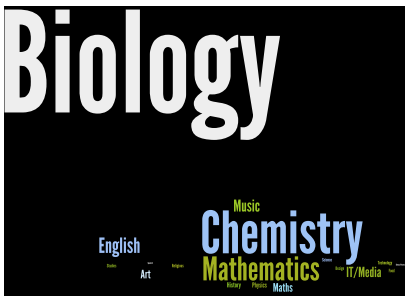
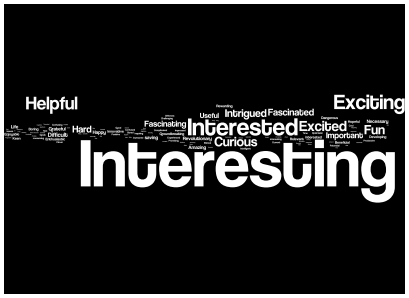
Virtual Lab Evaluation

October 2011





EXECUTIVE SUMMARY

Introduction

Virtual Lab is an online biomedical research platform developed – by the Public Engagement, Media & Grants (PEMG) Facility at the MRC Clinical Sciences Centre – to offer schools authentic experiences of how science works. A rolling programme of experiments is conducted through the website with guidance from senior MRC-funded research scientists. Each experiment is tailored A-level and/or GCSE curriculum science. Students simply register online and start doing experiments.

To test the platform and explore the best way to engage schools, two pilot experiments investigating cell division and stem cell biology were conducted with nine London schools throughout 2010 and 2011. An internal evaluation was conducted by the Virtual Lab co-ordinator (Emma Newall) and PEMG Facility Head (Brona McVittie) to assess the degree to which project objectives were met.

Platform

Students participate in research through an online platform – www.virtuallab.co.uk. There are 3 stages to each experiment: background (what you need to know to take part); training (how to appraise and/or score visual data); final experiment (submission of quantitative, qualitative and/or multiple-choice inputs from users, who score a minimum of 6 research slides – with or without controls – selected at random from the experiment database). The ideal use of the platform is to get students to analyse real unpublished research data in real time. Pilot experiments used real research data, but not in real time, owing to logistical difficulties including the timing of the experiment, and the fact that not all data rendered by research scientists can be easily understood by 14-19 year-old students. Some processing of data was required to render them in a meaningful way.

Delivery

Pilot experiments were delivered by the Virtual Lab co-ordinator, who worked 2 days a week on the science, experiment design, website, schools liaison and support, ambassador training, workshop scheduling and evaluation. The first experiment took 20 days to develop and was delivered over a 6-month period. The second experiment took 40 days to develop; additional teaching resources were created; lab-work had to be conducted and the ambassador scheme developed. The experiment ran for 6 months.

Findings and experience

Students

Questionnaires indicated that most of the participating students enjoyed and understood the experiment. Younger students were the most likely to have problems understanding and interpreting the data. Criticisms mainly encompassed the repetitive nature of the activity and the fact that it was not hands-on – inherent characteristics of an online activity that replicates the real research process. The text-based nature of the experiment may also contribute to this view and there was evidence that some students were not engaging with all the content.

Some students struggled with the ambiguity of the data. School students have little or no access to authentic research data and classroom practicals can give the impression that science has all the answers and that data is clear-cut. An objective of Virtual Lab was to expose students to authentic research and the uncertain, tentative nature of research findings. Some students also were frustrated by the lack of post experiment feedback and would have liked more information on the research context of the experiment and how the findings might be used.

Technical issues that the students reported mainly focused on the fact that it is not possible to go back a page once they start the experiment. This is as a result of the design and data management. Student data cannot be overwritten during an experiment, although repeat experiments can improve on their scores.

Teachers

All the teachers appreciated the opportunity for their students to take part in the project, and would be happy to take part in future experiments. They also said that they would recommend it to colleagues. Their motivation for taking part in the pilot was to both to challenge their students and expose them to real science. The most effective aspects of the experiment were access to real data and the potential to support and enrich curriculum topics. Teachers saw meeting scientists as a positive and important experience for students highlighting that careers in science go beyond medicine.

In agreement with students, they thought the stem cells experiment too difficult for some younger students. Apprenticeship did not fully prepare students and some students failed to understand the link between apprenticeship and the final experiment. The online tasks didn't fully support engagement with social/ethical issues. The experiment was not perceived as particularly helpful to student's university applications and was not regarded as equivalent to lab experience. However post-experiment feedback and dialogue with the scientist would be beneficial to student's personal statement and UCAS applications. Teachers also felt that students were not convinced of the authenticity of the research and this affected engagement.

Scientists

All the participating scientists were highly supportive of public engagement with science and saw the project as an opportunity to develop their communication skills and encourage school students to be interested in science and engage with scientific issues. All the scientists had a positive experience overall and would be willing to participate future workshops, although they would appreciate further guidance regarding the expected knowledge and understanding of the age group of students they visit.

The scientists felt that the students enjoyed the experience and for the most part understood their task however echoing the feedback from teachers and students the scientists did not think that the students appreciated the real nature of the data and the experiment. This has emerged as a dominant theme in the project evaluation.

The ambassador Handbook and Toolkit were seen as helpful and supportive of their role in the project, although more comprehensive guidance regarding timings would have been helpful to the scientists. The ability to use a ready-made resource was perceived as particularly useful and helped busy scientists get the most out of visiting a school without taking up too much of their time.

Impacts

Virtual Lab had a number of positive impacts:

- Student interest in science was rated before and after Virtual Lab intervention. A shift in 'somewhat interested' (31.3 % before to 24.5% after) and 'interested' (26% before to 31.4% after) suggests the intervention succeeded in generating greater enthusiasm for science among participants
- In a recent follow-up email campaign some students commented that the Virtual Lab experience had affected their career choices: Lauren Tough (St Robert of Newminster School, Year 11) said "*Virtual Lab was brilliant! It gave me an insight into ideas surrounding the sciences that I had not encountered before, and provoked me to read further into the subjects. I am applying to*

medicine for 2012 entry and Virtual Lab made me even more certain that the sciences is where my passion lies. Not only was it educational, it was fun, and enjoying what you learn is, in my eyes, even more important."

- The resource has been used all over the globe by students from Kosovo, Egypt, Pakistan, Australia, Brunei, Botswana, Saudi Arabia, the Gambia, Nigeria and Somalia as well as the UK and USA, clearly demonstrating that with a focused marketing and communications plan, the resource has much greater potential impact than initially conceived

Conclusions and recommendations

Platform

By far the greatest challenge to Virtual Lab exists in the tension between experiment 'design' and 'data'. The ultimate goal is to get students to analyse authentic biomedical research data in real time. Scientists don't necessarily render data that, in their raw form, can be appreciated by students. Yet processing of data – to make it more intelligible to school audiences – reduces experiment authenticity. Timing is another factor that impacts on the possibilities of realizing an experiment in real time, scientists' schedules not necessarily falling in line with school calendars. However, students need to feel they are doing the study with the scientist. Additionally (although this has not been experienced), scientists may not wish to disclose unpublished data.

- **Future experiments should maximise the possibility of engaging students in a real time investigation with actual research data** – the challenge then becomes to find the scientists whose research data could be delivered raw to school audiences
- **School audiences need to be engaged in the experiment throughout** (a more 'hands-'on' feel) **with effective follow-up**. Schools could be final data to analyse post-experiment, introducing an element of competition. Students need more of a sense of ownership

While the web-platform is user-friendly and facilitates the engagement of schools in biomedical research, the feedback suggests that some of its functionality could be improved by further development. Additionally, since every experiment is unique and may require different features, any running budget going forward should factor in an annual development cost.

- **Training could be provided for co-ordinators** to support their effective delivery of experiments, or administration of the website should be centrally controlled by a web-master
- **Students need clearer sign-posting throughout experiment** – the apprenticeship should be more closely related to the final experiment; a summary slide could emphasise key points to remember; video backstory could be provided instead of slides

Co-ordination

Both pilot experiments were conducted in different ways. The first, rather than intervention through ambassador-led workshops, was supported by co-ordinator-led workshops in schools. In either case, the workshops have proved an important means to encouraging students to complete the activity. Co-ordination was a challenge on 2-days/week, although after the experiment was launched this was sometimes surplus to requirement.

- **Development could be scheduled on a more intensive basis** (perhaps with a minimum of 3 days/week to keep up momentum)
- An average of 30 days (co-ordinator time) should be allowed to plan an experiment in association with the lead scientist, including time to develop teaching resources, recruit schools, train ambassadors

- Once the experiment is launched co-ordination may only require 1-2 days per week (especially if a web-master is employed in the maintenance of the online resource)
- **More time should be given to digital marketing strategies** in future to increase the number of unsolicited users completing online experiments. Virtual Lab clearly selects for highly-motivated users

Public engagement

Ambassador-led workshops provided an opportunity for MRC scientists to gain experience in public engagement. Workshops made students do the online experiments, but also supported enrichment around the subject, insofar as they were able to appreciate the scientific method; discover that scientists are normal people; and consider science is a career option. While the ambassador scheme didn't appear to impact on the accuracy of users, this outreach initiative was clearly perceived as valuable to scientists and schools.

