   (These 3 reasons constituted 21% of reasons.)

   The third of these reasons is less significant in the NSW data. It is hypothesised that internet speed may have biased the WA data, in the case of 1 or 2 students. Caution should be exercised.

8. The most common opinion of students (43%; NSW 59%) was that they had learnt a little bit, conceptually, by performing the remote lab experiments. However, 26% (NSW 35%) believe that they learnt a lot.

   68% of positive respondents were able to identify concepts that they believed were learnt during the remote lab session. In all cases, these identified learnings were objectively relevant to the experience.

   The WA and NSW results are very similar.

   Almost all negative respondents (7 students; 87%) identified a lack of understanding of the purpose or process of the remote lab experience for their lack of conceptual learning. Again, the greater diversity of treatment in the WA trial, compared to the NSW trial, may have led to a greater requirement for student independence and, again, the significant difference in the average age of participants may be a relevant factor (the WA sample being, on average, younger).

9. The most common opinion of students (43%, NSW 67%) was that they had learnt or applied some skills by performing the remote lab. experiments. Only 22% (NSW16%) believe that they learnt a lot, while 22% (NSW16%) believe that they did not learn any skills or new skills.

   These two sets of data are similar.

   Almost every student who identified the acquisition or application of skills was able to identify skills that he or she believed were learnt during the remote lab session. These learnings were all objectively relevant to the experience. In a few cases, identified learnings were, however, of a trivial nature.

   The most common skills identified by participants were:

   - interpretation, construction or analysis of graphs (13%, NSW 32%)
   - an appreciation of how using practical apparatus to gather data is related to the learning of concepts (13%,NSW 0%)
   - manipulation or analysis of experimental data (46%, NSW 18%)

   The second of these skills is not seen in the NSW data.
   The juxtaposition of the first and third skill sets is of interest, as well.
   An attribution is proposed that, because the NSW trial used *only* the inclined plane apparatus (for which graphical analysis is critical), whereas the WA trial used 3 different apparatus (shake table, hydroelectric, inclined plane) the gathering of data is a greater common factor in the latter triad of experimental apparatus.

   Students who identified a lack of skills application or learning attributed this, in general, to a deficit in hands-on work or engagement and/or a central focus on computer-based processes and ICT applications.

10. Despite a sample of students spread over three year groups, the respondents' views in this item did not appear to be linked to grade level to any significant degree.

    The majority of students considered the apparatus and the attendant experiments as either appropriate in difficulty (44%) or only slightly too difficult or too easy (a further 41%).

    The WA and NSW data are not at all significantly different.

11. The content of the remote laboratory experience with the inclined plane apparatus was considered very course-relevant or somewhat course-relevant by 44% (NSW 61%) of student participants, while 26% (NSW 18%) perceived the apparatus and practical experience to be of low relevance or irrelevant.

    The two sets of data are significantly different. The author believes that the inclined plane experiment used in the NSW trial was considered relevant, for objectively correct reasons, by the preponderance of Year 10 and Year 11 students in the NSW trial. The WA trial used three different apparatus and, thus, the match between apparatus, students and course content may not have been as obvious to students

Survey Page 2 - survey items 12 to 20

12. About half of students (48%, NSW 67%) expressed keenness or satisfaction with performing remote labs in the future, whereas 23% (NSW 18%) expressed dissatisfaction with or opposition to future remote lab experiences.

    It is not clear why this significant difference in opinion between the two trials arises. However, reference to significant differences in item 11 may explain some of the difference.

13. To the proposition that remote labs could become a regular learning experience, most students (59%, NSW 67%) favoured 1 to 3 per term, while a further 11% (NSW 22%) indicated a preference for one per week. A relatively high percentage (26%, NSW 7%) choose the *as often as possible* option.

    The total of students favouring a high exposure, to as seldom as only 1 per term is 70% in the WA sample and 64% in the NSW sample, results which are essentially the same (though the internal distributions among as often as possible, 3 per term, 1 per term *differ markedly in the two survey samples, giving a somewhat more favourable response from WA participants).*

    It should be noted that the outcomes for items 12 and 13 here appear to be somewhat internally contradictory when compared with the same outcomes of the NSW sample.

Items 14-20 are propositions which were responded to on a 5-degree scale.

14	*The remote lab. gave me results from a real experiment, not just from a simulation*	82% of respondents (NSW 82%) agreed or agreed strongly with the proposition. Of these, 33% (NSW 48%) of respondents agreed strongly *There is a strong, and similar, endorsement,, in both trials, of the realism and authenticity of the remote lab experimental environment.*
15	*Having the camera view was important for us to see the results as we controlled the apparatus*	74% (NSW 79%) of respondents agreed or agreed strongly with the proposition Of these, 33% (NSW 33%) of respondents agreed strongly *There is a strong, and similar degree of, opinion in favour of the need for video view(s) of the apparatus while controlling it, in both trials.*
16	*I trust the data that we measured.*	71% (NSW 69%) of respondents agreed or agreed strongly with the proposition. Of these, 30% (NSW 30%) of respondents agreed strongly; whereas 22% (NSW 22%) of respondents were neutral *Related to Item 14, there is general endorsement of the validity of data from the remote apparatus. There is a similar number of neutral responses (16% in Item 14) from a similar set of respondents.* *The WA and NSW data are almost identical.*
17	*I prefer remote labs to hands-on labs.*	Only 18% (NSW 8%) of respondents agreed or agreed strongly with this proposition. Some 51% (NSW 61%) of respondents disagreed or disagreed strongly. A further 26% (NSW 30%) of respondents expressed a neutral opinion. *This is a clear indication of a student preference, on balance, for hands-on experimentation; this general conclusion is equally valid for both trials, despite some differences in percentages.*
18	*I will probably visit the remote lab again, at home, in my own time.*	This item created a diversity of opinion, with 29% (NSW 25%) in some form of agreement, 26% (NSW 35%) neutral and 37% (NSW 26%) in some form of disagreement with the proposition. Again, despite detailed differences, both trials show considerable division of opinion. It might be opined that intention to revisit the apparatus in the home and the actuality of doing so are distinct. However, the results may also indicate the realistic likelihood that some students are attracted to the remote lab environment for various, while some students would not be prepared to pursue perceived schoolwork at home if not required. *The statistical outcomes of the two trials are sufficiently similar to reinforce each other in terms of general conclusions for this item.*
19	*I would have preferred to operate the equipment myself, rather than having a 'ready-to-go' experiment.*	52% (NSW 60%) of respondents agreed or agreed strongly with this proposition. Of these, 30% (NSW 15%) agreed strongly. Only 8% (NSW 14%) disagreed or disagreed strongly. *The result parallels the outcome in Item 17. Again, students indicate a clear on-balance preference for hands-on class practical work. As for immediately previous items, the WA and NSW results demonstrate very similar general opinions for this item.*
20	*I felt more motivated to try things with the remote experiment than I would with normal prac equipment.*	There was a diversity of opinion concerning Item 20. The single largest group of respondents (37%, NSW 32%) was neutral. Significantly more students disagreed (45% in total, NSW 41%) than agreed (19%, NSW23%). *It is hypothesised that this statistical outcome parallels the result s in Item 17 and Item 19 to some extent. The similarity between the two sets of trial surveys is significant.*

