education

Research Article

Development and Evaluation of an Undergraduate Science Communication Module

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Abstract

This paper describes the design and evaluation of an undergraduate final year science communication module for the Science Faculty at the University of East Anglia. The module focuses specifically on science communication and aims to bring an understanding of how science is disseminated to the public. Students on the module are made aware of the models surrounding science communication and investigate how the science culture interfaces with the public. During the module they learn how to adapt science concepts for different audiences and how to talk confidently about science to a lay-audience. Student motivation for module choice centres on the acquisition of transferable skills and students develop these skills through designing, running and evaluating a public outreach event at a school or in a public area. These transferable skills acquired include communication, interaction with different organisations such as museums and science centres, developing understanding of both the needs of different audiences and the importance of time management. They also develop skills relating to self-reflection and how to use this as a tool for future self development. The majority of students completing the module go on to further study, either a PhD, MSc or teacher training. The module can be sustained in its present formed if capped at 40 students, however it is recognised that to increase cohort size, further investment of faculty time and resources would be required.

Keywords: science communication, biological sciences, transferable skills, public engagement.

Introduction

Science communication can be defined as the popularisation of science (Davis, 2010) and it is gaining prominence at a national level with strong support from Research Councils UK (RCUK) and the Higher Education Funding Council for England (HEFCE) as demonstrated by the funding of the university Beacons of Engagement (National Co-coordinating Centre for Public Engagement, 2010; Concordat, 2011). It is recognised that for meaningful engagement between scientists and citizens there needs to be effective two way communication, understanding and learning (Stocklmayer *et al*. 2001; Brake and Weitkamp 2010). During the last thirty years the theory of how science should be communicated to the public has moved away from a deficit model of communication (where the public was seen as scientifically illiterate, or deficient in understanding) to a two-way engagement model, where new science and technology is discussed with citizens and their views are valued and recorded (Irwin 2009). This model of communication brings interesting challenges; including the mechanisms of how we as scientists engage with a diverse public. The 'public' can be defined as every person in society (Burns *et al*. 2003), but it is recognised that the concept of public is a complex mix of age, gender, race, socioeconomic status, educational and cultural background. Public engagement as concerns academia and higher education is defined by the National Co-ordinating Centre for Public Engagement (NCCPE) as the following:

> *"[Public engagement] describes the many ways in which Higher Education Institutions and their staff and students can connect and share their work with the public" (The Engaged University Manifesto, 2011).*

There has been a fundamental shift in the way that public engagement is viewed and undertaken by universities. Scientists are being asked to explain to funders how they intend to engage the public with their research in pathways to impact statements. Alongside this are the societal issues surrounding the application of science which need to be addressed (Christensen, 2007). The School of Biological Sciences (BIO) at the University of East Anglia (UEA), a Beacon University (CueEast, 2011), has embraced this change viewing it as an opportunity to develop staff and student interest in science communication. BIO is incredibly diverse in its research and investigates how biological systems work by joining together our understanding of genetic information with research on microbial, plant and animal systems. In addition, it has forged strong links with primary and secondary schools and the wider general public.

As scientists with a strong interest and experience in undertaking, delivering and valuing practical science communication to the public, the authors were ideally placed to design and provide an exciting and high calibre educational experience in science communication for our undergraduate students. The growing importance of achieving quality science communication events has identified the need for education and training at a sufficiently early level to allow science communication to become embedded as part of an academic role, akin to research and teaching. The Quality Assurance Agency for Higher Education (QAA) that provides subject benchmark statements for the design of and learning outcomes for bachelor's degree with honours, states that in subject specific skills for biosciences, students should *"engage in debate and dialogue both with specialists and non-specialists, using appropriate scientific language"*. In subject knowledge and understanding students should have *"engagement with some of the current developments in the biosciences and their applications, and the philosophical and ethical issues involved. Awareness of the contribution of biosciences to debate and controversies, and how this knowledge and understanding forms the basis for informed concern about the quality and sustainability of life."* By the time that students have graduated in the biosciences, they *should "have some understanding of ethical issues and the impact on society of advances in the biosciences"* (QAA, 2007).