- **Ambassadorship is not essential to the success of Virtual Lab** (measured by user accuracy), **but adds value** and where possible should be supported
- Training and/or support for ambassadors should be provided where possible
- Ambassadors could engage with schools after they've completed the online activity, with more focus on social/ethical implications around the research theme
- More concise supporting literature (Handbook) should be provided with a tighter workshop plan

CONTENTS

1.1) Introduction

The MRC Clinical Sciences Centre (CSC) based on the Hammersmith campus of Imperial College London was established in 1994 by the MRC to focus on both basic science research and the translation of research developments into improved clinical diagnosis and treatment. It is the aim of the MRC CSC to enhance public interest, understanding and trust in science. The Public Engagement, Media & Grants Facility at the CSC harnesses the work of MRC scientists and the broader biomedical research community to stimulate an interest in biomedical science among the general public.

The team has administered a number of outreach projects tailored to school audiences. Most recently, Virtual Lab – an online biomedical research platform – was developed to offer schools authentic experiences of how science works. The website provides an ideal means to explore effective ways to engage secondary school students in contemporary biomedical experiments. Virtual Lab has the potential to tackle the decline in student uptake of post-16 school science, and the cost-effective model could be extended across research communities.

It is increasingly difficult for schools to offer meaningful and interesting practical activities. Expensive equipment and reagents and a high level of technical expertise keeps lab research beyond the reach of school science lessons, yet experience of how science works has the potential to excite student interest. The Virtual Lab framework supports bridge-building between research centres and schools, offering students direct access to bench science online. Through the Virtual Lab pilot, students aged 14 to 19 from nine London schools were invited to participate in investigations into cell division and stem cell biology conducted at CSC. Both pilot experiments were designed to support curriculum science and provide opportunities for extension and enrichment.

1.2) Aims & Objectives

Virtual Lab aims to:

- Offer young people experiences in support of University applications
- Bring contemporary research into the classroom
- Support curriculum science and develop students' data interpretation skills
- Develop students' confidence in discussing and debating scientific ideas
- Encourage critical engagement with issues in biomedical research and their impact on society

An integral aspect of the pilot projects was to involve MRC scientists, not only senior scientists whose research schools were engaged in, but also early-career researchers, who by helping students do online experiments gained experience in public engagement.

The online nature of the platform means that more students than those from invited schools participated in the pilot experiments. This demonstrates the potential to expand its reach to a national audience.

1.3) Methodology

1.4) Website

The website – www.virtuallab.co.uk - and associated resources (VL Handbook and ambassador Toolkit) were developed by the Public Engagement, Media & Grants Facility (MRC CSC) between 2009 and 2011 to provide an outreach tool for MRC and other researchers to use in engaging local schools in contemporary research.

The platform is designed to host a rolling programme of biomedical experiments. Each experiment is live for a period of months, during which time data submitted contribute to a real-life bench investigation, and possibly a research publication. Once an experiment expires, it is stored in the archive, but may still be used by schools to support curriculum science. The findings of each experiment are shared through an online notebook.

Before participating in an experiment, users complete a registration form submitting name, email, password, school, age, gender, information about subjects being taken, favourite subject, and information about how they found the website.

The online infrastructure provides 3 areas of engagement:
Back-story to research – a series of slides and explanations detailing what students/teachers need to know to understand the experiment, including the broader context and the relevance of research to society
Training – the apprenticeship stage that teaches students how to score visual data, during which immediate feedback is provided to aid learning
Experiment – the real research project during which students may compare test and control data and submit quantitative, qualitative and/or multiple-choice inputs for consideration.

Scientists can submit large or small datasets for analysis by students. The data is pooled in the back-end database. Every time a user attempts an experiment (after the apprenticeship stage), they are presented with a random sample of 6 slides (video or jpg) from the data pool. This makes each user experience unique, but it means that for large datasets, many users and/or repeats are required to ensure all data in the pool are scored/appraised. Users can repeat experiments, but they cannot go backwards during an experiment to overwrite answers.

Students were recruited to participate in pilot experiments during 2010 and 2011 by the Virtual Lab co-ordinator. A-level and GCSE science teachers were targeted through a snail mail campaign of letters and leaflets to schools, followed by phone calls and email contact with interested teachers, and visits to schools to demonstrate the resource. London schools in the boroughs of Hammersmith and Fulham, Ealing, Brent, Enfield, Camden and Barnet were invited to participate.

In addition to securing confirmed participation in this way, a modest marketing campaign promoted Virtual Lab as a freely available educational resource through the Wellcome Trust's Big Picture magazine, Science Learning Centre website, Association for Science Education: School Science website and the Biotutor and Psci-Comm email lists. Unsolicited users discovered the resource through one or more of these channels, or by chance.

To support and encourage students to do online experiments, the second pilot was facilitated by an ambassador scheme, which trained and supported twenty early-career scientists to run workshops in local schools. Students completed Virtual Lab experiments during workshops after an introduction to the science from a real-life researcher. Six MRC scientists went out into schools locally in 2011 to run workshops based on the *Very Special Cells* experiment.

1.5) Pilot

1.5.1) Investigating Cell Division: Summary

Key Stage 5 Skills

The first pilot experiment for the Virtual Lab ran from January to June 2010. A-level students from schools in the Hammersmith and Fulham borough helped CSC scientists to investigate the role of post-translational modifications in a protein complex called 'cohesin' necessary for chromosome segregation during cell division (mitosis).

Professor Luis Aragon's research team work with yeast cells to try to understand the process of cell division, which makes identical copies of cells and all the DNA inside. DNA is organised into long threads called chromosomes, which are copied and separated out equally between daughter cells.

When a chromosome is copied, two 'chromatids' are formed. They need to stay together until the cell is ready to divide. Luis and his team are trying to understand how they manage to stick together. Cohesin plays a big part in this, holding chromatids together a bit like a hairband around a plait of hair.

The cohesin ring (made up of three proteins) breaks up just at the right time for chromatids to uncouple in to separate daughter cells. The researchers want to understand whether a biochemical modification on cohesin named sumoylation (involving attachment of another protein called SUMO) plays a role in this process. They used flourescent labels on DNA so they could watch where the chromatids went during cell division, and studied cohesin mutants that cannot get sumoylated.

Students analysed images of normal and mutant (defective SUMO) cells to see what happened. Chromatids in cells where SUMO could not bind to cohesin didn't always separate (one flourescent mark was counted), whereas chromatids in cells in which SUMO was working properly (wild type cells) always separated as normal (two flourescent marks showed they had moved apart). The students concluded that SUMO does seem to be quite important for cell division:

"If SUMO was the only factor in chromatid separation 100% of the mutant cells (without SUMO) should fail to separate their chromatids. Since the scientists only got this result for 18% of cells, it appears chromatids can separate without the presence of SUMO. It may however play another, more complicated role in chromatid separation."

1.5.2) Very Special Cells: Summary

Key Stage 4 and 5 Skills

The second pilot experiment ran from November 2010 to April 2011. Students from nine schools across London helped CSC scientists explore the role of the *Ezh2* gene in stem cell development. Students analysed microscopic images of normal and mutant mouse stem cells. They had to decide whether cells were differentiating (specialising into different cell types) and give their evidence.

The research was carried out by Dr Cynthia Fisher, who works with Professors Amanda Fisher and Matthias Merkenschlager (Lymphocyte Development Group). The first stage involved a titration with a growth factor called LIF, used to culture stem cells in the lab. Students had to choose the best concentration of LIF to use in the experiment, to keep stem cells from differentiating.

Differentiating cells are difficult to distinguish visually from non-differentiating cells. Stem cells clumped in the colony (dark region to the right, above) tend not to be

differentiating, and look regular in shape. Cells that differentiate move away from the colony and change shape generating an irregular pattern of cells.

Once they selected the ideal concentration of LIF, the experiment involved comparing mutant stem cells (those without a working copy of the *Ezh2* gene: 'knockouts') with normal mouse stem cells. The cells were all cultured at the chosen concentration of growth factor, to keep conditions as similar as possible. Any difference in differentiation between the two groups could then be attributed to differences in *Ezh2*.

Students analysed slides to assess whether the *Ezh2* gene had any effect on differentiation. The consensus was that it does seem to play some role in controlling stem cell specialisation:

"It seems as if Ezh2 is involved in stem cell differentiation, because in all the slides the Ezh2 knockout cells have more differentiating cells."

Although the students noted:

"It is not likely that Ezh2 is the only factor controlling stem cell properties. Other factors could include the temperature the cells are being stored at, the concentration of stem cells or the type of stem cell."

1.5.3) Public engagement

1.5.3a) Ambassador Scheme

Two training workshops were held at the CSC to equip scientists with the skills, confidence and tools to engage students in the *Very Special Cells* experiment. Twenty scientists from CSC, NIMR (National Institute for Medical Research) and LMCB (Laboratory for Molecular Cell Biology) were trained up. Six early-career scientists, who undertook the training, agreed to visit London schools as Virtual Lab Ambassadors.