Survey Page 4 - survey items 21 to 26

Items 21-24 are characteristics common to a remote lab and a hands-on practical experience; the quality of each characteristic was assessed to on a 5-degree scale.

In responding to all 4 items, the level of student uncertainty about each characteristic is minimal or zero.

21	*Reliability of observations and data*	Some 41% (NSW 70%) of respondents opined that the remote lab. yielded more (or much more) reliable data. The quality of data yielded from a hands-on experiment was regarded less favourably (23%, NSW 8%, considered it more reliable or much more reliable). A significant percentage of students (37%, NSW only 17%) regarded the two approaches as equally reliable. *There is a significant difference between the WA and NSW results for this item. WA students were relatively more in favour of the hands-on experiments, although the weight of opinion still favours remote labs over hands-on experimentation.*
22	*Ease of gathering data*	There is a pronounced preference for the remote lab methodology (56% in total, NSW 86%l) versus a hands-on approach (15% in total, NSW 3%). The neutrals here are significant (30% of responses, NSW 11%). There is symmetry between related items 21 and 22 for both the WA data and the NSW data, separately. Indicating a consistency of students' experiences. *As for item 21, there is a significant difference between the WA and NSW results for this item. WA students were relatively more in favour of the hands-on experiments, although the weight of opinion still favours remote labs over hands-on experimentation.*
23	*Personal involvement and motivation*	Respondents generally consider there to be a much lower level of motivation for the remote lab methodology. Only 11% (NSW 14%) in total find remote labs more motivating or personally involving. 63% (NSW 66%) in total find hands-on labs more motivating or personally involving. The neutral (equally good) opinions are similar and significant – WA 26%, NSW 20%. *The data for the two trials are very similar and strongly favour hands-on labs compared to remote labs.*
24	*Ease of learning new things*	Although, in the NSW trial, respondents made little distinction between the two methodologies when considering this characteristic (remote labs 25%; hands-on 29%), the WA data considerably favour hands-on experiments (16% for remote labs; 47% for hands-on). The percentage of students who consider remote labs and hands-on equally effective is highly significant (35% WA; 44% NSW). *In this item, WA respondents clearly prefer hands-on experiments to remote lab experiments by a factor of about 3.*

25. There was a high level of choices – 80 of 81 possible choices (99%, NSW 95%).
The five most popular of the 9 suggested advantages of the remote laboratory experience, as identified by the 27 participants accounted, together, for 87% (NSW 80%) of choices.
They were:

- measurements could be repeated easily **21% (NSW 25%)**
- experiment was real and not a simulation 20% (NSW 13%)
- (apparatus/control panel operation was) easy to use 18% (NSW 24%)
- liked using technology to perform experimentation 15% (NSW 8%)
- knowledge that the experiment could be checked or re-run at home 10% (NSW10%)

These survey results suggested that a high percentage of students recognises the convenience, efficiency and authenticity of the operation and behaviour of the apparatus and the experimental data it produces, together with the novelty or effectiveness of the ICT-based learning environment.
Although there are clear differences as to degree between the two samples, the consistency of the list of the top 4 or 5 preferred characteristics is noteworthy.

26. There was a high level of choices – 71 of 81 possible choices (90%, NSW 88%).
The 5 most-identified of the 9 suggested disadvantages of the remote laboratory experience accounted, together, for 88% (NSW 88%) of choices.

They were:

- less learning apparent, compared to a hands-on practical experience **25%** (NSW16%)
- lack of clarity of the video camera view 18% (NSW21%)
- more difficult to follow because apparatus not accessible nor visible first-hand 18% (NSW11%)
- lack of personal involvement due to remoteness of equipment 17% (**NSW25%)**
- less favourable group interaction because collaboration was less 10% (NSW15%)

These 4 characteristics, taken together, demonstrate that, compared to a hands-on collaboration on practical work, the remote lab experience is deficient in immediacy and the need for intense interpersonal collaboration. It appears that, for students, hands-on practical experiences have greater immediacy and impact.
In general terms, the WA and NSW are analogous, in that the same 5 choices or reasons predominate over the remaining 4 reasons, and these 5 choices all relate in some way to the effectiveness of the learning experience.

B. Educators

Among the four schools trialled, four teacher educators responded by way of the teacher survey. Consequently, a full statistical analysis of their opinions is not warranted. The following findings highlight the major *consistencies* of the teacher responses. In considering these points, the reader should bear in mind the comments in section A regarding the student survey and note the considerable degree of similarity of the teacher and student experiences of the remote lab learning environment.

