

A Blended Learning Approach to Laboratory Preparation

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Abstract

Students who are well prepared for laboratory classes are more likely to successfully acquire laboratory skills and gain the maximum possible benefit from the laboratory learning environment. To facilitate effective student preparation and improve their learning outcomes, we have designed and developed an online resource centre. These resources are used by students in conjunction with traditional resources including the laboratory manual prior to attendance in laboratories. Resources comprise a series of web based activities including visual and audio presentations, pre-laboratory questions and quizzes related to the laboratory activities that the students will complete. To determine how effective these resources were in facilitating laboratory preparation, students were surveyed both before and after the introduction of the resources. Surveys were designed to establish student perceptions regarding their preparatory practices. In addition, the effect on some measurable learning outcomes was established. This paper reports on how the implementation of this blended learning approach has improved the nature of student preparation practices. Presenting information in a flexible learning format, prior to participation, enhanced student familiarisation with theoretical and experimental procedures. Thus facilitated preparation reduced the potential risk of cognitive dissonance by improving student organisational abilities which in turn lead to better experimental learning outcomes and value-added student perception of the laboratory experience as a whole.

Introduction

There is widespread agreement that appropriate pre-laboratory preparation is beneficial to students as it facilitates their learning and understanding (O'Brien & Cameron, 2008; Jones & Edwards, 2008; Chittleborough, Treagust, & Mocerino, 2007; Johnstone & Al-Shuaili, 2001). There is also evidence that, the ability of students to adequately be prepared both conceptually and procedurally is of critical importance for any long term benefit to be obtained from practical laboratory sessions (Rollnick, Zwane, Staskun, Lotz, & Green, 2001). However, the high cognitive load of laboratory work, where both theoretical and practical tasks require simultaneous attention risks overwhelming the students working memory capacity and limit their capacity to actively construct knowledge and sense-making (Schmid & Yeung, 2005). This cognitive dissonance tends to result in students focusing purely on the immediate technical skill as a coping mechanism and thus failing to correlate laboratory experience with theoretical frameworks that would otherwise facilitate the development of deeper learning (Llorens-Molina, 2008; Winberg & Berg, 2007; Johnstone & Al-Shuaili, 2001). In addition to comprehension, the restrictions to working memory are likely to also impact on student thinking abilities, attitudes and confidence (Reid, 2009).

Effective pre-laboratory preparation contributes to improvements in prerequisite knowledge leading to a more contextualised learning environment in the laboratory (Llorens-Molina, 2008; Winberg & Berg, 2007). Various methodologies have been used to help students to

prepare in advance for laboratories including but not limited to pre-laboratory exercises in chemistry and biochemistry courses (Chittleborough *et al*, 2007; Pogacnik & Cigic, 2006; Schmid & Yeung, 2005), prelaboratory instructions and assignments on the web in an engineering undergraduate course (Powell, Anderson, Van Der Spiegel, & Pope, 2002), computer-simulated pre-laboratorys for a first year chemistry course (O'Brien & Cameron, 2008; Winberg & Berg, 2007), pre-laboratory multimedia presentations of dissection procedures in biology practical classes (Jones & Edwards, 2010), the concepts, tools and techniques questioning (CTTQ) method in physics (Huntula, Sharma, Johnston, & Chitaree, 2011) or combinations thereof (Limniou & Whitehead, 2010; Peteroy-Kelly, 2010; Saleh, 2008; McKelvy, 2000). However, Johnstone and Al-Shuaili (2001) caution that the development of pre-laboratory resources must be as thoughtfully developed as the laboratory itself and whilst it may be presented in different mechanisms it must be engaging to students and ensure their active participation in the process.

Previous findings suggest that the use of a blended learning approach to laboratory preparation can facilitate a more scaffolded experience. This in turn enables a more productive laboratory experience (Rollnick *et al*, 2001). The use of online resources to complement traditional laboratory preparatory methodologies is not necessarily new. Kempa and Palmer (1974) reported that the use of video demonstrations coupled with simple written instructions enhanced student laboratory practices. However, in recent years, with the advent of integrative technologies, science educators have reported that the capacity to support effective laboratory preparation can be more readily implemented allowing students to prepare in their own space and time resulting in a greater capacity to address pedagogical learning diversity (Patterson, 2010; Jones & Edwards, 2010; Di Trapani & Gregory, 2009; Chittleborough *et al*, 2007; McKelvy, 2000).

Flexible offering of pre-laboratory preparation can also effect capacity to provide real time feedback and enhance learning outcomes. The capacity to implement formative assessment of student comprehension by means of online quizzes provide opportunity for students to receive immediate feedback on their demonstrable comprehension of theoretical, mathematical, procedural and safety-related laboratory elements (Limnio & Whitehead, 2010; Di Trapani & Gregory, 2009; Chittleborough *et al*, 2007). These types of resources also facilitate the development of appropriate visualisation techniques (Saleh, 2008) that have been shown to improve learning outcomes in laboratory assessment of knowledge and report writing (Peteroy-Kelly, 2010) and for time management and competency standards (Caprette, 2005). In addition, Wyatt (2003) reported that student perceptions indicated that these types of activities did enhance their capacity and academic outcomes and that satisfaction with this provision for learning was equally important as actual skill development, although he was unable to directly link these to measurable learning outcomes.