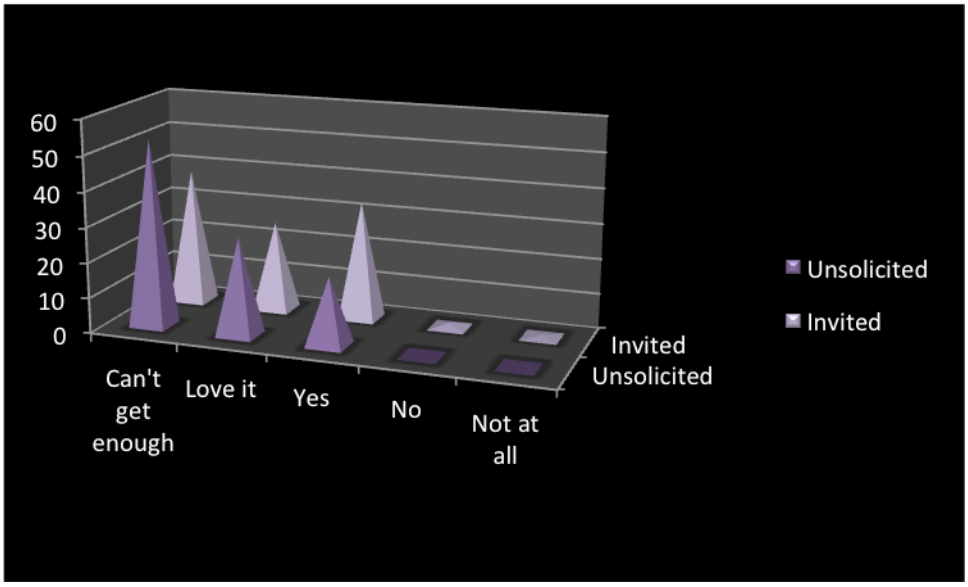
1.5.3b) Schools Workshops

Ambassadors engaged GCSE or A-level students at nine London schools (Ellen Wilkinson School for Girls, Elthorne Park High School, Esher College, Greenford High School, Latymer Grammar School, Preston Manor High School, Southgate School, Southgate Further Education College and William Morris Sixth Form College) in stem cell biology with a short presentation and a hands-on activity before students attempted experiments online. Each ambassador showed students how to (a) interpret the images of stem cells featured in the experiment and (b) to make decisions about whether stem cells were differentiating or not.

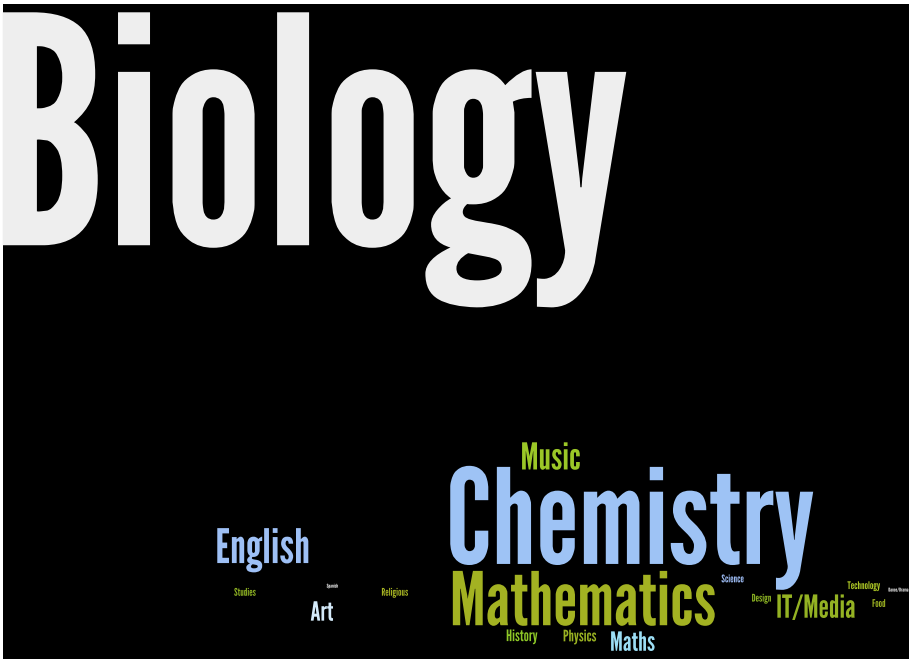
2) Participant motivations

2.1) Students

Every participant completed an online registration form prior starting the experiment, which has yielded some pre-intervention observations. In addition to name, school, age and contact, users were asked about their enthusiasm for science and about their favourite subjects. Grouping students into invited (students that completed experiments online through an ambassador-led workshop) and unsolicited (individuals and students that found the resource online) it is clear that, while all users have a high level of interest in science (proportions depicted below), those who found the website through their own motivation (while smaller in number) are slightly keener.

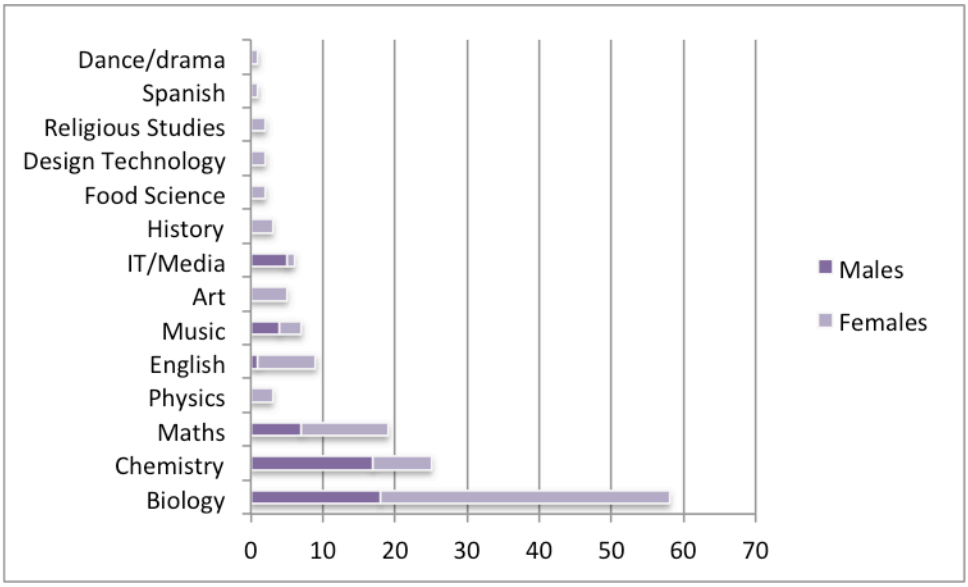


The favourite subject responses (depicted as Wordles) show Biology clearly predominates as the favourite subject among users, with perhaps a slightly greater propensity for same in the unsolicited user group, although it should be noted that this group (47 users) is much smaller than the invited group (145). Looking at favourite subjects in relation to gender, the data support the trend in male preference for scientific and technical subjects.



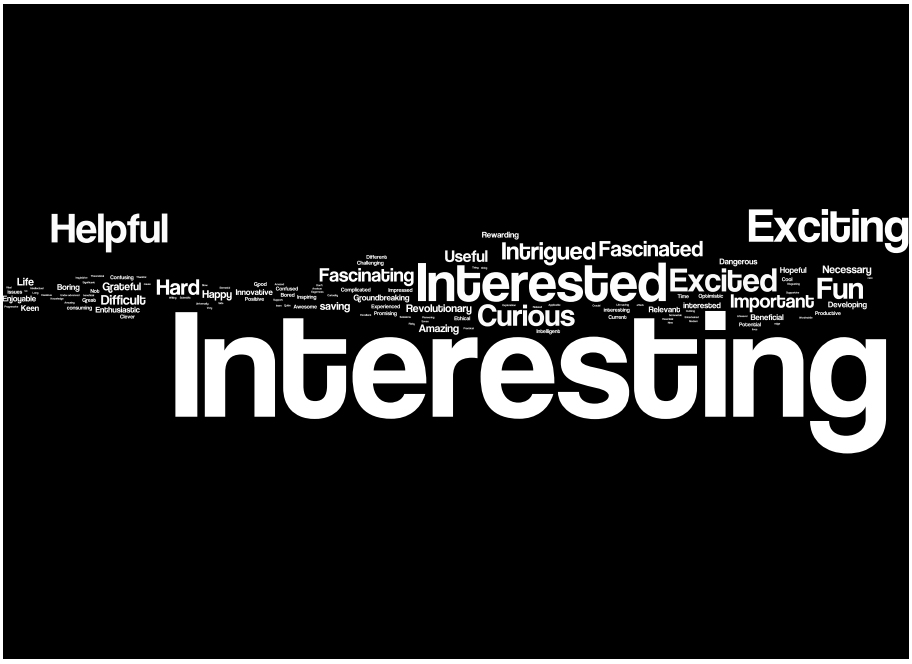
Favourite subjects of invited users (represented by Wordle, size reflecting frequency)

Favourite subjects of unsolicited users (represented by Wordle, size reflecting frequency)