1. An acknowledgement that, with some reservations, the support materials provided were appropriate for students and teachers.
2. Affirmation of the importance of providing teachers and students with support materials for each remote lab rig that is developed.
3. An assessment that the amount and quality of student team-work are similar in remote lab work and hands-on school-based practical work.
4. The view that team-work and data gathering and manipulation skills are common to both approaches, that data analysis and ICT skills are more pronounced for remote labs and that social interaction and manipulative skills are more significant for hands-on labs.
5. An assessment that the level of challenge of the three remote lab rigs and attendant experiments was, on balance, appropriate (despite the fact that the sample contained students across three school grades, Years 9-11).
6. A median view that teachers would probably use one or more remote labs in their planning of teaching and learning, if available.
7. Across teacher survey items 9-15, as a set, neutrality about, or slight favouring of hands-on experiments, when assessing the relative merits for teaching of remote and hands-on labs; a clear view that teachers perceive advantages of remote labs over hands-on practical work in terms of motivation, ability for students to work practically at home and the credibility of the data and context of the remote labs as real experiences with scientific apparatus, especially if the video camera views are effective.
8. Across survey items 16-20, as a set, reaffirmation of the student view that remote lab data are obtained more efficiently and are more reliable. However, unlike the mixed response of students, these 4 educators were clear that remote labs promoted learning, perhaps because students are able to focus on data collection, do so efficiently, have adequate focus time on its analysis and then learn conceptually by drawing conclusions.
9. All 4 respondents opined that they would focus on conducting remote lab interactions as a small group experience (mimicking hands-on modalities), though other applications were also identified.
10. Teachers identify that remote labs are efficiently able to allow students to focus on data gathering and data analysis (including graphical analysis) skills and promote concepts of scientific enquiry. Some say, as do some students, that the quality, recapitulation, reliability and time efficiency of remote lab data acquisition are critical factors in favour of the remote lab environment.
11. Teachers identify the issue that remote labs are most useful where they provide robust and reliable apparatus to conduct practical experiences and acquire data from the study of phenomena that cannot readily be provided in schools in the normal course, or cannot be observed and measured quantitatively or cannot be measured with sufficient accuracy and/or reproducibility and/or time efficiency.
12. For item 25, there is diversity about the key positive characteristics of the remote lab strategy. However, characteristics 5 (knowledge of remote control), 6 (team collaboration productive) and 7 (students are able to work more independently in the web-based environment) were not chosen. The most chosen characteristic was 3, that students could efficiently repeat data measurements within a space of time provided for practical work.
13. For item 26, there is some diversity about the key negative characteristics of the remote lab strategy. However, characteristics 4 (problems for students trying to control interfaces), 5 (less conceptual learning via remote labs) and 7 (support documentation difficult to follow) were not chosen. The most chosen characteristic was 2, that group interaction would not be as effective as for hands-on class practical work.

5. Conclusions and Recommendations

The sample size of the in-the Western Australia school trials and student survey is rather small (n = 27) and so caution and reservation must be exercised in drawing conclusions and recommendations.

The pronounced similarity in nearly all 26 survey items and the comparative similarity in all items, between the current WA trial data and the previous NSW trial data is such that most of the conclusions and recommendations identified in the report of the NSW trial can be repeated here, with mostly minor adjustments, as in the pursuing section, to reflect the more obvious differences.

A. Conclusions

5A.1. students have a positive opinion about clear, detailed, language-appropriate support materials

5A.2 students perceive the potential advantages of experimental apparatus which allows for a range and choice of investigations, especially at a variety of levels of challenge

5A.3 it emerges that, in general, participants are very aware that there are manifest differences between the remote laboratory methodology and more familiar hands-on experimentation within the school setting;
students regard hands-on experimentation to have certain readily identifiable advantages over a remote-access practical experience; these advantages include:

- the relatively greater amount of group interaction
- the psychological and motivational advantages of being able to see, handle and manipulate equipment first-hand
- the implications for student learning of the two dimensions immediately above

5A.4 students regard remote labs as somewhat less fruitful for social interaction, collaboration and the widening, practise and application of their skills base than hands-on, direct experimentation; some students identify that the pre-construction of apparatus in a remote lab affords greater opportunities to perform experimentation and gather and repeat data.

5A.5 students recognise a number of advantages in the remote laboratory methodology:

- most participants favour or strongly favour the use of remote labs as a valid, relevant and interesting addition to their learning options in courses with a practical component
- they identify and accept the reality of the experience, even though it is literally remote from them
- they recognise and affirm the validity and reliability of the measured data
- they place(greater) trust in the apparatus and the data it yields because they find the technical and technological precision of the apparatus convincing
- there is significant recognition of the flexibility of remote labs in allowing access outside the constraints of conventional lesson times, whether or not this option would be exercised by them in actuality

5A.6 a significant proportion of participants perceives material advantages in this characteristic of the methodology, given the potential partial failure, variation of data, variation of method and greater imprecision of typical hands-on experiments

5A.7 in respect of effectiveness of a remote lab resource for learning in general, participants:

- express a clear view that the approach is valuable and relevant;
- regard it, on balance, as slightly less effective than traditional school-based, hands-on practical work (this view focuses on immediacy, interaction with each other and with the apparatus and on a preference for practical work as part of the school-based learning experience (despite a clear view about the prized novelty and difference afforded by the remote lab modality)

5A.8 it emerges relatively clearly in the WA survey results that, on average, students prefer in-school, hands-on practical work to practical experiences delivered by the remote lab methodology. The responses to survey items 7 and 8 reveal a degree of contradiction but follow-up items among items 14-24 reveal a clear preference for hands-on experimentation over remote labs on matters such as motivation, interaction and intensity of learning, in contrast to the quality and effectiveness of acquired data, for which remote labs are clearly identified as superior. Nonetheless, it can be argued that the latter issues - student engaged and perceptions of learning – are more important when assessing the value (in financial, educational and motivational terms) of given teaching/learning strategies

B. Recommendations

5B.1 Any future development of the *Labshare for Schools* resource should include the development of support materials for students which are capable of framing their learning using a given experimental apparatus, through the provision of background information, explanations and resources that will assist them to structure their interaction with the apparatus.

5B.2 Students endorse the notion of an apparatus which is sufficiently flexible and adaptable that it can provide choice in the experimentation. Therefore, future development of apparatus types should consider the degree to which they provide, generically, several possible investigations across as wide as possible a range of student interests, and needs. This consideration also presents the possibility of a cost-effective development approach.

5B.3 Students identify drawbacks in being presented with a pre-constructed apparatus. However, they also recognise the advantages, in terms of the efficiency (predominantly time efficiency) reliability and reproducibility of collected data. To balance these views, it will important to consider the extent to which remote lab apparatus provide a degree of student planning, in particular by allowing students to plan and implement their own investigations, using the advantages of the apparatus. This requires a given apparatus to be able to deliver a range of conceptual and skills development outcomes via the flexibility of its conceptualisation and design.