Our experience in teaching undergraduate and postgraduate laboratory courses in the last ten years indicates better learning outcomes from students who are well prepared for laboratories. Our approach to pre-laboratory preparation is represented by the development of the Biotechniques Pre-laboratory Online Resource Centre (BPORC). This site provides a suite of activities whose development has been guided by the literature. The resources are presented in a blended learning context designed to complement existing resources, such as the laboratory manual and text book. These activities provide a more scaffolded, preparatory experience that facilitates student laboratory preparation prior to participation in experimental procedures. BPORC also allows students to prepare for laboratories in their own time and space and to chunk small pieces of applicable knowledge initially. This contributes to

student capacity to master the associated laboratory practices by enabling them to reduce the demands on and limitations of working memory (Reid, 2009) that could otherwise lead to cognitive overload during experimental time (Johnstone, 1999). When combined, these resources help to improve the overall potential quality of the laboratory learning experience (McKelvy, 2000).

Purpose of study

In this paper we report on the effectiveness of the implementation of BPORC to support the pre-laboratory preparation of students engaged in a series of biochemical practical exercises. Specifically this study questions whether the use of pre-laboratory activities led to improved perceptions of preparedness for laboratory classes. It also seeks to identify whether potential links between the utilisation of facilitated pre-laboratory preparation and experimental learning outcomes can be made. Data from two consecutive offerings of the BPORC, 2010 and 2011, are presented in this paper. This study elaborates on previous findings presented in abstract form at the Australian Conference for Science and Mathematics Education 2011 (Gregory & Di Trapani, 2011).

Methodology

The Biotechniques Pre-laboratory Online Resource Centre (BPORC) was implemented as a compulsory but non-assessable component of the Biotechniques laboratory course.

Institutional context

Biotechniques laboratory is a year long (two semesters) laboratory course, offered to second year science students within the School of Biomolecular and Physical Science at Griffith University. This laboratory course introduces students to basic, practical skills and competencies in experimental techniques commonly used across the biological sciences and not previously experienced. It is taught independently of lecture courses and is based on a full “hands-on” approach, with students exposed individually to a variety of practical exercises derived from selected disciplines within the biological science arena, including biochemistry and microbiology among others. Progress through the course is competency based and students are not graded but receive a non-graded pass or a fail grade for each practical exercise and for the course overall (Di Trapani & Clarke, 2012). In this study we are reporting the implementation of BPORC and related findings to only one of the two components of the course, Biotechniques laboratory-Semester 1 (2013BPS-Y1).

Participants

Three different groups of second year science students enrolled in 2009, 2010 and 2011 were included in this study. Students who are enrolled in 2013BPS-Y1 have limited relevant laboratory experience in the Biosciences area, since their first university courses do not have a laboratory component, except for two introductory Chemistry courses and an introductory Cell Biology course. In 2013BPS-Y1, students are allocated to 4 hours laboratory per week, with each student attending two, 2-hour laboratory sessions on consecutive days of the week, over a 9 week time period in Semester 1 of their second university year.

BPORC

BPORC comprised of a variety of different components relative to each of the laboratory sessions in 2013BPS-Y1 course. In total six different practical exercises derived from the biochemistry and microbiology disciplines were complemented by the online resources. These resources included photographs and diagrams of equipment utilised and their key

elements tagged in a simple but procedurally referenced format; video files showing how to perform key procedures supported by verbal descriptions of these techniques (eg how to streak a bacterial plate, how to calibrate a pH meter); links related to similar on-line laboratory activities; examples of data analysis and interpretation of experimental data similar to those students would need to complete in laboratory classes on their own experimental data; pre-laboratory questions covering the experimental design, methods and sequence of steps utilised during an experimental procedure, the use of equipment, laboratory safety aspects, and the theory underlying the practical techniques applied during the laboratory exercises.

Before attending a laboratory session, students were required to use the online resources specific to the practical exercises offered in that session and to complete an online pre-laboratory quiz by the previous evening. The quiz comprised of four questions in various formats choices available in the Blackboard[®] quiz tool (for examples, multiple choice, fill-in-the-blank, matching, to mention some). The number of attempts possible was unlimited but students were required to gain 100% success on each quiz in order to gain entry to the laboratory. In 2011, minor alterations in photographic and video resources were made. In addition, alterations to the presentation of the pre-laboratory quizzes also occurred. A pool of alternative questions was developed for each question type on a single quiz. When a quiz was generated the sequence of the questions was randomised as was each question selected from the individual pools. Therefore, each time a student attempted a quiz they were offered different questions, of a similar type, in a different order. This varied significantly from the 2010 pre-laboratory quizzes when a single set of non-randomised questions was utilised.

