Shaping Higher Education with Students

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Learning through mistakes

An important part of the learning and research process

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Learning from mistakes is key to understanding how things work when students enter the research laboratory. Sabrina describes the value of working in a system where everything does not work perfectly and the unlikely can always happen. She illustrates how we learn from practice. Her chapter is highly recommended to those embarking on a research career. It is a confidence booster. She highlights great discoveries arising from the unexpected result. Sabrina demonstrates how understanding why a mistake happened can be turned into a very positive outcome.

Professor Elizabeth Shephard

1. Introduction

The opportunity to make mistakes aids both learning and mental resilience. Unlike research, the current nature of education – favouring the errorless pursuit of learning – often overlooks the value of the serendipitous. This chapter reflects on how research-based teaching can remove the barriers between education and research by creating space for students to explore the unexpected, to change their perspective as well as gain invaluable knowledge and experience of the research process.
Here in the sciences we are relatively lucky – to my knowledge it is likely that you will have been exposed to laboratory or other experimental work during your journey. This may have varied in its success due to the very nature of experimental work. Experiments are the perfect environment for things to go ‘wrong’ or, arguably, ‘right’. The value of mistakes can be easily downplayed in an academic system that solely celebrates a narrow definition of success and arguably cultivates a ‘will this be in the exam?’ culture. In my experience, I learnt more about the science and technical aspects of, for example, analytical equipment when trying to solve why it was not working, than I ever did when it went according to plan. The process that follows from the initial mistake opens up a plethora of opportunities for learning via analysis and feedback loops between the student and their teacher(s), peers and even students themselves through self-evaluation and future reflection.

That is not to say that I find making mistakes an enjoyable experience and I imagine it would be difficult to find someone who does. Whether it is the fear of vulnerability, looking ignorant or going against the social norm, largely we do not deal well with these inevitable life events. These feelings can be made worse in a high-risk environment where we may become hyperaware of our surroundings, ourselves and the perception of others. University can indeed feel like a high-risk environment, where the future is at stake and your future colleagues and employers are the audience. To see a mistake, error or diversion from the plan as a new opportunity for learning (or research) takes both practice and resilience. I believe research-based teaching will be instrumental for students’ development of these qualities, as the boundaries between textbooks and research are replaced with experience. As a researcher, this exposure to mistakes and the subsequent problem-solving they require is our job, the research itself (or at least an integral part of it). Therefore, a research-based approach to university teaching will expand this environment so that students can make mistakes while learning just how normal they are, but through exposure rather than words.

2. Momentous mistakes

Early on in my exploration of research-based teaching methods I recognised the potential for it to be used as a tool that allows students to make mistakes in a safe environment. This led me to consider how mistakes are integral to both learning and research. The interpretation of mistakes has shaped both the research environment and the discoveries themselves.
Setting out towards an unknown with the belief that you will find one correct solution, on the first attempt, for a single problem can blind an individual to the potential of serendipity. For instance, I would love to have been able to ask Wilson Greatbatch how he viewed one of his greatest mistakes for the people it has saved. When producing a prototype for a device to record heart rhythms, he accidentally fitted the wrong resistor, creating a device that instead produced intermittent electrical pulses – otherwise known as the pacemaker.

Discoveries from mistakes like this in medicine are relatively well known. Arguably, one of the most famous examples is Alexander Fleming’s contaminated staphylococcus cultures. His mould-contaminated petri dishes could have been discarded as part of the main experimental goals; instead they led to the discovery of penicillin, which later changed the world. Another drug that has affected the lives of people all around the world was originally known by Pfizer as UK94280, which underwent unsuccessful trails as a treatment for angina, a heart condition where valves are constricted. The drug was initially going to be removed from further trials until volunteer feedback revealed an unusual side effect. After further testing, UK94280 was renamed Viagra and has since become one of the fastest-selling drugs of all time. However, it is not solely medical research that has found success in mistakes. Roy Plunkett was carrying out research for DuPont into a new refrigerant in 1938 when he found that one of his experiments had formed a resin resistant to extreme heat and chemicals. This later become known as Teflon.

As these examples show, just making the mistake is not enough. The researchers also had to see its potential, as well as having the desire to explore and analyse it. Individuals need to be aware of the larger process, opening their mind to mistakes and understanding that deviations from the expected are not automatically uninteresting, worthless or failures. It is within the hands of the researcher that these deviations can either become a mistake or a success. To quote Plato: ‘Science is nothing but perception’. But perception is not beholden to science alone. Along with consideration for the serendipitous, it is arguably part of the process of research.

Learning how mistakes are intrinsic to research and knowledge-acquisition, as well as creating a safe environment in which to explore these concepts, can be achieved through research-based teaching methods. At UCL, I met with two professors, Elizabeth Shephard and Anson Mackay, at the R=T Launch Event, during which they shared case studies from their own teaching practice. We talked about
innovative research-based methods that allow students the space to fail and make mistakes.