5B.4 Students, on balance, are clear that the quality of group interaction (be it intensity, amount, complexity) is less for a remote lab than for a hands-on lab. Consistent with 5B.3, remote lab design principles should seek to provide ways for students to interact with each other by having the option to design simple or more complex investigations of their own design, a process which would involve a high quality of interpersonal interaction and deeper learning. There may also be consequences for the types and modes of delivery of support materials and the presentation of learning tasks (see 5B.1).

5B.5 Students identify, on balance, that the practise of skills is less for a remote lab experience than for a hands-on experience. Consistent with 5B.3 and 5B.4, future remote lab development should focus on ways to incorporate key skills such as experimental design, control of variables,

reproducibility in data collection (especially given the likely convenience of collection, reliability and consistency of remote lab. data), data analysis (including graphical analysis) and evaluation of the experimental process. This has implications for the nature of the support materials referred to in 5B.1.

5B.6 Students see potential in being able to access remote lab apparatus outside the constraints of the traditional school timetable. Thus, the access/logon procedure for *Labshare for Schools* should provide as wide as possible an access over time to students. Consideration could be given to how, if students were to convert their intentions into reality, they could be encouraged to do so, if it were, indeed, feasible to provide 24-hour access to students.

5B.7 (a) Some students, in several items of the survey where they could, expressed frustration at slow data transfer speeds, especially in respect of using videocam views. This may be a combination of speed restrictions at any point in the communication chain between Sydney and Perth and the school. It emphasises that a provision such as the National Broadband Network will probably overcome this significant difficulty, particularly when high rates of data transfer are required. For the NSW trial, a USB Telstra modem was often used in schools and, regularly, the speed of data transfer proved to be a challenging issue.

(b) Firewall issues are the rule for at least two of the apparatus used in this trial, with the result that teachers, most often, and students, almost always, cannot access the control panels through their school systems' or individual independent schools' firewalls. It will certainly be necessary to overcome this difficulty for all existing Labshare rigs adapted for schools' use and to ensure that future apparatus, such as has been proved for the hydroelectric rig, do not attempt to send data of a type or route that will not be permitted through firewalls. Thus far, it has been difficult or impossible for systems to modify their fundamental firewall provisions in order to allow the passage of remote desktop information. In addition, in some contexts, even video camera feed for the hydroelectric apparatus has encountered some difficulties.

6

APPENDICES

6.1A – Student Survey Form

Labshare for School **STUDENT SURVEY**

School:	Year Group:	Experiment: *Inclined Plane*

Thank you for completing the trial of a *Labshare for Schools* experiment.
The following feedback on your trial will help us to improve the *Labshare for Schools* website.

1. Please describe your pre-existing understanding, if any, of remote labs or remote control of equipment.

2. If you know any other examples of where equipment or a process is controlled remotely, please write them down.

   •
   •

3. The supporting notes (background material, experiments and teaching/learning notes) were

very easy to follow	***easy to follow***	***adequate***	***difficult to follow***	***very difficult to follow***
☐	☐	☐	☐	☐

Please explain your choice: .....

.....

4. The support material offers a choice of 5 experiments. A choice of experiments to do is:

a very bad idea	***a bad idea***	***okay***	***a good idea***	***a very good idea***
☐	☐	☐	☐	☐

Please explain your choice: .....

5. During class experiments, you often follow a written Method to set up equipment; then you do the prac. The online experiment is already basically set up for you. Therefore, the online experiment is:

much better	***better***	***about the same***	***worse***	***much worse***
☐	☐	☐	☐	☐

6. Team-work is an important part of practical work.
   You get to learn/practice/apply working in a team. Compared to the type of team-work in a normal class prac. session, the team-work in doing the remote lab. is

much more intense; much more effective	***more intense; more effective***	***about the same***	***less intense; less effective***	***much less intense; much less effective***
☐	☐	☐	☐	☐

7. Give an overall rating of your remote lab. experience.

a lot of fun	*reasonable fun*	*I feel neutral*	*not pleasant*	*very unpleasant*
☐	☐	☐	☐	☐

Please explain your choice: .....

.....

8. Usually, learning more about a concept is an important goal of practical work.
In doing the remote lab., you

(A) learnt a lot ☐ (B) learnt a little bit ☐ (C) didn't learn anything ☐

If you chose (A) or (B), please write down some ideas that you think you learnt.
If you chose (C), please tell us why you think it was not a successful learning experience.

.....

.....

.....

9. Usually, practical work involves learning new skills + practising/applying skills.
By doing the remote lab. you:

(A) learnt/applied several skills ☐ (B) learnt/applied a few skills ☐ (C) learnt/applied no skills ☐

If you chose (A) or (B), please write down some skills that you think you learnt/practised/applied.
If you chose (C), please tell us why you think it didn't help you with your skills development.

.....

.....

.....

10. The remote lab. that my team did was

much too difficult for us	*a little too difficult for us*	*about the right level of difficulty*	*a little too easy for us*	*much too easy for us*
☐	☐	☐	☐	☐

11. How relevant was the remote lab. you did to the learning goals of the current Science course you are doing?

very relevant and useful	*relevant and useful*	*I'm not sure*	*not very relevant; not useful*	*irrelevant; useless*
☐	☐	☐	☐	☐

12. Suppose that online experiments could be a normal part of classroom learning for your class/teacher. You would:

be very keen to do more	*feel okay about doing more*	*not care either way*	*rather not do more*	*be opposed to doing more*
☐	☐	☐	☐	☐

13. Suppose that online experiments became one of the ways that your class did its learning. How often would you like to be given a remote lab. to do?

never	*1 per term*	*3 per term*	*1 per week*	*as often as possible*
☐	☐	☐	☐	☐

Please indicate your level of agreement with each of the following statements about the remote lab. experience. [Tick one circle for each item]

	Agree strongly	*Agree*	*Neutral*	*Disagree*	*Disagree strongly*	*Don't know*
14. The remote lab. gave me results from a real experiment, not just from a simulation	○	○	○	○	○	○
15. Having the camera view was important for us to see the results as we controlled the apparatus	○	○	○	○	○	○
16. I trust the data that we measured	○	○	○	○	○	○
17. I prefer remote labs to hands-on labs	○	○	○	○	○	○
18. I will probably visit the remote lab. again, at home, in my own time	○	○	○	○	○	○
19. I would have preferred to operate the equipment myself, rather than having a 'ready-to-go' experiment	○	○	○	○	○	○
20. I felt more motivated to try things with the remote experiment than I would with normal prac. equipment	○	○	○	○	○	○