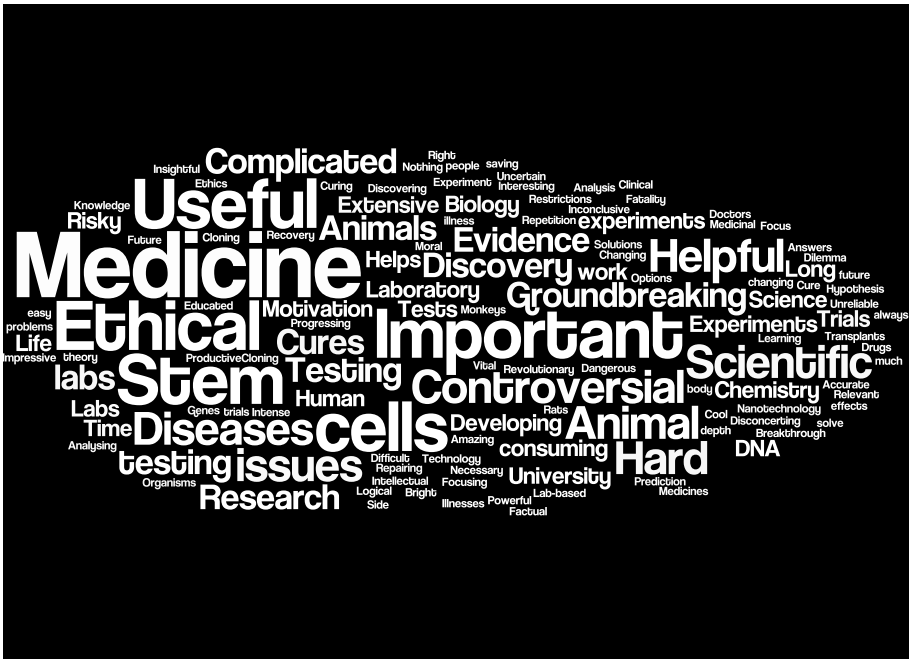


Favourite subjects of invited users reflecting gender

Invited schools represent a variety from the state sector, including a Further Education College, Sixth Form College, Grammar School, Community Schools, a single sex (girls) school and mixed sex schools. 119 questionnaires were completed by students from 8 participating school groups. Each student provided 3 words (depicted as Wordles) to explain (a) how they feel about medical research and (b) what they know about medical research.



Wordle depicting how invited users feel about medical research (size reflecting frequency)



Wordle depicting what invited users know about medical research (size reflecting frequency)

2.2) Teachers

4 teachers were interviewed (all taught both GCSE and A level Biology). Invited schools mostly experienced an ambassador-led workshop, whereby an MRC scientist had visited the school to introduce the research and support students with online experiments. Workshops were held with students in years 10 to 12. One school did not take part in a workshop but instead 50 year 10 and 11 students and the entire Biology year 12 cohort completed the online activity as an independent homework task. Most of the year 10 and 11 student participants were taking Triple Science and were top set or Gifted and Talented.

Teachers wanted to stretch and challenge able students and provide a novel experience for them. Most of their responses indicated that they saw Virtual Lab as an opportunity for their students to experience real science as opposed to school science, which is not perceived as authentic. They were interested in demonstrating the messiness and uncertainty of real science.

"My students read a text book...they would like to know what is the...world of science...It is different from the school's lab, how scientists collect results" T1

"...a lot of the experiments they do in school are very much this is an experiment to show this and they get very freaked out when they don't." T4

The teachers had limited expectations. One had expected a more traditional education activity and was pleasantly surprised. Others were expecting an activity pitched at an easier level than they experienced.

2.3) Scientist (Ambassador)

20 scientists attended public engagement training workshops as part of the pilot project. 6 visited schools as ambassadors. 3 ambassadors were interviewed. They were all MRC scientists working at CSC, LMCB or NIMR. All 3 ambassadors believe that science communication is important and that the project provided them with an opportunity to take part in an outreach activity.

" So I am very committed to science communication, um I think that it is very important...I never really had a scientist come in and speak to me (at school)*...To see what a real scientist would do and I thought this was my way to contribute to that."* A1

The participating scientists were keen to work with children and to support and encourage their interest in science. They also hoped the experience would help them develop their science communication skills. The fact that Virtual Lab involved the use of a ready-made resource was seen as positive aspect that would potentially save time.

"...a lot of the groundwork had already been done, so I wouldn't have to develop my own workshops or activities...That aspect of Virtual Lab definitely ticked all the boxes..." A1

"...The main thing I wanted to get out of it was a good experience of being able to work with kids, some of which may not have had much experience of science..." A2

3) Participant experience

3.1) Student

Based on questionnaires completed after ambassador-led workshops, the largest single response from the students was that they enjoyed the *Very Special Cells* experiment and found it interesting and informative.

"...I learnt a lot."
"Fun and enjoyable..."
"Everything it was all interesting"
"It was very inspirational"

Comments noted that the interactive nature of the activity was a positive and that the website was quick and easy to use, allowing students to explore the topic at their own pace. The experiment objective was understandable, at least to some of the students, although not many commented on this specifically. A significant number of responses indicated that it helped them understand the concepts involved, and they welcomed the information on a curriculum topic and a cutting edge aspect of science.

"You could see how stem cells really work"
"Explained it in a simple way that allowed everyone to understand easily, while being interesting"
"It was interesting and made you think about how stem cells actually worked"
"It was interesting to learn about stem cells in more depth"

One student provided evidence of deep learning, noting that for them the experiment had revealed a connection between development and genetics. They explained it provided an *"Obvious connection between experiment and gene..."*

Other comments indicated that the students appreciated the images and animation, explaining they made it more interesting and aided understanding *"...images helped me gain a better understanding."*

A small number of respondents understood that they were observing real experimental data. One respondent mentioned that they particularly liked the fact that there is no right answer and another indicated that it *"Gave me more insight into how real life experiments are done."*

A very small number responded less positively *"...wasn't very interesting"*

When asked what they didn't like – and why – a number of negative themes emerged. The most common issues that were mentioned specifically were:

- Too repetitive 14/119 students
- Not hands-on 19/119 students
- Difficult to understand 11/119 students
- Images difficult to interpret 9/119 students
- Too much text to read 15/119 students

A number of students remarked that they found the activity too repetitive.
"...it was a little monotonous"
"A bit repetitive near the end"

Although some older students understood that research requires repeated activity
"It was repetitive but research is!"

Some didn't find it engaging, expressing a lack of interest.
"... the experiment was pretty one dimensional."

The challenge for Virtual lab may be to present science as it really is – methodical – using close, repetitive observation, while also making it engaging and involving. Some students also reported that they thought the activity would be improved if they could interact with the website to a greater degree, including with the visual data.
"Wasn't very interactive"
"More interactive, physically with virtual slides."

The ability to zoom in on the microscope images was suggested as a potential means of making the activity more interactive and authentic. A number of students complained that the activity was "not hands-on".
"I like practical hands-on experiments, so if it was in real life it would have been more interesting."
"...I would have preferred to be actively involved in it"
"It could have been more hands on and less wordy..."
"I think we should have done a practical experiment ourselves"

The students from Greenford High took part in a hands-on activity looking at stem cells under the microscope in addition to the online Virtual Lab activity. Some students preferred the hands-on to the online elements.
"More active experiments for everyone to do."

Online activities by their nature are not 'hands on' although there may be ways of setting up an experiment and using the website to simulate this to some degree. Some of the respondents reported that they didn't fully understand the activity, that it was too difficult. This is very much in line with the feedback from teachers.
"Some concepts hard to understand"
"Some images hard to understand."
"It was a bit hard and sometimes the images were not clear."

Older students in general found it easier to understand than the younger year 10 and 11 students, but some found the images difficult to interpret and felt that more information on how to interpret the slides would have been helpful.
"Not very clear options when deciding whether cells were differentiated"
"More information about the control, differentiating and 'can't tell' images"
"...easier way of distinguishing between differentiating and undifferentiating cells"

Some found the idea that there is not necessarily a clear-cut answer quite challenging and were put off by the 'not sure' answer choice. A small number didn't understand or didn't read instructions or contextual information. Key points may need to be signposted in some way to ensure important information is not overlooked.

"Should tell us first about what to look out for."
"It was hard to see what was important information."

This problem may also be a consequence of the amount of text students needed to read as a large body of text can encourage skim reading. A significant number of responses criticised the amount of text in the activity.
"Reading through the slides because it was long"
"Make it more visual and simple"
"The text on the website was too long and I didn't really understand it."
"Quite a lot of info to take in at the beginning – hard to remember."

Some students expressed a desire to receive the information in other ways than through text, possibly visually.
"Video or picture animations of how the experiment takes place."
"Too much reading! It got me bored there needed to be a bit more exciting e.g. pictures, animations, better colours"

A number of students were frustrated when they didn't answer correctly according to the website's response.
"Not getting the answers right"

Some questions had ambiguous answers: more than one answer could be interpreted as correct. The website is not able to respond to this ambiguity as only one answer can be chosen as correct. The nature of real science means that sometimes it is not possible to say a particular interpretation is correct from the evidence presented. This could be explored more in the text based qualitative question.