Study design and data collection

Evaluation questionnaires were used to determine the effectiveness of BPORC. Students' participation was voluntary and anonymous. An amended version of the survey tool developed by Jones and Edwards (2010) was used to prepare two surveys, pre-BPORC survey and post-BPORC survey, which were given to students before and after the introduction of the online resources respectively. Both surveys used close-ended questions to seek student perceptions of their level of preparedness for laboratory sessions and how elements of BPORC contributed to these perceptions (Table 1). The responses were on a five-point Likert rating scale from Strongly Agree (5) through Strongly Disagree (1). Open ended questions were also used in post-BPORC survey to encourage students to comment on the beneficial features of the online resources. The pre-BPORC survey was conducted in the first week of laboratory sessions prior to students being introduced to BPORC. In 2010 (n=117), there were 82 respondents which represented 70% of the cohort. In 2011 (n=122), there were 24 respondents which represented 20% of the cohort. The post-BPORC survey was conducted in the final week of the laboratory course. In 2010, there were 78 respondents which represented 67% of the cohort. In 2011, there were 46 respondents which represented 38% of the cohort.

Table 1: Pre- and Post-BPORC survey questions

Pre-BPORC survey	Corresponding Results
Previously, how much preparation would you usually complete before attending a laboratory session? a) online b) other (reading manual, calculations etc) 0-30min, 30-60min, 60-120min, 120-240min	Figure 1
I feel prepared for the laboratory practical classes	Figure 6A
Post-BPORC survey	
How much preparation do you usually complete before attending each Biotechniques Laboratory session? a) online b) other (reading manual, calculations etc) 0-30min, 30-60min, 60-120min, 120-240min	Figure 1
I have found the following aspects of the pre-lab resource helpful: a) pictures of what equipment I will use b) videos of how to perform various laboratory techniques c) pre-lab quizzes d) examples of how to analyse experimental data	Figure 2
The pre-lab resources: a) helped me to develop my laboratory planning skills* b) helped me to manage my time more efficiently during lab**	Figure 3
I feel that the online pre-lab questions and resources have helped me to be more effectively prepared for laboratory classes	Figure 5
I feel prepared for the laboratory practical classes	Figure 6A
In comparison with other laboratory classes I have attended (in other subjects), the online pre-lab resources helped with my level of preparation prior to attending lab	Figure 6B

*Planning skills are organisational skills required to facilitate completion of experimental procedures, including mathematical computations, theoretical parameters and equipment manipulations.

**Ability to complete experimental tasks appropriately within allocated time frame.

Anonymous student reflections regarding the implementation of BPORC and its contribution to their overall learning in this course were collected from the Griffith University Student Evaluation of Course (SEC).

Verbal feedback and written reflections from teaching staff were also collected and presented in this study.

Influence of BPORC on technical skills

Student records of successful streaking of bacterial cells before and after the introduction of BPORC were also analysed to determine potential effects on achieving learning outcomes. Student results from a microbial practical exercise were collected over three offerings of the course before (2009, n=105), and after the introduction of BPORC (2010, n=98 and 2011, n=105). This exercise involved the successful isolation of three bacterial strains, *E.coli*, *S.aureas* and *S.marcescans*, using the 16-streak technique. The data is expressed as mean

(%value) of first attempt passes at the streaking technique plus SD for each group of students and analysed using a one way analysis of variance (ANOVA) followed by the Tukey's multiple comparison test to determine which specific groups were significantly different from each other (p value <0.05). Data was analysed using GraphPad Prism (Version 5).

Results and Discussion

Evaluation of the effect of BPORC on student preparation time

Figure 1 shows the 2011 student cohort responses to the question investigating the average amount of time they spent preparing for laboratory classes before and after the use of BPORC. In particular pre-BPORC survey captures what students had experienced in other courses without BPORC, whereas the post-BPORC survey captures the students experience in the course with BPORC. This preparation involved both online perusal (of freely available resources on the web for pre-BPORC survey and those specifically provided within the BPORC for the post-BPORC survey), review of the laboratory manual and discussions with other students.

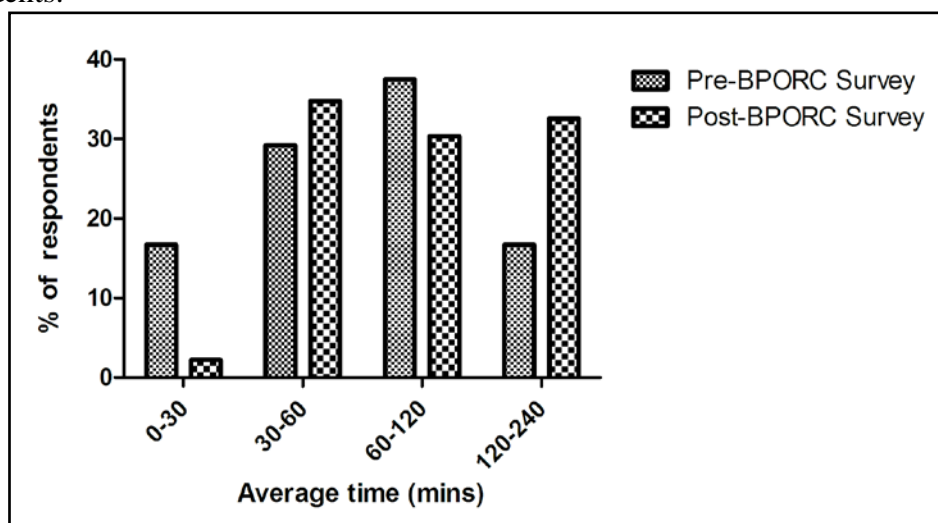


Figure 1: Average amount of time students spent preparing for laboratory classes before (Pre-BPORC survey) and after their use of the BPORC (Post-BPORC survey).