Please compare the remote lab. experience to a similar hands-on experiment (where you set up and manipulate the equipment yourself). [Tick one circle for each item]

		Remote lab. much better	*Remote lab. somewhat better*	*Equally good*	*Hands-on somewhat better*	*Hands-on much better*	*Don't know*
21.	Reliability of observations and data	○	○	○	○	○	○
22.	Ease of gathering data	○	○	○	○	○	○
23.	Personal involvement and motivation	○	○	○	○	○	○
24.	Ease of learning new things	○	○	○	○	○	○

25. Please *tick* (✓) UP TO 3 aspects that you most LIKED most about the remote lab. experience.

☐	• easy to use
☐	• it was a real experiment and not a computer simulation of a real experiment
☐	• we could easily repeat measurements
☐	• I know that I could go home and run the experiment again to check it
☐	• it increased my knowledge the possibilities of computer control of equipment
☐	• the collaboration in our group was more productive and task-focussed than normal
☐	• we could follow the guidance given on the website and work fairly independently
☐	• I liked using technology to do an experiment
☐	• the web environment and the control panel were friendly and easy to use

26. Please *tick* (✓) UP TO 3 aspects that you DISLIKED most about the remote lab. experience.

☐	• I did not feel personally involved because the equipment was remote from me
☐	• the group interaction was not as good because we didn't need to work together as much
☐	• I found it more difficult to follow what was going in because I couldn't see first-hand
☐	• controlling the apparatus indirectly with the interface was confusing/difficult for me
☐	• I learnt less than I would from a direct, hands-on experiment
☐	• the experiment did not give the results that I expected
☐	• I couldn't see properly from the video cams what was going on
☐	• we found the online support and guidance difficult to follow
☐	• the experiment that we did was too difficult and complicated

THANKS FOR YOUR PARTICIPATION

6.1B – Educator Survey Form

Labshare for Schools **TEACHER SURVEY**

School:	Experiment: *Inclined Plane*

Thank you for completing the trial of a *Labshare for Schools* experiment.
The following feedback on the trial will help us to improve the *Labshare for Schools* resource.

1. Please describe your pre-existing knowledge and understanding of the concept of remote labs and/or remote control of equipment.

……

……

……

2. Please rate how easy it was to follow the supporting written materials (background information, experiments and teaching/learning support).

very easy	***easy to follow***	***adequate***	***difficult to follow***	***very difficult***
☐	☐	☐	☐	☐

Please explain your choice: ……

……

3. How important is it for the experimental apparatus of a remote lab. to be supported by thorough notes, suggestions for teaching, learning and possible student experiments?

not required	***somewhat important***	***very important***	***vital***	***I'm not sure***
☐	☐	☐	☐	☐

4. Please assess the probable **AMOUNT** of student team-work required to perform a remote lab. with the **AMOUNT** you expect from a conventional class practical session.

much more	***more***	***about the same***	***less***	***much less***
☐	☐	☐	☐	☐

5. Please compare the probable **QUALITY** of student team-work when doing the remote lab. with **QUALITY** of team-work in a typical class practical lesson.

much greater	***greater***	***about the same***	***lower***	***much lower***
☐	☐	☐	☐	☐

6. Think about the skills applied or learnt by students when doing a remote lab.

Please list some skills which remote labs have in common with conventional practical work.

……

……

……

……

Please list some skills that are required for remote labs but not for class practical work.

……

……

……

……

7. Please assess the overall level of challenge and complexity embedded in the remote lab. with which the students interacted.

much too complex for them	***too complex for them***	***okay***	***too simple for them***	***much too simple for them***
☐	☐	☐	☐	☐

8. Suppose that online experiments could be a normal part of your array of teaching-learning strategies. You would:

definitely use them	***probably use them***	***perhaps use them***	***probably not use them***	***never use them***
☐	☐	☐	☐	☐

Please indicate your level of agreement with each of the following statements about the remote lab. experience. (✓)

		Agree strongly	*Agree*	*Neutral*	*Disagree*	*Disagree strongly*	*Don't know*
9.	The remote lab. gave students results from a real experiment, not just from a simulation	☐	☐	☐	☐	☐	☐
10.	Having the camera view was important for students to see the results as they controlled the apparatus	☐	☐	☐	☐	☐	☐
11.	Students are unlikely to trust the data they measure, compared to a hands-on prac.	☐	☐	☐	☐	☐	☐
12.	I prefer the concept of remote labs to hands-on labs for my teaching	☐	☐	☐	☐	☐	☐
13.	I would set home assignments where my students were asked to perform remote labs	☐	☐	☐	☐	☐	☐
14.	I think that a hands-on class lab. gives students a more valuable experience than a 'ready-to-go' remote experiment	☐	☐	☐	☐	☐	☐
15.	I believe that remote labs could be quite motivating for students	☐	☐	☐	☐	☐	☐

Please compare the remote lab. experience to a similar hands-on experiment (where students set up and manipulate the equipment personally).

		Remote lab. much better	*Remote lab. somewhat better*	*Equally good*	*Hands-on somewhat better*	*Hands-on much better*	*Don't know*
16.	Reliability of observations and data	☐	☐	☐	☐	☐	☐
17.	Ease of gathering data	☐	☐	☐	☐	☐	☐
18.	Personal involvement and motivation	☐	☐	☐	☐	☐	☐
19.	Ease of learning new things	☐	☐	☐	☐	☐	☐

20.Think about the 5 experiments (expts) that are provided in the support materials. Should these be:

all detailed and guided	*basic expts more guided; more challenging expts less guided*	*basic expts less guided; more challenging expts more guided*	*minimal detail and guidance; students design expts*	*I'm not sure*
☐	☐	☐	☐	☐

21.Think about how you would be most likely to/prefer to use remote labs in your teaching.

teacher demo; e.g. Smartboard	*small group experience*	*students work individually*	*adapted as an assessment task*	*I'm not sure yet*
☐	☐	☐	☐	☐

22.Please assess the relevance of this experimental apparatus and the experiments to the syllabuses or programs that you teach.
In doing so, please bear in mind curriculum strands such as:

National Science Curriculum	NSW Syllabus
• Science understanding • Science as a human endeavour • Science enquiry skills	• Knowledge and Understanding • Prescribed Focus Areas • Skills, Values and Attitudes

.....