Students suggested providing a greater number of responses to choose from when recording their own observations – this may have addressed the some of the problems students had when looking at the more ambiguous images. Students were given the opportunity to describe what they saw but not many recorded anything meaningful. This may have been because the images were both difficult to interpret and the question too open-ended. Providing students with an opportunity to record their observations in a structured way may address this.

For the apprenticeship phase, a lack of feedback regarding why an answer was incorrect was also a source of frustration. Feedback of this kind may help to develop understanding and encourage engagement with the experiment.
"Answers could have been more detailed – actually explaining why your answer was correct/incorrect."

Some also would have liked feedback on the qualitative question responses not just the numerical and multiple-choice questions. For the main experiment, similar frustration was also experienced from the fact that they didn't receive any feedback regarding their answers.
"Make the 2nd part easier...tell us the answers after we've done it."

Responses dealing with the experiment as a whole were very mixed. Some students expressed the opinion that the activity was too long while others remarked that they would have liked more data to examine. More contextual information was requested by

some participants e.g. how the experiment was conducted in the lab, how the research findings could be used, or more information on the scientist's research and why they were interested in stem cells and the gene under investigation. More information on the ethical issues associated with stem cell research was requested.
"More information about what was happening and how they did it."
"Didn't allow us to find out about how it is used"
"More...real life applications"

Some students responded that they would like the website to provide more experiments including in the same field of research – giving a wider overview of the research area.

A small number of students commented on the chicken animations exploring the concept of the scientific method 'How Eggsperiments Work'. They generally liked this element although a few felt that the format was more suitable for younger children. Some of the students commented on the validity of the chicken experiment, noting correctly that it was incomplete. The experiment looks at the effect the concentration of chicken feed the hens are given has on egg yield. The higher the concentration the more eggs are laid. The highest and most effective concentration is 50%, but no higher concentration is offered, so we do not find out if this correlation between concentration and egg yield continues.

Students suggested improvements to the website including:

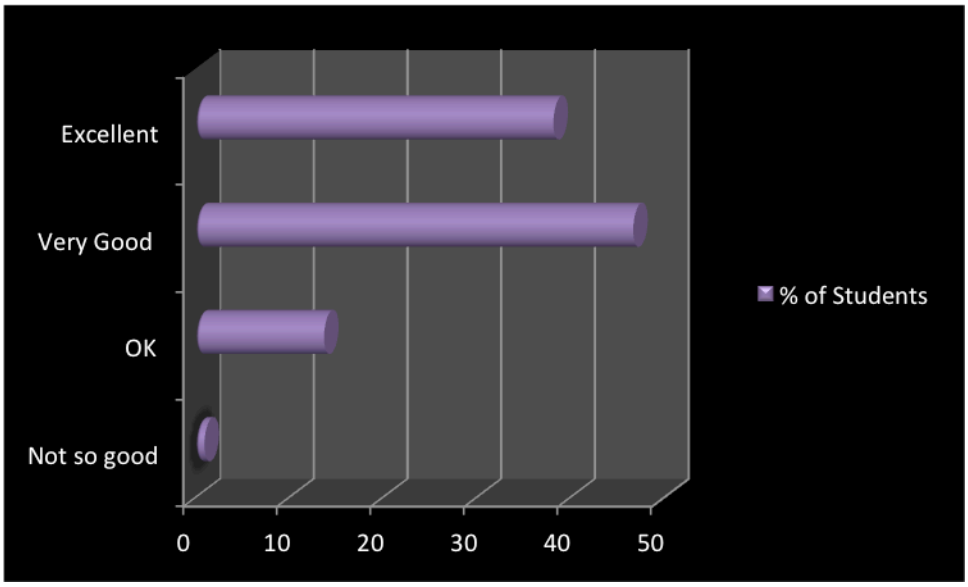
- More activities and experiments
- More supporting information on the science and the ethics
- Greater interactivity e.g. with the images
- Improve presentation – colour images
- Specific problems such as difficulties switching between control and test slides or needing to scroll down to view questions and responses

A small number of students suggested specific ways the website could be used that would enhance what it offers:

- Provide a teacher log in to allow teachers to assess students
- Materials for revising
- Allow students to design their own experiments and generate their own data
- Using an approach that isn't purely question based through which students complete the investigation
- More information to support discussion about the science and the ethics
  "I think they could contain more information about stem cell research today."
  "Maybe more info on views of stem cells."

Younger students were more likely to suggest that the wording and instructions could be clearer and requested that important information needed for the investigation be highlighted.

Students rated ambassadors very highly on the whole (depicted below)



3.2) Teacher

Half of the teachers felt their expectations were met or exceeded. Overall they were impressed. The remaining teachers both felt that it was too difficult for some year 10 and 11 students. One respondent explained that her students had been very keen to take part, but a significant number struggled with the activity and as result were not able to fully engage with it. The other respondent had expected some of his students to struggle with it, but did notice some of the more able and keen students started to grasp how the scientific plays out in the real world. Some of the students started to apply the ideas of 'How Science Work's (that they learn about in school) to what they had experienced in the workshop.

3.3) Scientist (Ambassador)

Ambassadors feel their expectations were met on the whole. However, it was noted that some of the students did not seem to fully grasp that the data was real – it did not feel authentic. In addition some students complained about the repetitive nature of the task and didn't appreciate that this is often a necessary feature of a real investigation.

The scientists thought that the ambassador Toolkit, teaching resources and training helped them achieve their aims and they thought the materials were generally very good although there was too much content and it was difficult to cover everything that was suggested for the workshop.

"There was much too much information in it." A3

One scientist did not feel they knew enough about the knowledge level of the students and more guidance about what to expect would have been helpful.

"...knowing your audience is important and I felt like I really didn't know my audience very well..." A3

The ready-made nature of the workshop was seen as a positive by all the ambassadors and was not felt to be limiting.

3.4) Scientist (Lead investigator)

"We thoroughly enjoyed involving students in our research experimentation, and the pilot experiment confirmed that Virtual Lab is a powerful tool to show school children what science is all about."

Luis Aragon (Cell Cycle Group Head), who led the experiment: *Investigating Cell Division*

4) Performance and Impacts

4.1) Platform and project management

The Virtual Lab co-ordinator was employed on a 2-day week basis to develop and deliver pilot experiments tailored to the curriculum, develop supporting educational resources, recruit schools, recruit and train ambassadors and evaluate experiment success with regard to the project aims and objectives. Salary for the co-ordinator post encompasses the bulk of the project costs.

The first experiment: *Investigating Cell Division* took 20 days to develop, which included schools recruitment. The co-ordinator ran workshops with local schools to support students in completing the online experiment. The experiment was live for 6 months (January – June 2010). This experiment was targeted at Key Stage 5 (A-level students).

The second experiment: *Very Special Cells* took 40 days to develop, including the recruitment of schools, design of supporting educational resources. The second experiment was delayed by the need for additional lab work on the part of the co-ordinator to provide suitable training slides (images of stem cells in culture) for the apprenticeship phase.

The website was modified to present an experiment pitched at different levels, so that GCSE and A-level students could simultaneously make use of the resource. Recruitment and training of early-career scientists and co-ordination of ambassador-led workshops in schools took place during the six months that the experiment was live (November 2010 – April 2011). This experiment was pitched at two levels: Key Stage 5 (A-level) and Key Stage 4 (GCSE).

A total of 625 individuals registered through the Virtual Lab website during the two pilot experiments. Registrants came from Australia, Botswana, China, Gambia, Kazakhstan, Korea, Nigeria, Portugal, Saudia Arabia, Switzerland, Somalia and Uganda, as well as the UK and USA, demonstrating the global visibility of the online platform. 31% of registrants completed one or more experiments online. This figure (calculated from the website database) would suggest that registrants weren't sure what the resource offered (in order to attempt an experiment registration is required), although there are many possible explanations for their failure to complete experiments.

Google Analytics confirms over 1500 unique visitors (from March-September 2011), however the bounce rate is over 70% (which means most visitors are viewing only the homepage before they leave the site). Visitors most commonly found the resource through search engines such as Google (52% of visitors), 29% found the resource directly, and the most effective referring website was www.schoolscience.co.uk (8% of visitors).

75% of individuals completing experiments were invited to participate, demonstrating the importance of local recruitment strategies. The remaining quarter found the resource online. With a marketing budget to promote the resource, it seems likely that unsolicited users would increase significantly. A marketing/communications strategy going forward is thus of key importance to promoting widespread usage of the resource.

Some difficulty was experienced by the Virtual Lab co-ordinator in administering the website, owing to a lack of experience with web-tools. The content management system (CMS) is presented with a number of features to assist administration. In future training could be offered to support the co-ordinator, or the workload divided among co-ordinator and a web-administrator to ensure experiments are delivered to a high standard.

The pilot experiments revealed a number of inadequacies with the platform, which have now been resolved:

- Data harvesting tools were not available through the CMS during pilot investigations
- Video data could not be accommodated through the front-end
- The user registration form was not customizable through the CMS

Demographic user data (registration form) had to be harvested manually from separate forms (one per user), thus collating demographic data was laborious. Additionally, harvesting data from the experiments was also extremely time-consuming, each user experiment being stored in a separate form in the back-end database. And video data could not be accommodated through the platform: each slide was presented in static jpeg format.