Responses in the pre-BPORC survey indicated that approximately 67% of respondents spent between 30 and 120 minutes on preparation without the availability of BPORC. A further 16.5% spent less than half an hour and the remaining 16.5% spent more than 120 minutes on preparation utilising a combination of resources. After completing all six practical exercises supported by the BPORC, 65% of respondents still spent between 30 and 120 minutes in pre-laboratory preparation. Only 2% of respondents indicated spending less than 30 minutes and a further 33% indicated that they spent more than 120 minutes on a combination of preparatory activities including the BPORC requirements.

These results indicate that although there was a shift being observed from those spending less than half an hour to this proportion spending more than 2 hours, the utilisation of the BPORC did not significantly alter the amount of time most of the students spent in preparation for practical exercises since the majority of the students spent between 30-120 minutes in preparation for laboratory with or without the BPORC. Evidence would suggest that the time spent preparing was a result of scaffolded preparation and that students were spending both a more appropriate and directed level of preparation. Specifically students were required to

actively participate in utilising the BPORC resources including videos and completing an online pre-laboratory quiz. This was in addition to other preparatory behaviours such as reading the laboratory manual. Discourse with students indicates that whilst considerable time was spent online in attempted preparation prior to the implementation of the BPORC that this time was not necessarily spent in effective and relative activities. Verbal feedback also suggested that those students spending more than two hours in preparation were those with either an English Second Language or weaker mathematical background.

Evaluation of student perceptions of the individual components of BPORC

In the post-BPORC survey, students were asked to reflect on how helpful were individual elements of the BPORC for laboratory classes (Table 1). The analysis of the responses obtained from both 2010 and 2011 students' cohorts is shown in Figure 2.

