Working towards evidence based practice in science teaching and learning.

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Abstract

High performing international education systems integrate evidence based practice into their initial teacher education programmes (BERA-RSA 2014). An example of informal practitioner research is described and discussed to illustrate the value and drawbacks of this approach and how this evidence based approach might be beneficial to teaching and learning in science. A science subject knowledge module was taught to two different cohorts of intending science teachers using a Science in Society (socio-scientific) approach. The aim was to demonstrate strategies for facilitating the development of critical thinking and scientific literacy. The use of anonymous voting devices during sessions highlighted a polarisation of opinions amongst participants rather than a more considered or critical response to the scientific questions.

Introduction

In both Scotland and Northern Ireland the importance of research and evidence is expressed clearly in statutory requirements for initial teacher training but in Wales and England this can only be implied (BERA-RSA, 2014, DFE, 2011, GTCNI, 2011, GTC Scotland, 2012 and Welsh Government, 2011). The interim report of the joint enquiry by the British Educational Research Association (BERA) and The Royal Society for the Encouragement of the Arts, Manufacturing and Commerce (RSA) (BERA-RSA, 2014) seeks to establish a link between school improvement and research based activity during initial teacher training and continuing professional development. The report identifies some common attributes shared by high performing international education systems including high quality teacher education that progressively develops research skills and critical engagement with evidence. Individual interim report papers link research based activity with school improvement (Mincu, 2013) and evidence based practice in education with improved pupil performance (Burn and Mutton, 2013).

The purpose of communicating this research is to encourage practitioner research and contribute to evidence based practice in science teaching. This report is an example of practitioner research that challenged the authors' assumptions about a pedagogical strategy modelled to two groups of aspiring science teachers.

Literature review

Some commentators demonstrate little regard for practitioner research in education. Dr B. Goldacre (see http://www.badscience.net/) wrote a discussion document for the Department for Education (GOV.UK, 2013a) on the need for teachers to understand better the importance of evidence based teaching and learning and the strengths and limitations of quantitative and qualitative research. Goldacre advocated (GOV.UK, 2013b) the increased use of Randomised Controlled Trials (RCTs) in education in order to answer questions about what actually works in schools. He argued that this is necessary to counter the vulnerability of education policy and practice to influences by senior figures claiming answers to challenges in schools- even when these are not based on any significant evidence. (See Harmes, Huijser and Danaher, 2015.)

Denzin (2009) makes the case that the criteria for quality that are applied to quantitative and qualitative data should be different and defends the case for qualitative research. As there are few or no opportunities for many schools to participate in the large scale research more common in Dr Goldacre's field (Medicine), small scale research (quantitative, qualitative or mixed method) is, for all practical purposes, the only approach feasible for education practitioners. However, distrust of the results of such research has to be acknowledged and addressed if it is to be accepted as useful evidence.

Practitioner research can take various forms and these are described and discussed in general texts such as Burton and Bartlett (2005) for whom a working definition of educational research would be any research motivated by the need for improvements in learning, teaching and assessment (LTA). To a greater or lesser extent, teachers have always conducted informal educational research as a matter of routine. In order to improve their pupils' learning, they observe the impact of what they do on learning, consult the learners, question trusted peers and read about areas of interest. In this way they are applying the principles of critically reflective practice (Brookfield, 1998 and 2002) and conducting informal research (Burton and Bartlett, 2005).

Teachers have little or no time to allocate to formal research or the communication of findings through publication. Their findings are usually disseminated through internal reports and meetings. Research carried out for accredited CPD courses is often only reported in written assignments. Merriam (1995) maintains that all research can be evaluated against some basic criteria concerning the making of generalisations from data: repeatability, taking into account potential researcher bias and the reliability of the researcher as an instrument for data collection and analysis. These translate into attempting to maximise internal validity, reliability and external validity. The purpose of any research influences how these and the usefulness of evidence gathered should be viewed. Logically, all findings are useful to some degree.

This investigation described in this paper is mostly quantitative and demonstrates some of the characteristics of small scale action research and case study approaches. It does not fit neatly into a single method - as might be expected if it was planned with an academic audience in mind. Its compensating strengths are its local contextual validity and, therefore, its potential local predictive power.