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23. Suppose that a range of curriculum-relevant remote labs was available in the future. Assume that such labs would be free of any negative practical issues and were well-supported with online documentation. Describe the kind of use, if any, that you would make of them in designing your teaching strategies towards delivering the syllabuses and programs that you teach.

……

……

……

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……

24. Think about a future in which a range of robust, curriculum-relevant remote was readily available to you in your teaching. Assess to what extent their availability would provide teaching/learning opportunities and possibilities that are not currently available to you for the courses which you teach.

……

……

……

……

25. Please select **UP TO 3** aspects that you regard as most positive about the remote lab. idea.

	• the apparatus is easy for students to access and operate
	• it was a real experiment and not a computer simulation of a real experiment
	• students could easily repeat and reproduce measurements during lesson time
	• students could go home and run the experiment again to check it
	• access to knowledge/understanding of possibilities of computer control of equipment
	• team collaboration in student groups will be productive and task-focussed
	• students can use the web support materials to work fairly independently
	• use of higher-level technology to do an experiment
	• the web environment and the control panel were friendly and easy to use
	• the apparatus is robust and reliable

26. Please select **UP TO 3** aspects that you dislike about the remote lab. idea.

	• personal involvement for students low because the equipment is remote from them
	• group interaction was not as effective as for classroom practicals
	• visualisation problems using remote equipment and video cameras
	• controlling the apparatus indirectly with a user interface creates problems for students
	• the level of conceptual learning from a remote lab. will be less
	• the level of skills learning from a remote lab. will be less
	• the support documentation was difficult to follow
	• the experimental apparatus appears to be too complicated/high tech.
	• the available experiments appear to be too complicated

THANKS FOR YOUR PARTICIPATION

6.2 – Full Student Survey Data

General Note

In the following statistical analysis of students' survey responses, frequencies and percentage frequencies of responses are indicated.
In the percentage frequency column, percentage frequencies for the results of the late 2010 student trials in NSW are retained, in order to cross-correlate with the Western Australia data. This approach appears to bear relevance and interest, as indicated in section 4A (where a comparison between the two data sets is, usually, fruitfully made).
Where relevant, the most common choice for each survey item, for each of the WA and the NSW trial are indicated in boldface type, to distinguish them.

Number of respondents (*n*) = 27

Item 1
27 responses
Please describe your pre-existing understanding, if any, of remote labs or remote control of equipment.

nil response	**18**	**67%** ***(67%)***
responses expressing vague or limited general awareness	3	11% *(11%)*
remote-controlled equipment in general	2	7% *(8%)*
remote-controlled cars, aeroplanes, toys	2	7% *(4%)*
generally important in modern-day technology	1	4% *(1%)*
operating processes in situations dangerous for people	1	4% *(r%)*
NSW only responses		
controlling scientific equipment	0	0% *(2%)*
present in modern household appliances	0	0% *(1%)*
online computer games	0	0% *(1%)*
controlling CCTV cameras	0	0% *(1%)*
used in any robotic devices	0	0% *(1%)*
TV remotes	0	0% *(1%)*
learning via satellite	0	0% *(1%)*

Item 2

27 responses

If you know any other examples of where equipment or a process is controlled remotely (RC in table below), *please write them down.*

nil response	**10**	**37%** ***(39%)***
handling dangerous goods; handling bombs	4	15% *(5%)*
performing medical procedures	3	11% *(7%)*
mining and engineering applications	3	11% *(0%)*
controlling spacecraft, space probes and rovers	2	7% *(9%)*
controlling drone aircraft	2	7% *(5%)*
controlling RC cars and toys	2	7% *(7%)*
in rescue and recovery operations	1	4% *(0%)*
NSW only responses		
operating TV/AV remote control devices	0	0% *(6%)*
robots and probes in general	0	0% *(6%)*
directing and controlling satellites	0	0% *(5%)*
operating RC doors	0	0% *(2%)*
controlling deep sea probes	0	0% *(1%)*
RC electronics	0	0% *(1%)*
operating nuclear facilities	0	0% *(1%)*
in household appliances	0	0% *(1%)*
control of CCTV cameras	0	0% *(1%)*
control of large equipment		0% *(1%)*

Item 3
27 responses

The supporting notes (background material, experiments and teaching/learning notes) were

3.1	very easy to follow	3	11% *(27%)*
3.2	mostly easy to follow	8	29% ***(46%)***
3.3	adequate	**11**	**40%** *(23%)*
3.4	often difficult to follow	4	15% *(4%)*
3.5	very difficult to follow	1	4% *(0%)*

Please explain your choice.

no reason given	1	4% *(15%)*
POSTIVE REASONS		
good detail and clear format are helpful	**3**	**11%** *(8%)*
easy to follow/interpret/understand	2	7% ***(18%)***
clear and concise	2	7% *(13%)*
language level is appropriate	2	7% *(5%)*
clear explanations and/or good, helpful detail	1	4% ***(18%)***
easy to use because experimental apparatus is so easy to operate	0	0% *(6%)*
diagrams provided are helpful and complement concise instructions	0	0% *(4%)*
NEGATIVE REASONS		
sometimes unclear (text or diagrams or instructions or questions)	**8**	**29%** *(2%)*
instructions are detailed but explanations of why are lacking	6	22% *(2%)*
notes difficult to follow – involve too much assumed knowledge	1	4% *(1%)*
adequate but could be improved	1	4% *(1%)*
language level is too difficult	0	0% ***(4%)***
excessive amount of text to read and interpret	0	0% *(2%)*
the teacher would need to provide assistance and supplement the guides	0	0% *(1%)*
excessively detailed	0	0% *(1%)*

Item 4

27 responses

The support material offers a choice of 5 experiments. A choice of experiments to do is

4.1	a very bad idea	1	4% *(0%)*
4.2	a bad idea	0	0% *(1%)*
4.3	okay	5	18% *(14%)*
4.4	a good idea	**13**	**48% *(44%)***
4.5	a very good idea	8	29% *(41%)*

Please explain your choice.