There are many employment opportunities that require specific skills related to science communication, for example the UK has over 3000 museums, galleries and heritage centres, many of which deliver science communication. There is also a wealth of publications, including those offered by web-based companies, which require effective science writers. Many students also enrol on Postgraduate Certificate for Education (PGCE) courses and of course, many other career opportunities also require excellent communication skills. Currently, some other UK universities offer Science Communication modules within their science degree programmes. Examples include a new module in Science Communication for the Biological Sciences degree at the University of Exeter (Exeter University, 2011) and a level 2 module at the University of Aberdeen in Science Communication aimed at enhancing employability skills (University of Aberdeen 2011). The QAA states that students are expected to have *"some personal experience of the approach, practice and evaluation of scientific research*", but that *"It may sometimes be appropriate for students to do this kind of work in areas not strictly related to research, for example, in education or in the public understanding of science".* Some universities, for example the University of Kent, offer final year Science Communication research projects (University of Kent 2011).

Despite these curriculum developments, there is little in the education literature that explores the reasons for the establishment of these modules, the content of the modules or the impact they have on student learning and career choice. We developed, organised and successfully delivered a level three module in Science Communication that can be undertaken as part of a science degree programme at the UEA. This module was initially piloted in 2007-2008 to a cohort of nine students from the school of Biological Sciences. During the following years

students from the Schools of Environmental Sciences and Chemistry have taken the module in addition to the biological sciences students. In 2008-2009, the cohort increased to 34 and in 2009-2010, it increased again to 38 students and in 2010-11 to 40 students. We have used a mixed methods approach (Yin, 2009) within a single case study designed to address the following research questions:

- Does the structure and content of this Science Communication module expose students to the four areas of study common to all courses (Mulder *et al.*, 2008) which support the teaching of science communication?
- Does the structure and content of this Science Communication module develop transferable skills in students?
- Were students motivated to enrol onto the module; because they felt it would provide them with additional skills and experiences that would give them an advantage in their future career plan, after they graduated from UEA?
- Before they undertook the module in Science Communication, what skills did the undergraduate students think they would acquire?
- After the students completed the module in Science Communication what skills did they feel they had acquired?
- Can the structure and content of the pilot module work effectively and remain cost effective and viable with significantly higher or lower cohort sizes?

Methods

Background to Participants

Science Communication is a 20 credit optional module which appears on the degree profile for all our undergraduate degrees in the Biological Sciences. The module has run for four years, and information was collected from the students in all four cohorts (Table 1).

Table 1 *The numbers of students, the male:female ratio, their School of study; Biological Sciences (BIO); Environmental Sciences (ENV); Chemistry (CHE) and their participation in the module development from four academic years spanning 2007-2011*

Academic Year	Number of Students	Male:Female Ratio	School of Study	Participation in Module Development
2007-08	9	1:8	BIO-9	Pilot module Final destination data
2008-09	34	20:14	BIO-28 CHE-2 ENV-4	Questionnaires pre- and post-module Final destination data
2009-10	38	3:35	BIO-36 ENV-2	Final destination data Action Learning
2010-11	40	14:26	BIO-35 CHE-4 ENV-1	ARKive Page Action Learning

In the pilot year (2007-8), the students all came from the Biological Sciences degree programme. In 2008-11, the students were drawn from across the Science Faculty and were enrolled from a variety of degree programmes; Environmental Sciences, Environmental Earth Sciences, Biology with Management, Biological Sciences, Ecology, Microbiology, Molecular Biology and Genetics, Biomedicine and Natural Sciences. Students from three cohorts (2007-2010) were followed into their first destinations by using a variety of methods, including personal contact, UEA Alumni and Facebook.

Data Collection

The evaluation of this communication module is framed using the outline designed by Smith (2008) which uses an integrated process for linking evaluation and development.