Action research in the classroom consists of one or more cycles of planned LTA interventions based upon the evaluation of preceding observations (Baumfield, Hall and Wall, 2008). In this investigation one cycle of action research was completed with each cohort. The intervention was the socio-economic approach adopted in the second session and the impact on attitudes was monitored at various stages using hand held voting devices.

On the other hand, using Bassey's (1999) reconstructed approach to educational case study, the investigation meets criteria for an educational case study:

- The research investigated a specific LTA strategy and evaluated its fitness for purpose.
- It was empirical and natural because it used anonymous cohort data collected during the planned LTA activities.
- It was concerned with a singularity limited by time and locality.
- The area was relevant to the practitioners and students.
- The study was informative and generated cautious conclusions and recommendations.

As a case study it could be questioned:

- Is there enough data collected to have confidence that all the significant features were identified?
- Plausible explanations could be constructed but how trustworthy or convincing can they be without more data?

How the research was carried out
A science subject knowledge enhancement module, Science in Society, was taught to 22 undergraduate students in their final year of a Primary/Secondary Education Honours degree with Qualified Teacher Status (QTS) and to 50 students following Graduate Diploma Subject Knowledge Enhancement (SKE) courses in Chemistry or Physics. The SKE students were preparing to take up places on Science Post Graduate Certificate in Education (PGCE) courses. The informal research was carried out during the topic, Genetically Modified Organisms (GMO).

For each topic in the module a lecturer introduced the scientific concepts involved and then set group tasks that required further research in preparation for the next session. For the GMO topic, groups were allocated and then assigned to one of a range of stakeholder roles. Each group then had a week to research GMO from that particular perspective and make the case for or against (as appropriate) during a mock public enquiry debate in the second session.

Hand held voting devices known as 'Clickers' were also used in conjunction with Turning Point 2008 software (Turning Technologies) to survey anonymously the participants' attitudes and display the results at various points during the topic. Voting occurred at the start and end of the topic for the undergraduate cohort but for the postgraduate group opinions were also sought just before the group work began. The possible implications for refining science pedagogy were discussed with the student participants and colleagues. A limited literature search was also conducted within the time constraints allowed.

Voting Results
The undergraduate group vote at the start of the topic demonstrated a range of opinion skewed towards caution with respect to the potential safety of GMO (Figure 1) but also in favour of making GMO foods available to the public (Figure 2). The use of GMO for medical purposes was strongly supported (Figure 3). After the topic was completed the distribution was bimodal for the first two questions apparently due to more 'neutrals' choosing a side (Figures 1 & 2). Attitudes to the medical use of GMO remained positive apart from a small number now expressing strongly opposing views (Figure 3). Experiencing the activities associated with this topic had apparently polarised the opinions expressed by the group.

The teaching of this module and topic to a second cohort provided an opportunity to add another opinion survey point at the mid-point in the topic before group work began. Opinions did change during the first, information based, session but the number expressing neutrality was much reduced after the group work component and debate and even reversed the trend demonstrated by the first two surveys (Figures 5 & 6). In short, the same polarisation of viewpoint after the group work was observed with both cohorts (Figures 4, 5 &6).