no explanation given	2	***(24%)***
caters for students' learning needs/required levels of understanding	8	***(14%)***
allows for greater flexibility of student learning	5	*(11%)*
is more motivating/interesting/appealing for students	3	*(12%)*
provides greater student autonomy/self-tailoring of learning	2	*(5%)*
allows the apparatus to provide greater learning possibilities	2	*(5%)*
widens students' understanding	1	*(5%)*
choice is always important in learning	1	*(5%)*
allows for extension work	0	*(5%)*
allows for wider learning	0	*(4%)*
can generate a greater sense of fun in using the apparatus	0	*(4%)*
the level of challenge in the learning can vary	0	*(4%)*
relationships between concepts can be easier to learn	0	*(2%)*
helps students to understand the apparatus thoroughly	0	*(1%)*
allows the promotion of better understanding	0	*(1%)*
choice is only good if well-guided by notes and students are clear on what needs to be done and how	3	*(0%)*

Item 5

27 responses

During class experiments, you often follow a written Method to set up equipment; then you do the prac. The online experiment is already basically set up for you. Therefore, the online experiment is:

5.1	much better	2	7% *(16%)*
5.2	better	**12**	**44%** ***(27%)***
5.3	about the same	8	29% ***(28%)***
5.4	worse	4	15% *(28%)*
5.5	much worse	1	4% *(0%)*

Item 6

27 responses

Team-work is an important part of practical work.
You get to learn/practice/apply working in a team. Compared to the type of team-work in a normal class prac. session, the team-work in doing the remote lab. is

6.1	much more intense; much more effective	0	0% *(1%)*
6.2	much intense; more effective	6	22% *(14%)*
6.3	about the same	**12**	**44%** *(31%)*
6.4	less intense; less effective	7	26% ***(47%)***
6.5	much less intense; much less effective	2	7% *(7%)*

Item 7

27 responses

Please give an overall rating of your remote lab. experience.

7.1	a lot of fun	7	26% *(11%)*
7.2	reasonable fun	**10**	**37%** ***(53%)***
7.3	I feel neutral	9	33% *(32%)*
7.4	not pleasant	1	4% *(5%)*
7.5	very unpleasant	0	*(0%)*

Please explain your choice.

27 respondents, 2 non-respondents

(Neutral or negative reasons for choice of one of 7.1 to 7.5 are indicated below in *italics*.)

no reason given	2	7% ***(7%)***
data collection is efficient and effective	**4**	**15%** ***(1%)***
novelty and/or variety	3	11% ***(16%)***
interest level high, engaging	3	11% ***(13%)***
less fun, less motivating, less engaging than hands-on experimentation	2	7% ***(21%)***
use of quality technology is exciting, motivating and/or effective	2	7% ***(15%)***
has pros and cons compared to hands-on experimentation	2	7% ***(2%)***
results obtained are reliable/effective/stimulating	2	7% ***(2%)***
camera view is not ideal and causes operational/motivational issues	2	7% ***(2%)***
less effective for learning than hands-on practical work	1	4% ***(5%)***
no actual physical engagement with apparatus; low level of interactivity	1	4% ***(4%)***
easy to access and operate/use	1	4% ***(4%)***
the experience felt realistic/authentic	1	4% ***(3%)***
high level of interactivity	1	4% ***(1%)***
a good alternative method for learning using practical experience	0	0% *(6%)*
independent learning and pacing possible	0	0% ***(1%)***
there is less social interaction than with hands-on experiments	0	0% ***(1%)***

Item 8

85 responses

Usually, learning more about a concept is an important goal of practical work.
In doing the remote lab., you

8A	learnt a lot	7	26% *(35%)*
8B	learnt a little bit	**12**	**43%** ***(59%)***
8C	didn't learn anything	8	30% *(6%)*

If you chose (A) or (B), please write down some ideas that you think you learnt.

19 respondents

no response	1	5% *(12%)*
identified a relevant concepts or concepts related to the apparatus or a specific experiment	**13**	**68%** *(83%)*
how theory and practice/experiment inter-relate	3	16% *(5%)*
the concept of robotic control of procedures, in general	1	5% *(0%)*
not sure about what was learned	1	5% *(0%)*

If you chose (C), please tell us why you think it was not a successful learning experience.

8 respondents

no response	0	0% *(20%)*
I did not understand much about what was meant to be happening	**7**	**87%** *(20%)*
too little detail provided to allow me to understand	1	13% *(0%)*
did not extend pre-existing knowledge and understanding	0	0% *(20%)*
I did not engage very actively with the apparatus	0	0% *(20%)*
this was not hands-on practical work	0	0% *(20%)*

Item 9

27 responses

Usually, practical work involves learning new skills + practising/applying skills.
By doing the remote lab. you:

9A	learnt/applied several skills	6	22% *(16%)*
9B	learnt/applied a few skills	**15**	**55%** ***(67%)***
9C	learnt/applied no skills	6	22% *(16%)*

If you chose (A) or (B), please write down some skills that you think you learnt/practised/applied.
13 respondents, some with multiple content

no response	0	0% *(12%)*
manipulation of data; data analysis	**11**	**46%** *(16%)*
graphical interpretation; graphical analysis	3	13% ***(28%)***
linking practical experiences to a concept or concepts	3	13% *(0%)*
specific IT skill(s); IT skills in general	2	8% *(20%)*
skills in interacting with technology	2	8% *(3%)*
control of variables in experiments, scientific method	1	4% *(5%)*
experimental design	1	4% *(3%)*
reading a range of gauges	1	4% *(0%)*
use of Microsoft Excel, especially for charting	0	0% *(10%)*
applying procedures and carrying out experimental sequences	0	0% *(2%)*
construction of line graphs	0	0% *(1%)*

If you chose (C), please tell us why you think it didn't help you with your skills development.
14 respondents, 1 with multiple content

no response	0	7%
no practical skills involved; no new practical skills involved	3	27%
not a hands-on practical experience	2	20%
involved just button-pressing, mouse-clicking	1	13%
the experience was not engaging, motivating	1	7%
did not extend pre-existing skills set	0	20%
apparatus was pre-constructed and practical experience was pre-specified	0	7%

Item 10

27 responses

The remote lab. that my team did was

10.1	much too difficult for us	1	4% *(0%)*
10.2	much too difficult for us	3	11% *(13%)*
10.3	about the right level of difficulty	**12**	**44% *(48%)***
10.4	too easy for us	8	30% *(26%)*
10.5	much too easy for us	3	11% *(13%)*

Item 11

27 responses

How relevant was the remote lab. you did to the learning goals of the current Science course you are doing?