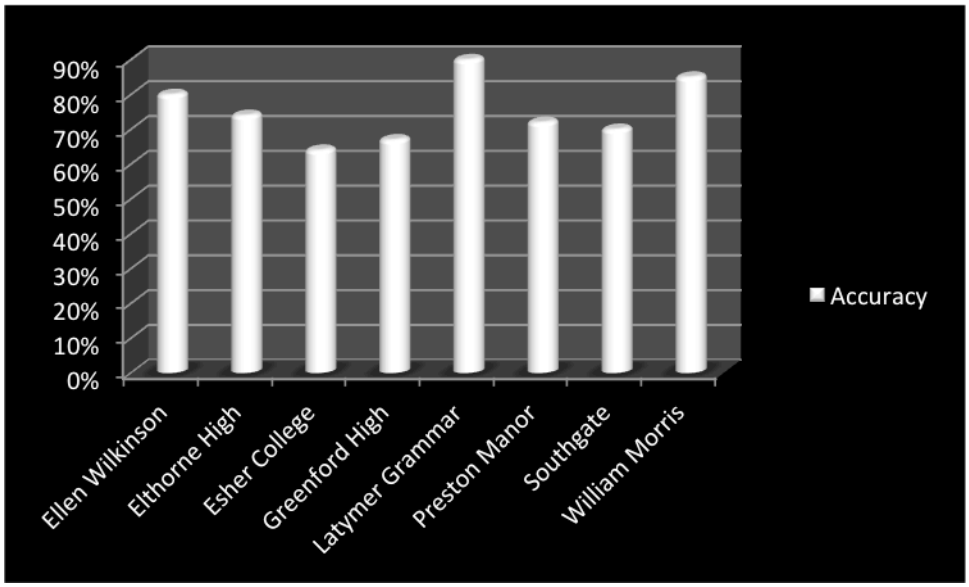
Revisions have now been made to accommodate all of the above. Video data may now be accommodated, which will add to the dynamic presentation of experiments. Data harvesting tools have also been added that allow the administrator to download experiment results and user data into an Excel spreadsheet for analysis. This is critical to the evaluation of experiment results. Data can be filtered based on the accuracy of student scores (calculated during the apprenticeship stage). Scientists can harvest data from students based on their accuracy (if applicable). i.e. input data from only the most accurate students could be included in an investigation.

A customisable questionnaire tool has been added to the CMS, which allows scientists to ask particular questions about users in advance of the experiment (in addition to the standard questions in the registration form). This is an important revision because it allows scientists to engage users as research subjects rather than research analysts helping to probe their data. The website can effectively be used as a means to collect data about user behaviour, for example. This broadens the scope of the platform and opens up new possibilities for its use that had not formerly been considered. The improved online platform provides a powerful tool to instigate, manage and evaluate biomedical experiments involving school students.

4.2) Student

The content management system allows the administrator to analyse who completed experiments and how accurate their scoring ability was; each user is graded on accuracy during the apprenticeship stage of the experiment. Students were each provided with a printable PDF certificate demonstrating their participation and accuracy, further to completing each online experiment. Accuracy is graded based on the apprenticeship phase of each experiment – which effectively trains users to analyse the visual data presented. This provides information about the degree to which students are likely engage with the final experiment.

A total of 192 individuals completed one or more experiments online both for *Investigating Cell Division* and *Very Special Cells*. 145 of these were students from invited schools: Ellen Wilkinson School for Girls, Elthorne Park High School, Esher College, Greenford High School, Latymer Grammar School, Preston Manor High School, Southgate School, Southgate Further Education College and William Morris Sixth Form College. These schools were provided with an ambassador-led workshop (for the *Very Special Cells* experiment) to support their participation. Invited schools had an average accuracy of 75%. Latymer Grammar School had the highest accuracy levels (90%) of all schools (see below chart for results) and Esher College the lowest (64%).

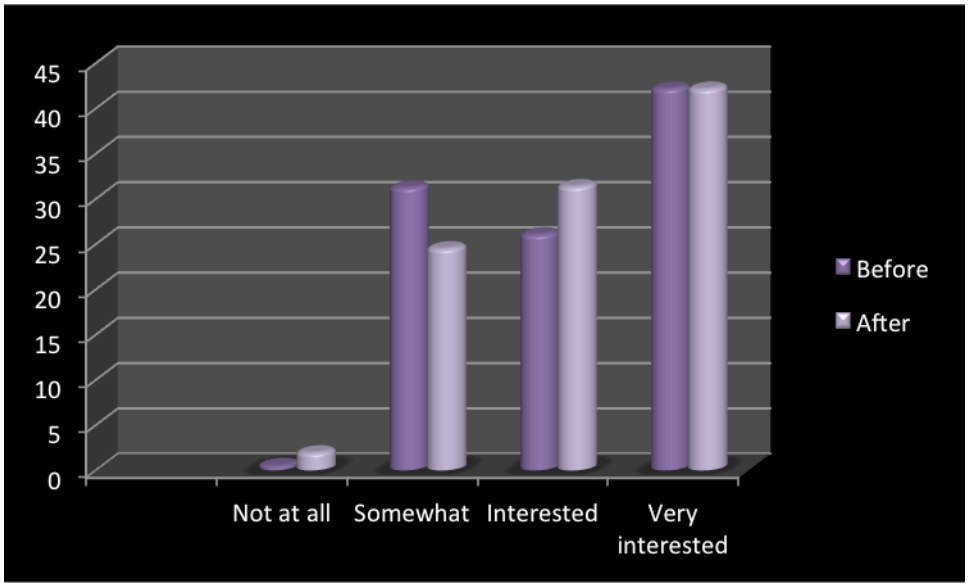


47 unsolicited users completed one or more online experiments. Users were from: Amity Institute of Biotechnology (India), Amity University (India), Arnold School (Lancashire), Bedales School (Hampshire), Clan Carthy High School (Jamaica), Finchley Catholic High School (London), Hvitfeldtska Gymnasiet (Sweden), Highgate School (London), Ilford Ursuline High School (Essex), International Schools Brunei (Brunei Darussalam), Mayfield School (Essex), Moreton Hall (Shropshire), Putney High School (London), Simon Langton Grammar School for Boys (Kent), St Olave's Grammar (Kent), St Robert of Newminster Catholic School & Sixth Form College (Essex), Sydenham High School (Kent) and Woodhouse College (London).

The unsolicited group had a slightly higher average accuracy than the invited school group (79.4%). Although the sample size is small, when contrasted against the high number of registrants who didn't complete an experiment, the data would support the notion that the platform 'selects' for participation from the most highly motivated individuals. This notion is supported by the enthusiasm for science of both groups (as depicted in **Participant motivations**: *Students*).

These data suggest that ambassador-led workshops don't necessarily improve the accuracy of student scoring through the online platform, although it is certain that without the workshops fewer students would have completed experiments. Based on positive feedback from schools and early-career scientists who engaged with them as ambassadors, face-to-face interaction with scientists is clearly of value to both groups.

Student interest ratings in science were measured through written questionnaires (119) completed after ambassador-led workshops. The Virtual Lab also collects data online, both about users and for experiments in a back-end database. Interest ratings had been collected – through the registration form – in the online database prior to the intervention. The proportion of students in each interest category is compared (below) before and after intervention.



Student interest ratings in science before and after they completed online experiments

While there are no drastic differences in the before and after ratings, the shift in 'somewhat interested' (31.3 % before to 24.5% after) and 'interested' (26% before to 31.4% after) would suggest that the intervention had a positive impact on students and succeeded in generating greater enthusiasm for science. It hasn't been possible to determine whether this might be a result of the ambassador-led workshop or the online experiment, or both.

Teacher

Teachers were asked which of the following were the greatest opportunities for their students:

- Access to real experimental data.
- Contribution to published results in a real research paper
- Finding out more about curriculum topics such stem cell biology
- Finding out more about careers in medical research
- Meeting and talking to a real scientist
- Carrying out an independent investigation
- Generating data for a mass participation experiment

The response was mixed but teachers indicated that opportunities for students to find out more about curriculum topics and analyse real data were most valuable.
"...requires them to use their skills to process data and to make judgements, cos it forces them to think independently, which is something the curriculum doesn't encourage them to do, and that is the difference between an A grade and B grade student. That's a skill that needs to be developed if you are going to pursue science post-16." T3

One teacher felt it was particularly helpful for high ability students as the activity provided a high-level challenge and a new context for data analysis activities, which the students found engaging and inspiring. Another felt her students had – up until their participation in Virtual Lab – not really appreciated the uncertainties inherent in research findings, and that they very much benefitted from being exposed to the ambiguous nature of real data. The younger students in particular want answers; they find it challenging to be in a position where the answer is not known.

"...they are going to university expecting everything to work...cut and dried answers...rather than sometimes, well we are expecting this one is better than that that but we are not really 100% sure, it's this desire to have everything black and white." T4

The opportunity to access and analyse real data was particularly important to one school as their year10 and 11 students have to perform an assessed data analysis exercise, producing a graphical representation of numerical data (21st Century Science GCSE). The teacher remarked that if Virtual Lab could directly support this kind of activity it could help to raise attainment.