Two questionnaires were used to assess perceptions of skills that students developed during this module; one pre- and one post-module. These were completed by all students (*n*=34) enrolled on the module in the 2008-9 academic year. This was the second cohort of students to have enrolled on the module and consisted of students across the Science Faculty. The questionnaires consisted of 11 questions in four sections which were answered on the first and last day of the module with a mix of Likert scale questions from one (strongly disagree) to five (strongly agree), tick boxes and free text responses. Ethical approval for the study was obtained from the School of Education's Ethics Committee at the University of East Anglia. Section one asked details on respondent gender, age, school of study and degree programme. Section two asked about motivation for enrolling on the module, where questions had tick boxes against set options and an option for a free text response. Section three asked about expectations of the module with tick boxes against set options, an opportunity for a free text response and a Likert scale question on how much the students though they would enjoy the module. Section four asked for information about career ambitions upon completing their degree; there were tick boxes against set options with an opportunity for a free text response. The full questionnaire can be found in Appendix one. Analysis of the free text responses provided to questions two, three and four of the questionnaire was undertaken. An initial, simple text analysis using a quantitative approach was undertaken by creating a 'wordle' document (Wordle 2011). In addition, an in-depth qualitative evaluation was undertaken by each co-author independently by performing a thematic analysis of the responses. The themes defined by each investigator were compared and, after discussion, a consensus was reached.

The process of self-reflection in the form of a personal diary maintained by the module organiser was used to comment upon the effectiveness of the pedagogical approaches developed in this module. Written permission from the students was obtained to reproduce their work and evaluations in this paper in accordance with local ethical rules.

Science Communication Module Structure

The module is designed to reflect the research that underpins the growing discipline of science communication and it includes specific case studies presented by research-active staff. There are three strands to the module design; the lecture programme, a project and the evaluation of the project, which includes self-reflection and action learning (see Table 2). This module takes an outcomes based approach to teaching and learning assessment. Upon completion of this module students should be able to:

1. discuss how science communication in the UK has been shaped by historical institutions such as the Royal Society;
2. recognise the models surrounding science communication theory;
3. recognise learning and communication theories;
4. describe how science is communicated to the public through the use of case studies, such as genetically modified (GM) food and the Bovine Spongiform Encephalopathy (BSE) crisis;
5. demonstrate an ability to communicate science to a public audience;
6. learn to draw information from a wide variety of sources, e.g. the primary literature, reports from the Government and Research Councils, the internet and public health leaflets; and
7. develop a set of professional and transferable skills in communication, time management, event design, organisation and administration.

Table 2 *The final year science communication module has a three stranded pedagogy*

Lecture Programme	Project	Project Evaluation
History of modern science	A public or school engagement event	Questionnaires
Theories of learning and communication		Participant observation
Models of science communication	Design of communication materials	Self reflection
How the public culture and science culture interface		Action Learning
Specific case studies e.g. Stem Cell research, GM food, BSE crisis, Bird Flu		

The assessment strategy and how this links to the learning outcome and examples of the relevant QAA benchmark statements are shown in Table 3.

Table 3 *Assessment profile of the final year science communication module related to example(s) QAA benchmark statement(s). *Introduced in 2010-11*

Assessment	Weighting	Relation to learning outcome (see numbered outcomes)	Direct Quotes from QAA benchmark statement(s) (QAA, 2007)
Essay Proposal	Formative	1;2;3;4;6	- "the ability to think independently, set tasks and solve problems"
Essay	25%	1;2;3;4;6	-"have some understanding of ethical issues and the impact on society of advances in the biosciences"
Oral Presentation	10%	4; 5; 6;7	-"communication, presentation and information technology skills"
ARKive Page*	15%	5;7	-"use the internet and other electronic sources critically as a means of communication and a source of information"
			-"communicate about their subject appropriately to a variety of audiences using a range of formats and approaches, using appropriate scientific language"
Project Report	50%	1;2;3;5;6;7	-"develop the skills necessary for self-managed and lifelong learning (e.g. working independently, time management, organisational, enterprise and knowledge transfer skills)"