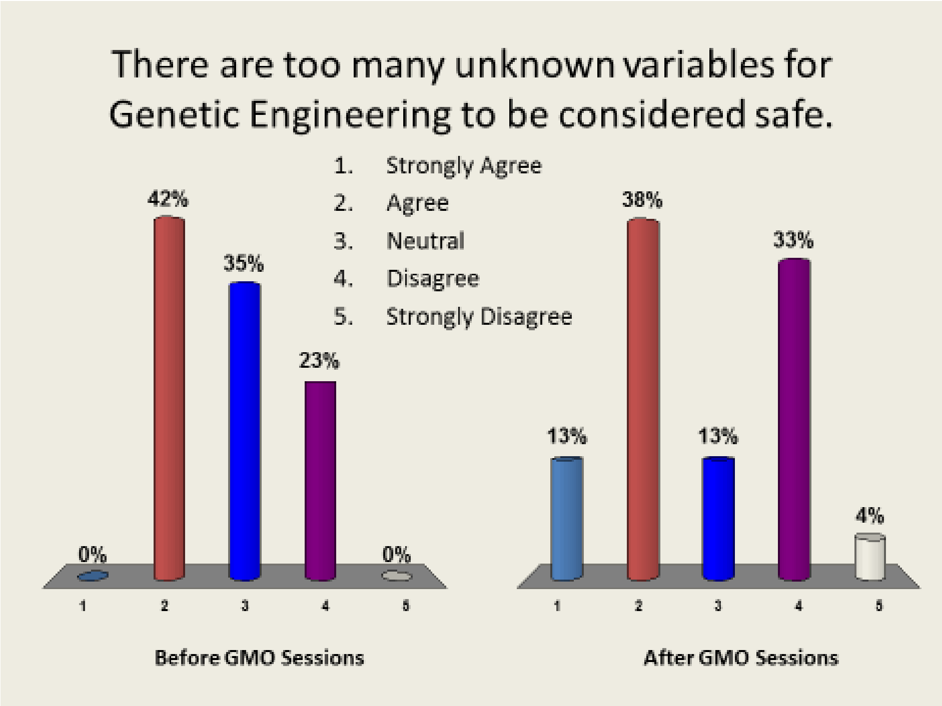

Figure 1 Confidence in the safe use of GMOs: Voting Results slide for the Undergraduate Cohort (n=22) before and after the topic

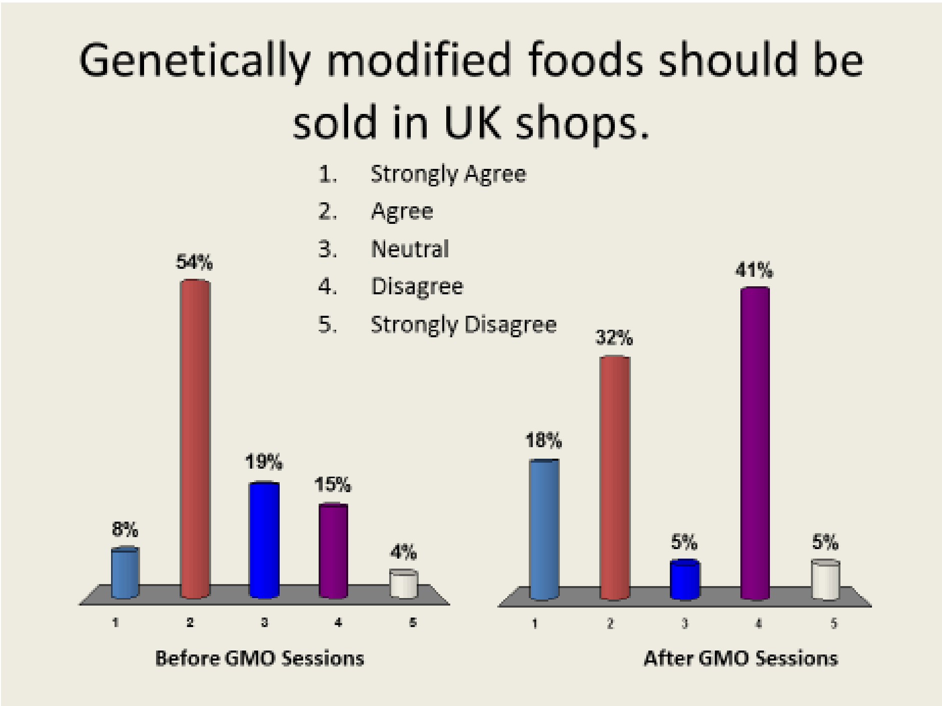

Figure 2 Use of GMOs in the human food chain: Voting Results slide for the Undergraduate Cohort (n=22) before and after the topic