11.1	very relevant and useful	3	11% *(9%)*
11.2	relevant and useful	**9**	**33% *(52%)***
11.3	I'm not sure	8	30% *(21%)*
11.4	not very relevant; not useful	6	22% *(17%)*
11.5	irrelevant; useless	1	4% *(1%)*

Item 12

27 responses

Suppose that online experiments could be a normal part of classroom learning for your class/teacher. You would:

12.1	be very keen to do more	4	15% *(22%)*
12.2	feel okay about doing more	**9**	**33% *(45%)***
12.3	not care either way	8	30% (*15%)*
12.4	rather not do more	4	15% *(13%)*
12.5	be opposed to doing more	2	8% *(5%)*

Item 13

27 responses

Suppose that online experiments became one of the ways that your class did its learning.
How often would you like to be given a remote lab. to do?

13.1	never	1	4% *(4%)*
13.2	1 per term	7	26% *(32%)*
13.3	3 per term	**9**	**33% *(35%)***
13.4	1 per week	3	11% *(22%)*
13.5	as often as possible	7	26% *(7%)*

Items 14-20 *are propositions which were responded to on a 5-degree scale:*
27 responses

Item	Proposition	*Agree strongly*	*Agree*	*Neutral*	*Disagree*	*Disagree strongly*	*Don't know*
14	*The remote lab. gave me results from a real experiment, not just from a simulation*	**11** 41% ***(48%)***	**11** **41%** *(34%)*	3 11% *(16%)*	1 4% *(1%)*	1 4% *(0%)*	0 0 % *(0%)*
15	*Having the camera view was important for us to see the results as we controlled the apparatus*	9 33% *(33%)*	**11** **41% *(46%)***	4 15% *(14%)*	1 4% *(6%)*	2 7% *(0%)*	0 0% *(1%)*
16	*I trust the data that we measured.*	8 30% *(29%)*	**11** **41% *(40%)***	6 22% *(22%)*	2 7% *(6%)*	0 0% *(1%)*	0 0% *(1%)*
17	*I prefer remote labs to hands-on labs.*	0 0% *(1%)*	5 18% *(7%)*	7 26% *(30%)*	**9** **33% *(44%)***	5 18% *(17%)*	1 4% *(1%)*
18	*I will probably visit the remote lab. again, at home, in my own time.*	3 11% *(7%)*	5 18% *(18%)*	**7** **26% *(35%)***	3 11% *(19%)*	**7** **26%** *(7%)*	2 7% *(14%)*
19	*I would have preferred to operate the equipment myself, rather than having a 'ready-to-go' experiment.*	8 30% *(15%)*	6 22% ***(45%)***	**11** **41%** *(25%)*	2 8% *(9%)*	0 0% *(5%)*	0 0% *(1%)*
20	*I felt more motivated to try things with the remote experiment than I would with normal prac. equipment.*	2 8% *(8%)*	3 11% *(15%)*	**10** **37% *(32%)***	8 30% *(25%)*	4 15% *(16%)*	0 0% *(4%)*

Items 21-24 *are characteristics common to a remote lab. and a hands-on practical experience; the quality of each characteristic was assessed to on a 5-degree scale:*
27 responses

Item	Characteristic	*remote lab. much better*	*remote lab. somewhat better*	*equally good*	*hands-on somewhat better*	*hands-on much better*	*don't know*
21	*Reliability of observations and data*	7 26% ***(42%)***	4 15% *(28%)*	**10** **37%** *(17%)*	2 8% *(8%)*	4 15% *(1%)*	0 0% *(4%)*
22	*Ease of gathering data*	8 30% ***(64%)***	7 26% *(22%)*	**8** **30%** *(11%)*	1 4% *(1%)*	3 11% *(2%)*	0 0% *(0%)*
23	*Personal involvement and motivation*	0 0% *(2%)*	3 11% *(12%)*	7 26% *(20%)*	**12** **45% *(34%)***	5 18% *(32%)*	0 0% *(0%)*
24	*Ease of learning new things*	1 4% *(8%)*	3 12% *(17%)*	**9** **35% *(44%)***	**9** **35%** *(15%)*	3 12% (14%)	1 4% *(2%)*

Item 25

80 choices from 27 respondents (81 possible choices)

Please tick (✓) UP TO 3 aspects that you most LIKED most about the remote lab. experience.

25.1	easy to use	14	18% *(24%)*
25.2	it was a real experiment and not a computer simulation of a real experiment	16	20% *(13%)*
25.3	we could easily repeat measurements	**17**	**21%** ***(25%)***
25.4	I know that I could go home and run the experiment again to check it	8	10% *(10%)*
25.5	it increased my knowledge the possibilities of computer control of equipment	5	6% *(5%)*
25.6	the collaboration in our group was more productive and task-focussed than normal	0	0% *(2%)*
25.7	we could follow the guidance given on the website and work fairly independently	2	3% *(8%)*
25.8	I liked using technology to do an experiment	12	15% *(8%)*
25.9	the web environment and the control panel were friendly and easy to use	6	8% *(6%)*

Item 26

71 choices from 27 respondents (81 possible choices)

Please tick (✓) UP TO 3 aspects that you DISLIKED most about the remote lab. experience.

26.1	I did not feel personally involved because the equipment was remote from me	12	17% ***(25%)***
26.2	the group interaction was not as good because we didn't need to work together as much	7	10% *(15%)*
26.3	I found it more difficult to follow what was going in because I couldn't see first-hand	13	18% *(11%)*
26.4	controlling the apparatus indirectly with the interface was confusing/difficult for me	4	6% *(4%)*
26.5	I learnt less than I would from a direct, hands-on experiment	**18**	**25%** *(16%)*
26.6	the experiment did not give the results that I expected	0	0% *(3%)*
26.7	I couldn't see properly from the video cams what was going on	13	18% (*21%)*
26.8	we found the online support and guidance difficult to follow	2	3% *(2%)*
26.9	the experiment that we did was too difficult and complicated	2	3% *(2%)*