

Research Article

Molecular Biology Masterclasses – Developing Practical Skills and Building Links with Higher Education in Years 12/13Paul Hooley¹, Phillippa Cooper² and Nick Skidmore¹¹*School of Applied Sciences, University of Wolverhampton*, ²*Highfields Science Specialist School, Wolverhampton*.

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Abstract

A one day practical course in molecular biology skills suitable for year 12/13 students is described. Colleagues from partner schools and colleges were trained by university staff in basic techniques and then collaborated in the design of a course suitable for their own students. Participants carried out a transformation of E.coli cells with a plasmid and cut lambda virus DNA with restriction enzymes for display via agarose gel electrophoresis. Practical demonstrations of the polymerase chain reaction (PCR) and fermentation technology were also given. An evaluation of year 12/13 student responses revealed considerable enthusiasm for the activities.

Keywords: DNA technology, outreach, post-16 education**Introduction**

There is renewed interest in the UK and elsewhere in school/university partnerships that ease the transition to higher education and raise aspirations amongst groups previously under-represented at university. In many families with parents or carers who themselves did not attend university, there is little or no direct experience of higher education to inform a younger generation (HEFCE, 2007). Masterclass activities that challenge school/college students with visits to higher educational institutions are one method of improving subject knowledge and developing transferable skills. Such schemes can also enhance the university participants' teaching skills and motivation too (Todd and Murphy, 2003; Tomanek, 2005). Some programmes, particularly in the USA, have evolved into elaborate long term commitments over several years that incorporate a considerable degree of laboratory work (e.g. Niemann *et al.*, 2004; Dolan and Tanner, 2005). However, in the absence of significant funding, it can appear daunting to set up such school/university links and unfocussed campus visits can be seen as irrelevant by the participants (Aim Higher, 2006).

Responding to the demand from local teachers for updating in molecular techniques that were appearing in Advanced level and equivalent curricula some 10 years ago, we set up a two day training course for teachers. Typically two university staff taught 6–10 teachers in an informal and stimulating atmosphere.

The latter part of the course was a challenge to the teachers to adapt the practicals to a level useful for their year 12/13 students that would be directly relevant to their own curricula. It was recognised that whilst some procedures were too technically challenging or dangerous to carry out in school, there was scope for trained teachers, together with university staff, to deliver practical sessions in the university laboratories. This would have the dual attraction of providing a training in technical skills coupled to an introduction to the university as part of a mission to widen access. The title "Molecular Biology Masterclasses" was chosen to arouse the students' curiosity. Here we explain the structure of the class for years 12/13 and analyse an evaluation of students' feedback.

Course Structure

The initial two-day course for teachers was based around a series of first and second year undergraduate molecular biology practicals delivered by university staff. These were designed to update staff on developments since the majority of them had concluded their own degrees, often many years previously.

Table 1 Example syllabus units relevant to molecular biology from the three main examination boards in operation in the West Midlands

Specification	Examination board	Module
Current (to 2007)	AQA: Specification A	AS Module 2 Genetic Engineering
	AQA: Specification B	AS Module 2 Genes and Genetic Engineering
	Edexcel: 9040	A2 Unit 6104 Microbial Culture and Measurement A2 Unit 6105 Further Gene Transfer
	OCR: 3881/7881	AS Foundation : Genetic Control of Protein Structure and Function A2 Microbiology and Biotechnology (optional module)
New (from Sept. 2008)	AQA: 2410 [link]	A2 module 5 Control in Cells and Organisms
	Edexcel: 8B101/9B101 and the Salters-Nuffield Advanced Biology Project [link]	AS Unit 1 Lifestyle, Transport, Genes and Health A2 Unit 4 The Natural Environment and Species Survival A2 Unit 5 Energy, Exercise and Coordination
	OCR: H021/H421 [link]	A2 Unit F215 Control, Genomes and Environment: Module 2 Biotechnology (now mandatory)

The training course concluded with a final session where school/college staff produced a blueprint for a course suitable for their own year 12/13 students by mapping activities to the relevant Advanced level curricula. Table 1 illustrates the relevant syllabus components common to a variety of Advanced level and equivalent courses used by local schools and colleges.

Table 2 Example One Day Programme

Time	Activity	Activity
09.30	Arrive at University Main reception	Introduction to the course. Health and Safety issues.
10.00	Demonstration of general techniques	Basic definitions, volumes, use of micro pipettes
10.15	<i>E. coli</i> transformation mix <i>E. coli</i> with plasmid DNA, incubate on ice for 60 mins	Restriction Digests
10.30		Mix λ virus DNA , water, buffer, enzymes, incubate at 37°C for 60 mins
11.30	Add Luria broth, incubate at 37°C for expression of plasmid genes	
11.45		Stop digests, load agarose gels
12.00	Plate out transformed cells, aseptic technique	
12.15	Lunch	Agarose gels run
13.30	Talks and demonstrations – PCR, fermentation	Gels stained and photographed by university staff
14.30	Data analysis - example transformation plates set up previous day viewed	Data analysis - gel photos viewed.