The connection with the curriculum was very important to this group of teachers. One teacher explained that this was because the teaching time available is very limited.
"...we are so short of time in terms of teaching...you are doing triple science in the same time you are doing double science...you can't really have the time to put in anything extra, whereas if it is curriculum linked you can include it as a way of enhancing..." T4

Virtual Lab was felt to support what students have to learn as part of the curriculum, but it goes further by enriching the topic.
"It makes the science come alive more; it's not just established facts written in a text book, it's more relevant." T3

Some of the respondents also cited student attitude as a problem for enrichment activities.
"...students have a horrible attitude which is, if it is not on the spec I'm not doing it ...if it's not going to help me to pass my exam I don't care...One of the reasons I wanted to do this...to try and snap them out of it." T4

All the participating teachers appreciated the experiment as an opportunity to find out more about stem cells. One even felt that she had learnt something herself from taking part.

Virtual Lab and the ambassador-led workshops were also perceived as useful by all the teachers as a means to finding out about careers in research. Teachers appreciated the opportunity to expose students to the idea that biology goes beyond just studying medicine. One teacher felt that some of her students were more interested in learning about scientific careers as a result of taking part in Virtual Lab. The opportunity demonstrated to some of the students that science is relevant and accessible – something they could see themselves doing.

The opportunity to meet real scientists was also seen as a positive, although this did in some part depend on the communication skills of the scientist visiting the school. The teachers saw the scientists as potential role models for their students and were keen to tackle the stereotypical image some students have of scientists. Meeting a real scientist was also a revelation to some – confirming they are normal people the students could relate to.

"Oh but she is very friendly, she is very normal...they expect like monsters!" T1

The teacher felt that the younger students particularly benefited from the visit from an MRC scientist who made a very positive impact on the students.

"He was really fantastic, very friendly...easy going...he went through all details of the experiment. Because this is very difficult for GCSE students to understand, how to design an experiment and he did it in a very friendly way...I am very grateful to you for organising this."
"...He used his scientific language; however it was easy for the students to understand him...there wasn't a barrier...it wasn't boring, they really – Oh miss, oh can we have another meeting with him?"
"...both of them (students) said science is not boring any more, Oh I'd like to go to study science...not many students like science, because it is difficult..." T1

The opportunity to take part in an independent investigation was not perceived as particularly important by this group.
"No they get plenty of opportunities to do that in school, although they are insecure about their ability to do it, but I think it is much more important that they can critique an experimental design or some experimental data." T3

However, some did feel their students would benefit from the opportunity to contribute to published results. Although not without reservations, one teacher felt it would encourage students to consider a career in research but another 2 of the teachers could foresee practical difficulties.
"Nice idea and I think the students would enjoy it, but it's a slow process and I don't think it will benefit their university applications, as it either won't get published or at least not in the timescale the UCAS process requires." T4

There was an uncertain but mainly positive response to the idea of a mass participation experiment for schools.
"A nice idea and engaging but it would need to encourage them to evaluate the purpose, design and outputs of the experiment and to demonstrate their understanding. This would need scaffolding so they are very clear what they need to do and the timeframe would need to be short as students particularly in yr12-13 have very little time."

When asked how Virtual Lab could additionally support students, teachers centred mostly on the provision of more experiments. Specific suggestions included summaries of research written like abstracts at an appropriate level but with obvious links to the curriculum and scientist biographies demonstrating their education and career paths. One teacher suggested the website provide greater guidance for younger and less able students to allow them to work on their own more easily.

Teachers seemed uncertain about whether Virtual Lab could support students with university applications. They agreed that it would help, but were not convinced it would make a significant difference. One teacher explained that students are not actively involved enough and it does not allow them to demonstrate their skills and abilities in such a way that would be helpful to an application. They suggested that students would need more ownership of what they were doing to write or talk about it convincingly. Another teacher suggested that a real contribution to a piece of research would make a greater difference.

"Yes, everything helps, but won't make a big difference, may boost an application to some degree." T2

"I don't think a 1 hour session on a computer is a proper enrichment experience, but it is a start." T3

The majority response was that teachers felt the intervention did develop students' data interpretation skills, but one teacher felt it could be improved with greater support for younger and less able students who found some of it too challenging. Also the experiment should differentiate between AS and A2 students, providing different levels of challenge for each.

The teachers were not fully convinced that the intervention promoted discussion about the science and the ethics. They felt that the activity was not presented in such a way as would support discussion, but they appreciated that it could be used for this purpose. One teacher mentioned that a teacher would need to feel confident in their ability to lead a discussion and that other initiatives such as "I'm a Scientist Get Me Out of Here" are more effective in that regard.

More positively one teacher also revealed that they she felt that the activity had helped her students to understand the science and develop the language to explain and discuss stem cell biology at home with their families.
"Yes, it helps actually the students to understand the topic better and also to translate it into normal language for their parents and families...They go back to their families and explain to their parents...I work with students from um, difficult backgrounds; some of them don't speak English even." T1

Another teacher explained it would help if the students were able to receive a response to their ideas at the time, as this is then a real dialogue and would encourage them to engage with this aspect.

All the teachers felt the website was easy to use
"...all very clear, they just needed to follow instructions" T2

The response to this question varied with no elements of the website coming out strongly as most successful. Features mentioned included the images and the structure, which was felt to be similar to the way a real experiment is structured. The 'Eggsperiment' animation was described as fun, although some students were distracted by the fact that it was about chickens and eggs.

There was more consistency in the teachers' reactions to unsuccessful aspects of the experiment. The strongest responses were about the degree of challenge and authenticity. Some of the teachers felt it was too challenging and that clearer instructions are necessary for lower ability students. The LIF titration presented the greatest challenge for younger and lower ability students who did not understand how to respond. Another teacher felt that there was too much text and the actions they had to perform were very repetitive so that they ended up answering the questions without thinking.

Some of the teachers were not sure that the students really appreciated that it was real research and the outcome was unknown and this therefore needs to be more explicit. Schools experiments are more often simulations designed to give the desired results rather than true experiments, and this was seen in the same light.

One teacher in contrast to another respondent for the previous question replied that the chicken animation appeared to be aimed at a younger audience and that some of her students commented on this.

Teachers felt the website should:

- Provide more experiments on a variety of topics
- Have less text, be clearer,
- Have a more intuitive navigation.
- Present a summary for teachers
- Be more explicit about the fact that it is the student's own interpretation that is important, that there is not a right answer.

Two teachers also suggested the possibility of using video to explain the science rather than text although one qualified this with the view that many students need practice in extracting information from text and need stretching in this way in preparation for university.

All the respondents agreed that *Very Special Cells* did support student's knowledge and understanding of stem cell biology, although some felt that it was at too high a level for GCSE and went beyond what that age group needs to know.

Most of the teachers felt that this experiment provided an effective means to develop data interpretation skills, but could benefit from more explicit guidance and a clear

message that interpreting the images is a form of data analysis. Some students will not appreciate this and tend to equate science with quantitative data.

One teacher did not feel student's data interpretation skills were supported, but that it had the potential to do this. They commented that students were randomly picking answers and suggested that this could be addressed by accumulating data as class or school and making make decisions about the significance of their data set.

The responding teachers did not feel Virtual Lab helped students gain confidence to discuss and debate science through *Very Special Cells*, although they agreed the platform could be used for this purpose. The consensus was that most of the students didn't engage with the content enough to take it further in this way, and that there was no obvious connection to the ethics of the science in the experiment itself. The link to associated social and ethical issues would need to be clearer. Suggestions were made for a complementary activity such as a structured discussion exercise to support tis objective.

4.3) Scientist (Ambassador)

Scientists were asked during interviews to consider the relative importance of the potential objectives for Virtual Lab and public engagement.

- To support scientist's professional development in the area of public engagement
- Provide an easy to use and ready made resource to support public engagement
- Provide scientists with an opportunity to work with a schools audience and inspire the next generation of scientists
- Enhance scientists communication skills and confidence in talking to a non-specialist audience
- Support the strategic aims of the MRC in terms of communication and showcase the research of the MRC

The most important objectives that emerged for these scientists were the provision of an easy to use and ready-made resource and the opportunity to enhance their communication skills and confidence in talking to a non-specialist audience.
"... above all for this project. It's great to have that structured resource..."
" having that structure gives you more of an opportunity to kind of practice your skills and enhance them ... having that structure gives you more support in that context." A2

The least significant aspect was felt to be the potential to showcase MRC research; it was felt that the platform would need to present a broader picture of the MRC's activities to achieve this.
"To showcase your research to the public you really need to give them the broader picture." A3

The scientists suggested Virtual Lab could be available to other communities such a parents, the University of the Third Age or university undergraduates.

All scientists interviewed felt the training was helpful and although there was a lag between training and workshop was large in some cases, a re-cap session was not required. The opportunity to share knowledge and experiences with peers also interested in public engagement was particularly appreciated.

One scientist felt that more information regarding the knowledge base of the students would have been helpful. This is difficult to give for the 14 – 16 year old group in particular, as it depends on which Awarding Body the school uses, and when the scientist visits the students. They may or may not have covered a particular topic at any given time.