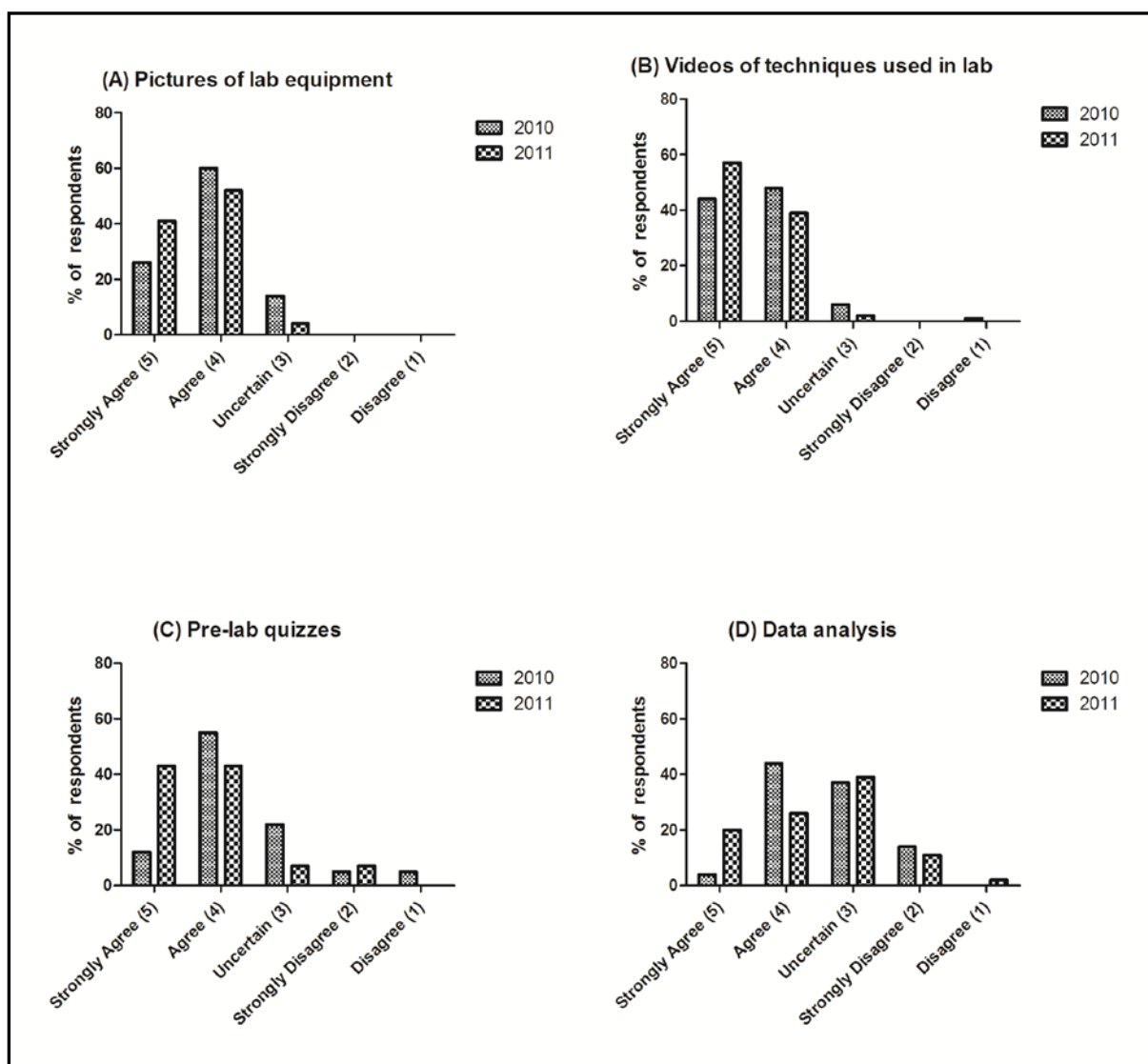


Figure 2: Students' responses to the question evaluating their perceptions on how helpful individual components of the BPORC were in assisting their preparation for laboratory classes (post-BPORC survey). The responses are on a 5-point Likert rating scale from (5) Strongly Agree through to (1) Strongly Disagree. Data was collected for 2010 and 2011 cohorts.

As shown in Figure 2, the majority of the respondents in both cohorts found that key components of the BPORC online resources such as pictures of laboratory equipment (Figure 2A), videos highlighting key areas of experimental techniques (Figure 2B) and pre-laboratory quizzes (Figure 2C) were highly helpful (rated as 5 and 4) as pre-laboratory tools. These positive findings are supported by students' written comments such as:

the online resources are fantastic! They really help heaps since I'm a visual & auditory learner and it suits me really well; I like the online section of this course, it helped me to visualise what I would perform in the lab but it also gave me something to refer to when preparing for the lab; the videos on the learning@griffith website really helped me understand what I had to do; the prelab questions helped enforce my understanding before the experiment.

In 2011, minor improvements were made to some of the online photographic and video resources providing a slight increase in the degree of positive influence (from 4 to 5 point of the Likert scale) students perceived (Fig 2A, B). In particular, the improvements made to the Pre-laboratory quizzes were shown to be very beneficial to student preparation. There was an increase in the overall percentage of positive (rated as 5 and 4) student responses (67% in 2010 to 86% in 2011) with 43% rating the pre-laboratory quiz a 5 in 2011 when compared with only 12% in 2010. Also a positive change in the rating of students finding the data analysis resources to be helpful was observed as seen in Figure 2D. In this case, whilst the overall positive response (rated as 5 and 4) is similar for both 2010 and 2011 there is an increase from 4% of 2010 respondents' to 20% of respondents in 2011 indicating they strongly agree (5) that the data analysis resources were helpful.

Overall the data analysis presented in Figure 2 indicates that the combination of visual instructions (video, photographic, and animated accompanied by key textual reference) proved to be very helpful in students' preparation. This is not surprising given recent reports on how potentially a large fraction of any given cohort have a propensity to visual/aural learning styles not well supported by the traditional paper-based laboratory manual (Patterson, 2010). That the resources could be reviewed multiple times, videos could be paused and rewound for complex components also facilitated student comprehension of complex theoretical and physical components of experiments. This enabled students to prepare in an environment that was less likely to lead to cognitive overload. This flexibility has previously been reported to be beneficial to student learning in other sub-disciplines (Limniou & Whitehead, 2010; Saleh, 2008; Chittleborough et al, 2007; Schmid & Yeung, 2005). These findings also support those of Kempa and Ward (2005) who demonstrated that it is insufficient to merely tell students to observe experimental outcomes. If students lack the theoretical and analytical frameworks behind experimental process it will prove difficult for them to identify how to look or where to look and consequently their observations may be inaccurate. Kirschner, Sweller and Clark (2006) also reverse this notion that guided instruction can lead to a much richer and deeper learning experience in the laboratory.

Evaluation of the effectiveness of BPORC on generic skills

As part of the post-BPORC survey, students were asked to reflect on the impact that the BPORC had on their capacity to plan ahead and manage time efficiently during practical exercises. In these particular laboratory sessions students are expected to successfully complete a series of experimental tasks within a designated time frame. Their capacity to achieve this learning outcome is one component of the marking criteria for each experiment. This is quite different to traditional laboratories where more than sufficient time is provided

for experimental completion with penalty for incompleteness being loss of grade rather than failure for not demonstrating competency in laboratory time management.