It was emphasised that the majority of schools would be unable to provide the release of students and staff for more than one day – consequently the ideal activities would be packed into one day. Students would need an initial introduction to laboratory safety as well as the key jargon used for equipment and reagents. Molecular protocols are notorious for requiring lengthy incubation stages so more than one experiment was planned together with demonstrations of techniques either too lengthy or dangerous for students to perform directly. Table 2 illustrates an example programme and Appendix 1 and Appendix 2 give detailed protocols used in handouts to students and laboratory requisitions respectively.

Following an introductory revision session on DNA, the A level students' course centred around two main experimental activities. Firstly it was considered essential that students learn to handle live cells so a standard disabled non pathogenic *E. coli* strain was chosen to demonstrate the uptake of naked DNA from outside the cell – the process of transformation. This would also allow the teaching of basic sterile technique. Most groups could not afford to attend the university for a second day to view overnight bacterial growth, so demonstration plates of previously prepared cells would be provided. A plasmid vector giving two clear selectable markers for transformation (ampicillin resistance and blue colour derived from the IPTG induced lacZ/Xgal system) was chosen. For the second activity the students would learn how to use restriction enzymes by cutting a viral DNA molecule then running the samples on agarose gels. Each group prepared digests of lambda DNA using two different enzymes, EcoRI and HindIII – additionally each group were given previously prepared samples to load alongside their own preparations giving guaranteed results on each gel. By setting up gels at the end of the morning, sufficient time was then allowed for electrophoresis to run over the lunch break.

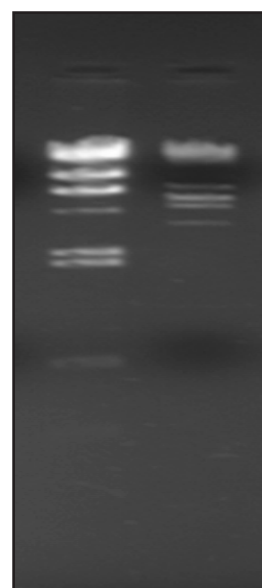


Figure 1 An example of student work showing an agarose gel with bacteriophage λ DNA cut with HindIII (left) and EcoRI (right)

The best methods for visualising DNA on gels involve staining with a carcinogen (ethidium bromide) followed by viewing with ultra violet light at the wavelength (254 nm) maximally absorbed by DNA, and so implicated in skin cancer. University technical staff could carry out these latter stages safely whilst the students performed each step up to the staining stage. Technical staff would stain and prepare gels for visualisation whilst the students attended demonstrations of fermentation techniques and the polymerase chain reaction. The final session would then comprise analysis of the gel photographs (Fig. 1) together with plate counts of transformed bacteria set up the previous day.

Table 3 Example feedback scores for individual activities. Students were asked to score on a subjective scale: 1 poor, 2 OK, 3 good, 4 very good, 5 excellent. Scores are given as means \pm standard error solely to indicate the variation in responses ($n=115$). Ranges are given for the highest and lowest mean values from individual school/college groups. Results of students from five different schools/colleges taught in five separate classes in January 2008 are presented. Group sizes varied from 11 to 56 with evaluation returns of between 68% and 100%

Introductory Talk	Transformation Experiment	Restriction Digest Experiment	Fermentation Demonstration	PCR Demonstration	Overall
3.62 \pm 0.09	3.91 \pm 0.09	3.89 \pm 0.09	3.41 \pm 0.10	4.05 \pm 0.09	3.94 \pm 0.08
4.5–3.1	4.6–3.4	4.6–3.5	3.7–3.0	4.5–3.7	4.8–3.5

Evaluation

Students were asked to complete a short evaluation sheet in confidence before their departure which rated each activity (Table 3) and they were also encouraged to write other comments

(Table 4). Each activity was generally rated as good to very good with the clear impression that the course overall was considered to be very good.

Table 4 Examples of Student Comments from evaluation sheets

- “It was interesting to do a practical at a higher level than we are used to...”
- “Fascinating, enjoyed all of the practical work.”
- “Some talks could have been clearer – sometimes too fast.”
- “It was interesting and helpful.”
- “Very good day at a university of my choice.”
- “The experiments were really interesting but the process was slightly unclear.”
- “A lot of information packed into one day.”
- “Never done anything like this before – very interesting.”
- “Everything was fantastic – a good day out.”
- “Very eye opening.”
- “Need more information on courses to do with biology.”
- “Nice to be able to see Wolves university”

Written statements were relatively few in number with the commonest comment relating to the recognition of the acquisition of a new skill for measuring small volumes using micro-pipettes.