3. Research-based teaching in practice: the practical

Practice is key and the ability to repeat and learn from practice is crucial. In the laboratory, however, time is restricted. We therefore designed a virtual learning platform (VLP) to provide additional support for a hands-on research project in DNA cloning and analysis. The VLP allows students to practise numeracy, reagent preparation and experimental procedure. We wanted a platform that students could use in private, one where mistakes could be made and exercises repeated as many times as required. Practice and repetition has built confidence, aided further learning and enjoyment, and encouraged students to develop more advanced research skills. Repetition in a class laboratory environment is not always possible and there is little time to redo an aspect if a mistake is made. By building an understanding through practising the component parts of an experiment when mistakes are made, we can turn these into a positive learning process.

Professor Elizabeth Shephard believes that teaching in the life sciences is entrenched in research and therefore using a research-based approach comes naturally. The hardest aspect of this process is preparing the students for using the laboratory and trying to find new ways to engage them with safety and methods beforehand. As part of their studies, undergraduate students are required to clone a section of DNA. To support this, the department designed a virtual laboratory where students can go through the steps of a real experiment and get familiar with the methods and equipment. Students adapt quickly to the programme, enjoying earning points for making the right choices and being able to repeat the exercise until they either pass the activity or are satisfied with their score. These virtual activities are useful for ensuring students understand health and safety, methods, instrumentation and the general layout of a laboratory before the experiment begins. However, the virtual experience cannot replace reality: perhaps unsurprisingly, in modules that mixed virtual and real laboratories the students exhibited a preference for the latter.
Despite this preparation, mistakes can still be made and some students will find that their experiments fail to clone the DNA. Elizabeth explained how she goes through the work with her students as an important aspect of their understanding of the practical. She encourages students to consider the experiment in a real-world setting, reminding them that outside of a module practical the process would be repeated until they got it right. She believes students need to learn and understand that not everything is perfect. The practical is not one where all factors are manipulated in their favour; it is a reflection of research. Therefore, problems may arise as a natural by-product of the experience. Importantly, Elizabeth has noticed that on contemplation the students comment that they learn better through mistakes.

Even here the environment for making mistakes is shown to be hugely important. It helps students to understand that one failure in the laboratory does not mean they would not succeed with repetition, as by using virtual resources Elizabeth and her department have developed a programme that allows students to practise. For the numerical aspects of the course, this approach has been applied through creating a quiz that asks different questions for both different students and attempts. This was felt to be particularly important, as numeracy often requires practice. This level of repeatability could not be achieved on paper, nor could paper assessment and feedback be provided with such immediacy.

From being able to make mistakes and repeat tests for factual knowledge to learning through practice, the next logical question becomes: Is this factual knowledge enough? It is then the role of the practical to allow students to explore how they can apply this knowledge and gain additional skills in the process. One method of assessment used in my department (Civil, Environmental and Geomatic Engineering, UCL) that illustrates research-based teaching and assessment is the use of scenarios. A group of students are given a brief, just as they would be if they were carrying out a project in the workplace, and it is their responsibility to complete it using the resources available to them. These resources may include a site visit, online resources or a member of industry and will have been backed up by a series of lectures on frameworks and theory, scientific principles, etc. The students need to assign themselves roles and complete tasks both individually and as a team to create different solutions for the brief. It was noted in the discussion with Elizabeth and Anson that peers learn very well from each other and that peer review and engagement can be an effective way of creating an environment for mistakes that aid the learning process.
4. Research-based teaching in practice: writing and feedback

The motivation for creating an advanced-level assessment in the form of a 14-week blog was to engage students, in depth, in an environmental issue. But the unintended consequences have been just as important, and which speak to the topic of this chapter. Students are fearful of making mistakes. We judge and grade them on their mistakes; they judge themselves and they judge one another. Allowing students to write publicly – effectively rehearsing and developing an argument in a series of blog posts – raises their confidence in terms of both writing styles and research skills. Peer-to-peer feedback allows other students (and indeed anyone from around the world) to contribute to this learning process. Readers make criticisms, but these are nearly always constructive. It is how a student takes these on board that allows us to see their learning in progress.

Professor Anson Mackay

Laboratory or practical exercises are not the only environments in which mistakes play a key role in the learning process. What happens when students fail and how these failures can be incorporated into teaching, learning and assessment are important considerations when designing research-based approaches. Professor Anson Mackay described one of his assessments in the Geography department at UCL to try and achieve this.

Third-year undergraduate and Masters of Science (MSc) students are required to write an academic, yet public, blog, publishing regular posts over three months. The subject, design and research direction are under the total control of the individual within an environmental focus in either the sciences or humanities. As the blogs are publicly available online, fellow students and Anson can leave feedback and praise in the comments as well as instigate debate, helping the students to develop a deeper understanding and support learning. The assessment is designed in a way that accepts that mistakes or areas of weakness may exist. Through the course of the task, students should address these weaknesses, improving the quality of the blogs over time. This approach means that the students develop a voice as well as peer-to-peer skills. The task also offers a novel assessment, using technology in a way that benefits learning, while introducing students to a versatile media. It may be interesting to explore the difference between the perfect, polished
product that is an essay and the developmental nature of blogs. This scope for self-correction as a result of further research or understanding, peer review and feedback creates an opportunity for students to identify and explore their mistakes.