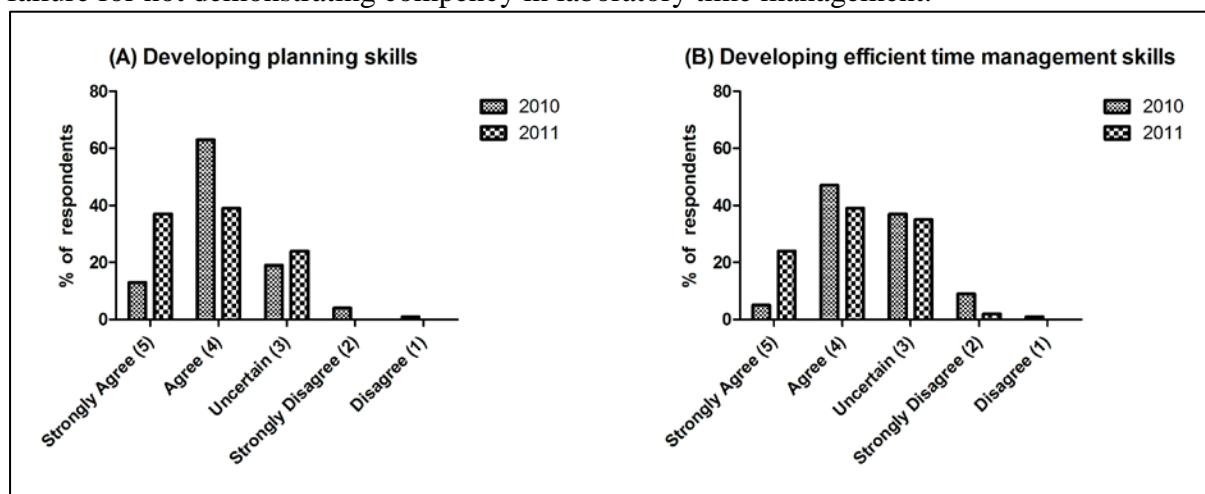


Figure 3: Students' responses to the question evaluating their perceptions on how helpful the components of the BPORC were in developing pre-laboratory planning skills and time management skills during practical exercises (post-BPORC survey). The responses were on a 5-point Likert rating scale from (5) Strongly Agree through to (1) Strongly Disagree. Survey responses were collected for both 2010 and 2011 cohorts.

As shown in Fig 3A, approximately 76% of the respondents (rated as 5 and 4) of both 2010 and 2011 cohorts found the BPORC was helping them developing planning skills in preparation for laboratory sessions. It was also interesting to observe that 37% of the 2011 responding cohort strongly agreed (rated as 5) that the BPORC tool was effective in promoting the development of their planning skills compared to the 13% of the 2010 cohort. When students were asked to comment on how they perceived the effect of BPORC on their development of efficient time management during the laboratory sessions (Figure 3B), 37% of respondents in 2010 and 35% in 2011 indicated that they were uncertain as to what extent this generic skill was supported. However, an increase in the overall positive perception respondents had of the BPORC activities was seen with 52% in 2010 and 63% in 2011 responding either a 5 or 4. In addition, a shift in the percentage of responding students indicating they strongly agreed (5), was also noted with an increase from 5% in 2010 up to 24% in 2011. This positive response is furthermore supported by student comments such as

I love the pre-labs...They are very helpful, especially the videos. It shows clearly what we have to do, and showing it in the video saves time in the labs. So, we have more time to do the experiment; prelab work helps with understanding the labs. I would have had difficulty finishing labs on time without it; the mandatory prelab quizzes and activities ensured that...we were able to think of effective ways to complete the tasks within the limited time allocated.

Verbal feedback from experienced demonstrators also supports these statements commenting that students appear to be more organised and to more efficiently manage the time they spend on the practical exercises leading to successfully completing tasks in the allocated time.

From these student perceptions we can conclude that the BPORC was able to improve planning skills. This is most likely as a direct result of providing a more scaffolded approach to preparation and thus planning of experimental processes, particularly in allowing

flexibility and diversity to this process (Patterson 2010; Jones & Edwards, 2010; Obrien & Cameron, 2008). It is not unexpected that approximately one third of students indicated that they were uncertain as to how much the BPORC resources had contributed to their efficacy in time management. This result may be more indicative of the variability of student skills acquisition. Student ability to effectively manage experimental time during laboratory exercises is a complex skill that is not solely dependent on the type, amount or depth of preparation a student engages in. It also involves experimental competencies (Caprette *et al*, 2005), learning styles (Patterson, 2010) and previous laboratory experiences (Di Trapani & Clarke, 2012) among other factors.

Evaluation of the effectiveness of BPORC on measurable learning outcomes

To determine whether the BPORC resources were capable of influencing measurable learning outcomes the ability of students to successfully complete a 16 streak technique and isolate individual type of bacteria from a mixed culture of three different bacterial strains on their first attempt was measured over three offerings of the laboratory course.

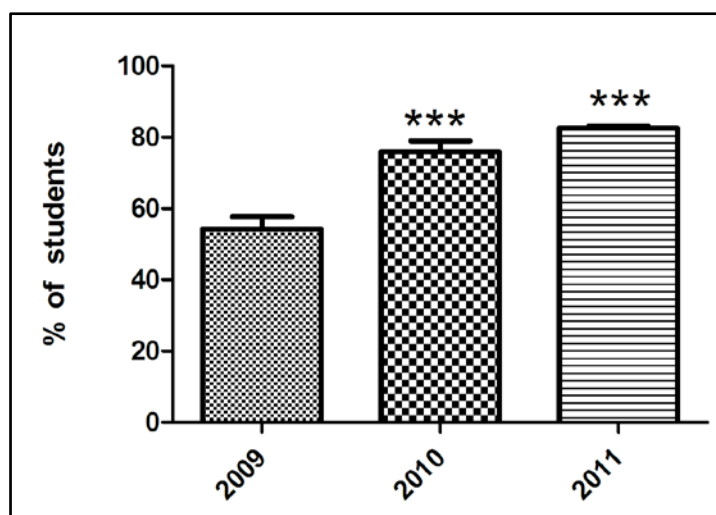


Figure 4: Ability of students to successfully perform a 16-streak technique on their first attempt. Comparison between student capacity to achieve this specific learning outcome over three offerings of the course show a significant difference ($p < 0.0001$) using a one-way ANOVA analysis followed by a post hoc Tukey's Multiple Comparison test. *** represents a statistically significant difference between the 2009 ($n=105$) cohort and the 2010 ($n=98$) and 2011 ($n=105$) cohorts ($P < 0.05$). No difference was determined between the 2010 and 2011 cohorts.