"I think the training was really useful." A1

"...certainly having the peer group around you...doing the training together was really useful." A2

Working through the teaching materials and looking at how to plan the workshop session was seen as the most useful aspect of the training. Considering the types of questions that could arise and having the opportunity to consider the experience from the student's point of view was also a useful element of the training. Training was relevant to scientists' needs and generally prepared them well for their school visit. However, one scientist again mentioned the issue of understanding the student's knowledge level. Another scientist also mentioned that they were not fully prepared for how long different activities would take. Further guidance in these areas would therefore enhance training.

All 3 scientists interviewed felt the support provided by the Public Engagement, Media & Grants Facility was highly adequate and helpful.

"...I think it was very well organised, very useful...I always knew there was somebody to go call on if I had any problems, so yeah I don't think it could have been done better." A2

All scientists considered the Toolkit very useful, especially the presentation, although they could have benefited from more guidance regarding timings. The workshop timetable provided was a rough guide and a gross underestimate in some cases. The least useful elements were discussion activities. There was simply not enough time to do these with the students. Some of the scientists did use the 'stem cells in the news' activity, but were unsure how it should be used effectively and did not feel the students understood it. Further guidance in using these teaching tools would be recommended.

2 of the 3 scientists felt that the website was easy to use. However one scientist did not agree. The respondent reported that navigation through the experiment was difficult because you couldn't go backwards (this was part of the design, to prevent answers being overwritten in the database – users were free to complete as many experiments as they liked, but they couldn't go back to change answers). Other criticisms of the website were that it contained too much text and intuitively the images on the home page should be 'clickable' but aren't.

The most successful element of the website was thought to the chicken 'Eggsperiment' animation, which worked very well as an introduction. Recommendations for how the website could be improved included introducing an element of competition and providing more information on careers, live online Q&A sessions, links with social media and less use of Flash.

The scientists were asked to consider to what extent the experiment had achieved its objectives in terms of:

- Helping students understand stem cell biology and the MRC research project it showcased
- Being interesting and engaging to the students. What part in particular was interesting/was not interesting?
- Providing an insight into real research and how it is conducted
- Encouraging critical engagement with issues in biomedical research and their impact on society

All the scientists felt that the students they met found the workshop interesting and engaging, and in most cases aided understanding of the basic science.
"It definitely helps kids understand stem cell biology..." A2

But in terms of the research:
*"Getting the full gist of what the whole experiment was about was a bit difficult getting that across."*A2

Grasping the rationale for the experiment and what it revealed was particularly challenging for the younger students.
"I don't think the experiment did. By and large it went over their heads...there was no way they were going to appreciate the relevance of the project..." A3

The older students grasped most of the concepts, but did not seem to appreciate that the data was real, and as was also the case for the younger students, the distinction between the LIF titration and the knockout experiment was not fully appreciated. All the students were most enthusiastic about the hands on activities like the egg cloning simulation and the 'what's in the box' activity. One scientist commented that although the nature of the project is online, it would work better if the experience better simulated a hands-on activity and... *"Make it more like it is in your hands..."* A1

"It very much engages kids with real research..." A2

The time available for the workshop did not allow the scientists to engage the students in dialogue about the broader societal aspects of the research, but the opportunity meet a real scientist was clearly appreciated. The scientists did not offer many specific recommendations for improving the experiment, but one suggested that the use of images of other cell types to emphasise how cells change during differentiation could be helpful.

5) Conclusions and Recommendations

5.1) Teacher

All the teachers said they would recommend Virtual lab to a colleague and some already had. A couple of provisos were made – one response was qualified with the suggestion that they would recommend its use alongside other resources. Another teacher was concerned that colleagues without a research background may not find it so easy to use. They felt that if a teacher is not familiar with the research process or doesn't know a great deal about the topic they would be less likely to use it with their students. They suggested concise supporting information for educators would be required.

All the teachers said they would be willing to take part in future experiments.

"Yes definitely, any enrichment activity makes a difference to the students learning and success." T2

Suggested topics for future experiments were:

- Genetically Modified Organisms
- Transplant research
- Environmental science (pollution)
- Gene therapy
- Genetic engineering
- Developmental biology

Overall any topical issue or area of cutting edge science that they will follow up in further study either at A-Level or university would be useful, and particularly if it is relevant to the GCSE and A-Level curriculum, and students find it challenging.

Recommendations for future project development included:

- Differentiation for differing ability students
- Background reading
- Feedback on data analysis and dialogue with the scientist

The teachers appreciated the basic premise of the project and they expressed a recommendation that it should continue with the same aims and objectives.

5.2) Scientist

All the scientists stated that they had enjoyed their experience as an ambassador and would be willing to take part in future experiments. They would recommend the project to colleagues. The fact that it did not offer an opportunity to present their own research was not perceived to be a problem.

An additional recommendation for the development of the website was to include an opportunity for the students to research the topic area via a structured pre-experiment activity such as a literature search. A way for the students to consider the robustness of the results was also offered as a possible enhancement.

The aspect of the project that was considered to be most successful was the suggested hands-on activities, which were well received by all the groups visited.

5.3) Platform

By far the greatest challenge to Virtual Lab exists in the tension between experiment 'design' and 'data'. The ultimate goal is to get students to analyse authentic biomedical

research data in real time. Scientists don't necessarily render data that, in their raw form, can be appreciated by students. Yet processing of data – to make it more intelligible to school audiences – reduces experiment authenticity. Timing is another factor that impacts on the possibilities of realizing an experiment in real time, scientists' schedules not necessarily falling in line with school calendars. However, students need to feel they are doing the study with the scientist. Additionally (although this has not been experienced), scientists may not wish to disclose unpublished data.

- **Future experiments should maximise the possibility of engaging students in a real time investigation with actual research data** – the challenge then becomes to find the scientists whose research data could be delivered raw to school audiences
- **School audiences need to be engaged in the experiment throughout** (a more 'hands-'on' feel) **with effective follow-up**. Schools could be final data to analyse post-experiment, introducing an element of competition. Students need more of a sense of ownership

While the web-platform is user-friendly and facilitates the engagement of schools in biomedical research, the feedback suggests that some of its functionality could be improved by further development. Additionally, since every experiment is unique and may require different features, any running budget going forward should factor in an annual development cost.

- **Training could be provided for co-ordinators** to support their effective delivery of experiments, **or administration of the website should be centrally controlled by a web-master**
- **Students need clearer sign-posting throughout experiment** – the apprenticeship should be more closely related to the final experiment; a summary slide could emphasise key points to remember; video backstory could be provided instead of slides

5.4) Co-ordination

Both pilot experiments were conducted in different ways. The first, rather than intervention through ambassador-led workshops, was supported by co-ordinator-led workshops in schools. In either case, the workshops have proved an important means to encouraging students to complete the activity. Co-ordination was a challenge on 2-days/week, although after the experiment was launched this was sometimes surplus to requirement.

- **Development could be scheduled on a more intensive basis** (perhaps with a minimum of 3 days/week to keep up momentum)
- An average of 30 days (co-ordinator time) should be allowed to plan an experiment in association with the lead scientist, including time to develop teaching resources, recruit schools, train ambassadors
- Once the experiment is launched co-ordination may only require 1-2 days per week (especially if a web-master is employed in the maintenance of the online resource)
- **More time should be given to digital marketing strategies** in future to increase the number of unsolicited users completing online experiments. Virtual Lab clearly selects for highly-motivated users

5.5) Public engagement

Ambassador-led workshops provided an opportunity for MRC scientists to gain experience in public engagement. Workshops made students do the online experiments, but also supported enrichment around the subject, insofar as they were able to appreciate the scientific method; discover that scientists are normal people; and consider science is a career option. While the ambassador scheme didn't appear to impact on the accuracy of users, this outreach initiative was clearly perceived as valuable to scientists and schools.

- **Ambassadorship is not essential to the success of Virtual Lab** (measured by user accuracy), **but adds value** and where possible should be supported
- Training and/or support for ambassadors should be provided where possible
- Ambassadors could engage with schools after they've completed the online activity, with more focus on social/ethical implications around the research theme
- More concise supporting literature (Handbook) should be provided with a tighter workshop plan

5.6) Extension of programme

Virtual Lab in the future has the potential for use across the research councils. With the retiring Researchers in Residence scheme, and the clear demand from the research community for opportunities to engage school audiences, and schools for opportunities to engage with research communities, the MRC Clinical Sciences Centre is keen to explore diverse use of the platform by multiple partners, and is happy to facilitate same by central web-administration, if desirable.

Alternatively the platform infrastructure may licensed for independent educational not-for-profit use by a third party through a separate domain.

Experiments for the academic year 2011/2012 are already in hand, although ideas for future use are welcome.

Contact:

Brona McVittie

Head, Public Engagement, Media & Grants (PEMG) Facility
MRC Clinical Sciences Centre, Imperial College Campus, Hammersmith Hospital, Du Cane Road, W12 0NN
Email: brona.mcvittie@csc.mrc.ac.uk
Tel: 020 8383 8247