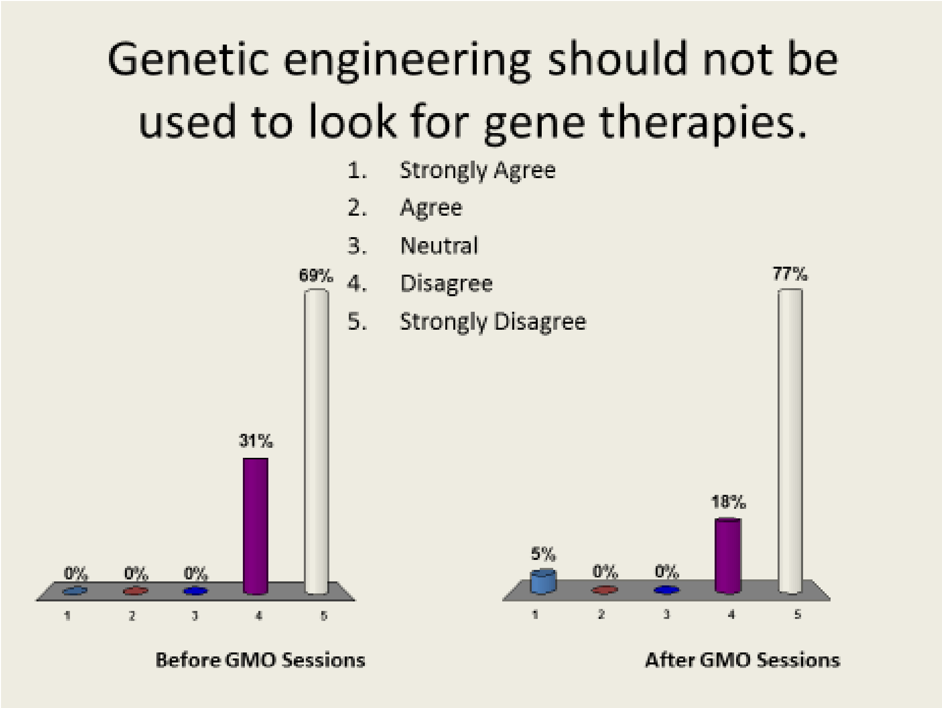

Figure 3 Use of GMOs for medical purposes: Voting Results slide for the Undergraduate Cohort (n=22) before and after the topic

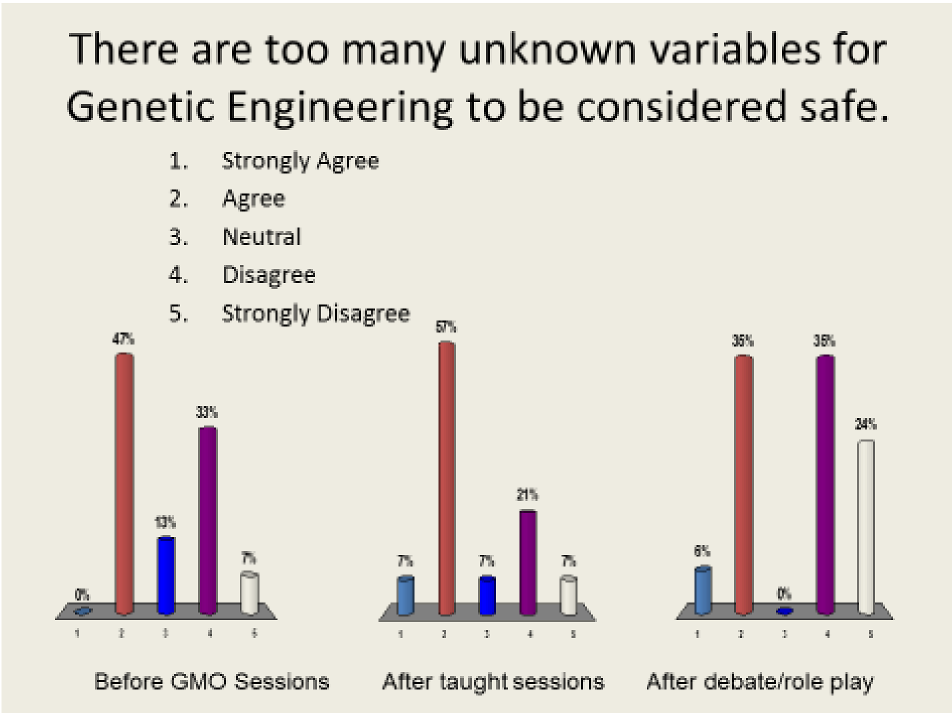

Figure 4 Confidence in the safe use of GMOs: Voting Results slide for the Postgraduate Cohort (n=50) at the start of the topic, before group work and after the topic