The number of students to successfully complete a 16-streak technique on their first attempt for three independent bacterial strains over three offerings of the course can be seen in Figure 4. Students in the 2009 cohort did not have access to the BPORC resources for pre-laboratory preparation, whereas both 2010 and 2011 cohorts had the same resources provided. When no additional pre-laboratory resources were utilised by the 2009 students' cohort only 54% of the students were able to complete this experiment successfully at their first attempt. In 2010 and 2011 when the same experimental process was followed but the BPORC resources were available to each cohort, this number increased to 76% and 83% respectively. These results suggest that the ability of students to successfully achieve this specific learning outcome is significantly improved as a result of the implementation of BPORC.

Traditionally the microbiology experiments in this course require a certain element of learning through repetitive physical manipulations to achieve appropriate learning outcomes (Di Trapani & Clarke, 2012). However, we have shown that the implementation of photographic illustrations and minimal explanatory text that demonstrate common technical errors has been able to improve assessable learning outcomes of the experimental processes. The inclusion of these troubleshooting resources as part of the BPORC significantly altered the number of students capable of succeeding on a first attempt at the 16 streak technique with three different bacterial strains. In addition the same positive outcome was reproducible since it was obtained over multiple cohorts. Other groups have also reported improvements in measurable learning outcomes primarily related to report writing capacity and post quiz results (Peteroy-Kelly, 2010; Saleh, 2008) when blended pre-laboratory resources were utilised. Our results support enhanced learning outcomes for competency-based practical sessions.

The evidence suggests that more efficient pre-laboratory preparation can enhance the ability of students to demonstrate desirable learning outcomes. When combined we observe that students thus perceive that the preparative activities they were involved with were effective in facilitating their learning in the laboratory environment. These findings support those of Rollnick *et al* (2001) and Peteroy-Kelly (2010) who suggest that the level of preparedness is important in ensuring that students ascertain the underlying meaning of each experiment and thus gain the maximum benefit of this active learning environment.

Evaluation of the influence of BPORC on effective pre-laboratory preparation

When students were asked to comment on whether the BPORC helped to effectively prepare for practical exercises in the laboratory, 81% (2010) and 91% (2011) of the respondents (rated as 5 and 4) felt that they had a positive influence (Figure 5).

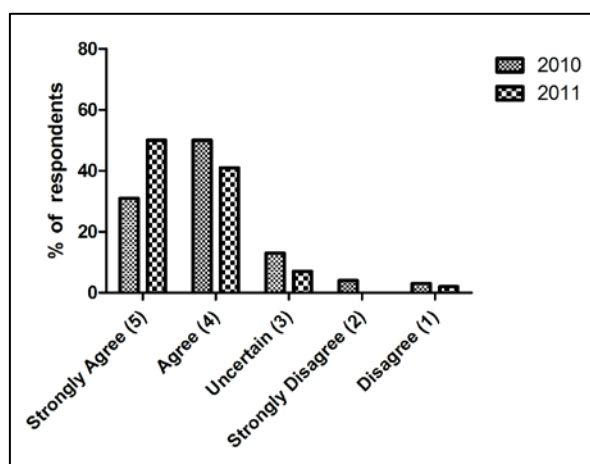


Figure 5: Student perceptions of the influence of BPORC on the effectiveness of their laboratory preparation. The responses are on a 5-point Likert rating scale from (5) Strongly Agree through to (1) Strongly Disagree. Data was collected for 2010 and 2011 cohorts.

It is interesting to note that whilst the average amount of time the majority of students spent in preparation for practical exercises did not alter particularly (Figure 1), students indicated that the effectiveness of their preparation was greatly enhanced by the use of the BPORC resources. This suggests that the provision of a scaffolded framework for appropriate preparatory practices can reduce cognitive dissonance during laboratory time thus freeing up

working memory and enabling a deeper level of comprehension and correlation of theory with practice and is in accordance with other literature reports (Jones & Edwards, 2010; O'Brien & Cameron, 2008; Kirschner, Sweller, & Clark, 2006; Schmid & Yeung, 2005; Johnstone & Al-Shuaili, 2001).

Experienced laboratory demonstrators have also commented that “*I felt students came better prepared for class*”; “*I spent more time helping students resolve complex issues rather than trivialities*” and “*I felt students were more confident and less stressed.*” Combined these findings indicate enhanced student capacity to be more prepared for laboratory classes and to be able to plan and manage experimental time more effectively. The value students place on the benefits of using online pre-laboratory preparation has been previously reported with chemistry students who find improved organisational skills, better comprehension of theoretical concepts and general preparedness for laboratory (Chittleborough *et al*, 2007).