Discussion

The curriculum in post -16 education is very crowded and staff can only justify activities that are directly linked to their teaching objectives. In order to fit in with university staff and laboratory teaching commitments, the masterclasses avoid the major undergraduate modules and are offered at three times in the year — September, January/February (intersemester) and June/July. This can create problems for matching the ideal curriculum stage to the practical experience. So far the winter slot has been the most popular as it allows the completion of AQA outcomes related to molecular biology within the requisite year 12 period. With the new specifications in place from September 2008, the majority of the relevant work will be at A2 level which will probably increase the demand for June/July delivery as an introduction to year 13 (Table 1). It is interesting that references to molecular biology seem to occur to an even greater extent in the new curricula which are designed to reduce assessment loads, ensure reliability and fairness and to help young people maximise their potential.

A recent Aim Higher report (2006) was critical of some masterclasses in HE where the material was pitched at too high a level and perhaps delivered by university staff who were inexperienced in teaching younger students. The groups described in the present paper included two conventional school sixth forms, two specialist 6th form colleges and one sixth form/FE provider. One specific group was responsible for four of the lowest mean scores for the six ratings and a second group consistently gave the highest mean scores shown in the range values in Table 3. It is difficult to claim any significance or identify a single cause for this variation. Groups varied in total size from 11 to 56 students, some travelled independently to the university, others as a group on school/college transport. Participants may have reached different stages in their curricula and so perhaps had differing expectations of the day. Nonetheless there is an indication of the robust nature of the work as (with the exception of the PCR and fermentation demonstrations delivered each time by the same university staff) the rest of the activities were taught by the different school/college staff. The written comments (Table 4) and informal conversations with staff do indicate though that a minority of students were still struggling with the level and amount of work presented. The molecular biology masterclasses now operate with a typical aggregate of around 250 year 12/13 students annually from 8–10 local schools and colleges. Generally the same group of participants on the initial teacher training course are represented by these institutions with a close relationship being built between colleagues

over several years. The enthusiastic support of these colleagues from schools and colleges reflects an understanding that they are best placed to judge where curriculum enhancements are needed (Tomanek, 2005), reinforcing their role in the original masterclass design (Table 1). This more equal partnership, where the university takes on a mentoring role, seems to be a common indicator of the sustainability of a school/university relationship (Moreno, 2005).

A further series of school/college based activities have been based on the one day class including the construction of a calibration curve relating the molecular mass of DNA to distance travelled together with mathematical transformations to make such a calibration more accurate. These exercises could be performed directly upon the students' own gel photos also (Figure 1). Individual groups have also made their own DNA preparations in school/ college prior to the visit, (for example from kiwi fruit) which they can bring to the class and load on the gels for visualisation. Demonstration activities can vary – one group for example regularly incorporates a visit to the scanning electron microscope (SEM) whilst the gels are staining. This single group of 30 students rated the SEM visit on the same scale as given in Table 3 at 4.2 ± 0.19 (mean \pm s.e.). In some cases the masterclass is preceded or followed by a visiting lecture from the university staff. For most students it is a novelty to set up and run two separate experiments in one session and this demanded some preparation beforehand on the part of the school/ college teaching staff. Depending upon the overall group size, students worked in pairs, threes or sometimes fours. This did allow for some division of labour when the timings of activities on the two experiments overlapped. Teaching staff took care however to ensure that each student had direct experience of each technical procedure.

Students choose their university course based strongly upon their enjoyment of a subject often reinforced by a visit to the institution (Scott, 2006). In this context a masterclass could provide a useful support for recruitment. In the present model no attempt was made to directly market any course literature. Nonetheless some student responses (Table 4) and questions to staff clearly indicated a growing interest in university life. There seems to be a widespread recognition of the importance of the development of school / university links to raise participation in HE in the UK (HEFCE, 2007). Nonetheless there is only limited evidence that “one off” activities raise attainment or aspirations. It is essential that universities provide ongoing support which give opportunities for personal contact with both staff and the university environment (Aim Higher, 2006). To this end the masterclass was effectively provided free by the university with schools/colleges covering the cost of transport and photocopying although in one case Aim Higher funding was made available. We propose that the masterclass model outlined here represents a modest, effective and inexpensive means to develop outreach activities into true partnerships (Dolan and Tanner, 2005) that genuinely benefit both institutions.

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