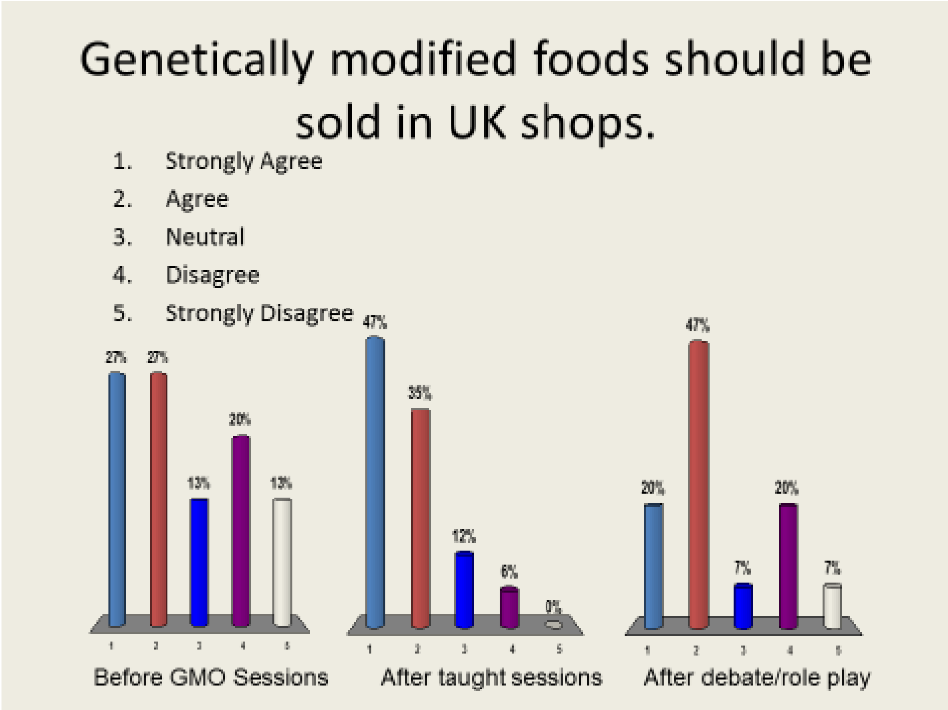

Figure 5 Use of GMOs in the human food chain: Voting Results slide for the Postgraduate Cohort (n=50) at the start of the topic, before group work and after the topic