Overall student perceptions of how prepared they felt prior to attempting practical laboratory exercises

Students were asked to reflect on how prepared they felt with respect to laboratory classes both before and after the implementation of BPORC.

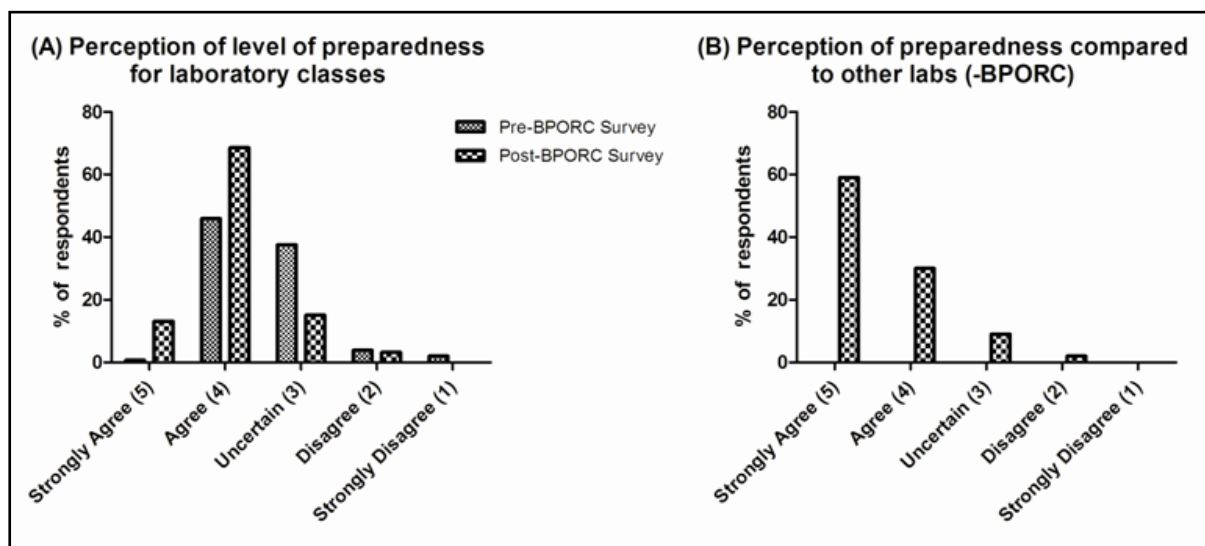


Figure 6: Student perceptions of how prepared they felt prior to attending laboratory classes after utilising the BPORC and how this differed to their preparation in other laboratory courses. Data analysis of survey responses collected from the 2011 student cohort.

Pre-BPORC survey results in Figure 6A indicated that prior to the introduction of the BPORC, 47% of students (rated as 5 and 4) felt that they were appropriately prepared for experimental sessions. In addition, 38% of the respondents indicated that they neither felt prepared nor unprepared for laboratory classes. The post-BPORC survey results indicated that with the introduction of the BPORC resources there was a shift in student perception of their preparedness for laboratories. 82% of the respondents (rated as 5 and 4) positively identified themselves as feeling prepared for experimental sessions. In addition there was also a shift in the number of respondents who felt very prepared (5) from 1% (before using the BPORC) to 13% (after using the BPORC). Experienced laboratory demonstrators have also observed that students appear to suffer less cognitive overload during laboratory time as a direct result of the more scaffolded approach to laboratory preparation students engaged in:

“students come with notes and questions allowing for a richer learning experience and resulting in deeper learning of course materials.” Other research groups have also reported the value that students place on this type of flexible learning environment and how it contributes to their overall feeling of being prepared to attempt practical exercises (Limniou & Whitehead, 2010; Chittleborough *et al*, 2007).

When asked to reflect on how their experience utilising the BPORC was different to the preparatory activities they had engaged with in previous laboratory courses, the majority of the respondents (89%, rated as 5 and 4) agreed that they felt more prepared for the laboratory classes supported by the BPORC in comparison to other laboratory classes without the BPORC (Figure 6B). This reflection can be attributed to several factors. The BPORC provide better equity opportunities for students by ensuring that the majority of learning styles are facilitated (Patterson, 2011; Jones & Edwards, 2010). In addition, students were not required to absorb this information at the beginning of each laboratory session in the combination of auditory, visual and written forms. Instead they were able to self-pace their review of materials and demonstrate their acquisition of key knowledge related to the practicals they were to participate in. Students felt that the use of a blended learning strategy successfully enhance their laboratory experiences when used in addition to traditional preparatory methods (Jones & Edwards, 2010; Limniou & Whitehead, 2010; Saleh, 2008; Chittleborough *et al*, 2007).

Conclusions

This study has characterised the effectiveness of the Biotechniques Pre-laboratory Online Resource Centre with respect to both student perceptions of the level of laboratory preparedness and with some specific learning outcomes. The combination of visual components (video demonstrations, photographic illustration, and animations supported with written textual references), theoretical background information, data analysis methodology and online pre-laboratory quizzes that provide instantaneous feedback complement previous literary findings from other discipline areas. The BPORC has been shown to successfully improve the capacity of second year students to prepare more effectively for laboratory classes. It has also been shown to have a positive impact on the capacity of students to achieve desirable learning outcomes in microbiology practicals.

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