Understandably, at first many students are nervous. However, Anson noticed that after approximately four weeks there is a marked improvement in both the quality of their work and the students’ enthusiasm. I feel this is a result of the students taking ownership of their own work and being given the opportunity to express their perspective in an environment that encourages discussion between peers. Students come to university for many reasons, including education but also personal growth. I believe choices are more often made based on passion and therefore it is understandable that having a platform to explore and present this, as well as being encouraged to discover the cutting edge of their interests alongside their peers, would be met with enthusiasm.

An assessment like this is in stark contrast to the norm. Breaking from the mould in this way is something I think I would have enjoyed and found inspiring during my undergraduate studies. Elizabeth supported this assessment approach arguing that you should not worry about pushing the boundaries of the student’s academic comfort zones, because in the end they come back to you and say it was the best experience. This viewpoint was supported by feedback on Anson’s module, which shows the assessment is enjoyable and often a highlight of the student’s degree experience. However, Anson also noted that while this assessment works brilliantly and receives good feedback, it requires a lot of energy on the part of the assessor.

5. The importance of peer review

In academia, the application of peer review is integral for opening oneself up to outside opinions and, through this, the publishing process. Just because an individual believes their work is fantastic, it does not mean that reviewers or peers will agree. Elizabeth mentioned that when students come to her, asking how to make their work perfect, she explains this uncomfortable truth to them. Like students, academics must submit their work. Sometimes reviewers will respond with praise, at other times they will suggest necessary additions or improvements. Everyone feels uncertainty and pressure, but after you have had more exposure, you have practised taking the knocks required for success. In other words, you need to learn to make mistakes. This also relates to the undergraduate
experience, where a student’s pursuit of knowledge may only be witnessed by their examiner. Universities should provide a platform of learning for a community that does not end in the lecture theatre or with graduation ceremonies. Research-based teaching provides an opportunity for teaching staff to break down the barriers between researcher and student, encouraging students to become researchers themselves and take an active role in the exchange of knowledge and ideas.

6. Interdisciplinary relevance

Arguably the science sector already uses research-based teaching. A university-wide shift towards this approach is therefore an opportunity for both further improvements and sharing knowledge and experience across disciplines. Critical thinking integrated with active learning (such as through a laboratory practical) is a key part of university education that teaches students how methods and knowledge are applied to research questions in their discipline (Healey 2005, 183–201). However, in the case study from Elizabeth’s teaching approach, it can be seen that laboratory experience alone is not enough. It needs to be supported by allowing students to practise basic principles in a safe environment that allows them to fail (an approach that can be applied widely across subject boundaries) while putting tasks into a real-world context. One way to achieve this may be through the use of outward-facing assessments that promote module design directed towards real-world problems, applications and public engagement, as seen in the case studies above. This would allow students the opportunity to learn how to apply their knowledge, skills and experience in a relative context.

To allow cross-disciplinary discussion about how to effectively incorporate mistakes into the teaching method, it may be important first to clearly understand and define how failures are approached and engaged with (perhaps differently) across disciplines; how we define what makes our students successful; and how we encourage students to seek opportunity from the unexpected. My university experience has been largely dominated by the sciences. However, during the progress of this discussion I have often thought back to how different my experiences of mistakes were in my A-level English literature and art classes compared to my pre-university science and other subjects. For instance, our art teacher constantly encouraged us to look for opportunity at every stage of our project development, to question how we defined when our work was completed and not to give up in the face of what we perceived
as errors. Incorporating unexpected spillages, wonky interpretations of reality or being unable to physically form the exact vision in your mind was placed in the context of the developmental process, which allowed us to learn cross-disciplinary problem-solving skills and resilience. As students we were taught to search for both the positives and the opportunities: even if we had to start again, how could we apply what we had learnt? How had this changed our perception and ideas? Sometimes starting again is necessary and does not reflect your ability. In this context, what may have been labelled as a failure elsewhere was only truly one if you allowed it to be such: if you failed to learn.

7. Conclusion

For me this conversation has highlighted how, as teachers, researchers and students, we do not need to limit peer exchange to what are perhaps arbitrary definitions of a discipline in the face of learning. This is especially true where mistakes are concerned – a common currency of humanity.

One benefit of research-based teaching is that it allows the creation of a safe space to make mistakes and build resilience: accepting that it is okay to fail. It is how the community and the individual deal with mistakes that defines the experience and value gained. Allowing students to develop the confidence to take a chance that may result in failure, teaching them how to respond to mistakes and changing their perspective on the serendipitous can only be good news for research and learning within universities. We need individuals with their minds open to learning, engagement, opportunity and discovery, not crippled by an impossible pursuit of ‘perfection’.

Research-based teaching provides us with the opportunity to enhance the university experience at all levels of the learning community. It allows us to grasp valuable benefits by encouraging collaboration and discourse at earlier stages of career development and by supporting research. Overall, it feels appropriate to end this chapter with the conclusion of our discussion where I asked Elizabeth to describe research-based teaching in one word. For both the students and myself: inspirational. But in two words: wanting more.

References