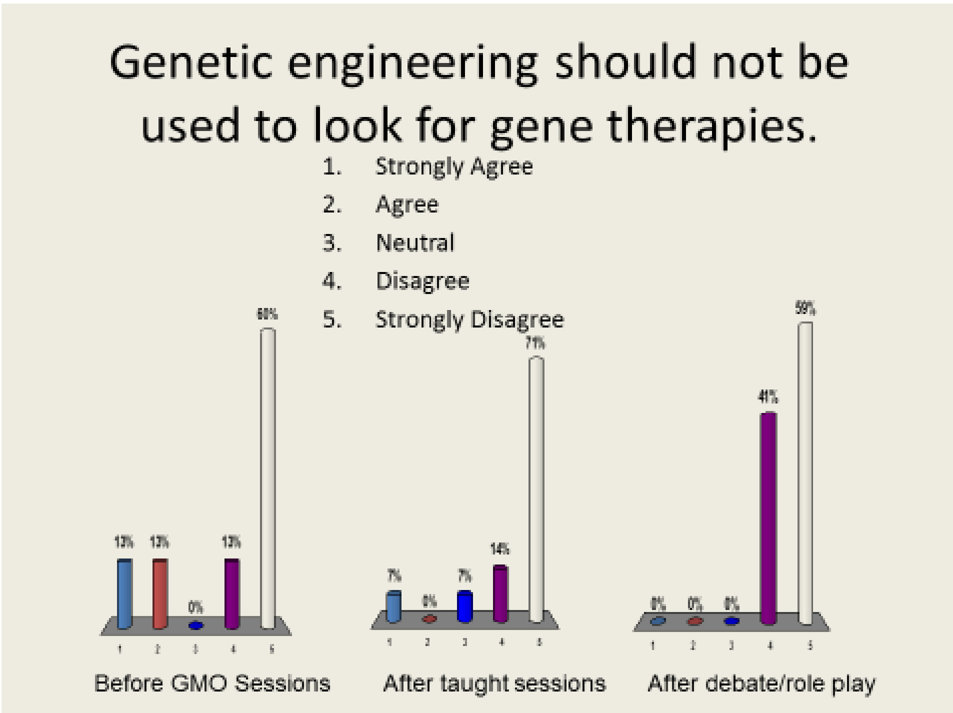

Figure 6 Use of GMOs for medical purposes: Voting Results slide for the Postgraduate Cohort (n=50) at the start of the topic, before group work and after the topic

Discussion

The module investigated was designed to enhance science subject knowledge and understanding and place it in a technological and social context. The role play/debate strategy was intended to facilitate skills involved in the explanation, feedback and dissemination of group research outcomes to the whole cohort and to demonstrate strategies that could improve scientific literacy and develop critical approaches to evidence (Simonneaux 2001).

In Cavagnetto's (2010) view, it is already established that teaching scientific argumentation improves school learners' communication skills, metacognition and critical thinking. Cavagnetto (2010) identified three main approaches to teaching pupils scientific argumentation. The use of group work and role play debate for the GMO topic was an example of the Science in Society or Socio-Scientific approach. However, Cavagneto's (2010) meta-study of 54 articles suggests that, although lessons and activities with a Socio-Scientific orientation provide authentic contexts for science learning, other approaches to argumentation may be more useful in developing all aspects of scientific literacy.

For both cohorts the group work and debate was associated with a marked polarisation of views during anonymous voting. The instant visual display of the voting results within the PowerPoint presentation and the ease of comparison over time enabled this comparison. The survey results raised many questions. Was there a link between short term voting behaviours and longer term learning? Why did individuals maintain or change their opinions? Would other groups of adult or school age learners give similar results?

Complex scientific issues like GMO require learners to consider multiple perspectives using background knowledge and understanding of a range of scientific concepts. The authors' intuition was that for such issues scientific literacy and critical thinking skills might be reflected by fewer voters expressing strong agreement or disagreement and more neutral votes. However, two cohorts of intending teachers from different programmes demonstrated on separate occasions similar polarisation in anonymous voting after completing the topic. The extra survey before the group work and debate pinpointed this as the activity most likely to be linked with this observation. As the same questions were used each time opinions were surveyed, the possible questionnaire effects would have been the same on each occasion. Therefore, it is reasonable to question either the assumptions made about the participants' voting behaviour and/or those concerning the expected learning outcomes for the LTA strategy.

Cavagnetto (2010) focused on evaluating the contribution of teaching argumentation to improving scientific literacy. He highlighted the unique competitive but also collaborative nature of scientific argumentation. In role play participants can adopt other more adversarial styles of argument in order to win the debate. The polarised voting viewpoints at the end of the second session might indicate responses to individual and group performances during the debate rather than a more critical evaluation of the evidence provided.

The voting results were discussed by students during plenary sessions and the effect of rational and irrational influences on decision making was an issue raised. The students observed that some participants employed un-scientific tactics and strategies in order to secure 'a win'. The list of students' observed and additional 'ploys' that were suggested in discussions included:

- ignoring contrary evidence and only reporting supporting evidence,
- distorting evidence,
- mis-representing the opponents' arguments,
- ignoring established causal relationships,
- reporting fictitious causal relationships and
- deliberately mixing up cause and effect.

It was acknowledged that this had caused lots of fun but not much science.
The investigation was consistent with the aim of developing critically reflective evidence based practice envisaged by Brookfield (1998, 2002). There was enough confidence in the findings to plan and recommend the next intervention in the action research cycle – the development and use of de-briefing materials to emphasise the differences between science argumentation and other forms such as political or legal argumentation.

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