Lecture Material, Case Studies and Assessment

The lectures covered the history of science, communication and learning, the models of science communication to the public, science culture and risk perception. The theory was underpinned by specific case studies, looking at areas of scientific controversy, e.g. GM foods, BSE crisis, badger culling and bovine tuberculosis, stem cells, nosocomial infections and climate change. Guest speakers came to talk about science communication in different organisations, e.g. schools, museums, science centres and charities. The summative assessment associated with this strand of the module was a 2000 word essay based on one of the case studies. An essay proposal (formative assessment) was written which was discussed and refined. The essay was then written and subsequently presented in a ten minute talk. Thus a traditional form of HE assessment, the essay, was transformed into a learning experience supporting the development of knowledge, critical thinking, awareness, oral communication and timekeeping, all recognised employability skills (CBI, 2009).

The Project

For project allocation, students submitted a first and second choice of title. Over four cohorts, all students were allocated their first choice. A variety of projects have been offered over the last four years (2007-2011) and these include:

- Public events at the Norwich Castle Museum -'Norfolk Science Past and Present' in 2008-9, 'Norfolk Rocks' in 2009-10 and 'Look Who's Talking' in 2011
- Science club for year 6 (Key Stage 2) at Avenue Junior School (with pupils working towards a British Science Association Bronze Crest Award) in 2008-10
- Helping to design an interactive area for the newly refurbished Natural History gallery at the Norwich Castle Museum
- Video clips of research in our Biomedical Research Centre, for the Big C (local cancer charity). For this and the next project the students were given a day's training at BBC Voices at The Forum in Norwich (BBC Voices, 2005)
- Documentary production of climate change and the Norfolk Coast (BBC Voices, 2005)
- Organising and running a DNA mutation event at Hethersett High School for Key Stage 4
- Turning research generated images into postcards
- Editor of the newly established 'Science Gossip Magazine'
- Public event at the Inspire Discovery Centre themed around the human body in 2007-8 and around colours in 2009-10
- An event for 'gifted and talented' pupils on the ethics of natural history collections a collaboration between the Norwich Castle Museum, BBC voices and the UEA outreach office
- Key Stage 1 activity day on the human senses at Heartsease Junior School

The types of project were varied, but they all had to include the following on which the students were also assessed:

1. an understanding of the models of science communication;
2. a design component which has to be embedded in the light of learning theory;
3. a developed resource e.g. activity resources, lesson plans, DVDs; and
4. a self-reflective component to the individual report where the student reflects upon the design and delivery of the project.

Projects had one primary supervisor and additional support from other members of Faculty. The projects were double-marked by the primary supervisor and another member of Faculty who supported the projects as a second assessor. Students submitted a project report (5000 words) that had a common structure based on the bullet points above. There were clearly defined marking criteria (Table 4) and examples can be found on the UK Centre for Bioscience website (Bioscience, 2009).

Table 4 *Marking Criteria for the project component*

		5	4	3	2	1	
Appraises the models of science communication and apply the models to the project component	Project report clearly demonstrates that appropriate model is clearly applied to the project						Inappropriate knowledge of model and does not apply model to project
Provides background to the organisation (eg School, Museum, Science Centre) hosting the project	Background information provided, is well structured and comprehensive						Background information is scanty and poorly structured and inaccurate
Discusses the scientific context and relevance of the project	Provides a thorough and detailed discussion that is well organised and relevant						Scientific context is poorly discussed, lacks detail and relevance
Discusses project design, and relates design to learning styles of participants	Able to clearly discuss how learning style of participants has influenced design of project						Demonstrates a lack of awareness of participant learning styles and a lack of detail about project design
Evaluates project	Project evaluation, is clear, informative, detailed and insightful						Evaluation is lacking or confused, shows little insight.
Demonstrates independent thinking, and self reflection. originality	Report clearly shows candidate has demonstrated originality or independent thinking and has used self reflection						Report lacks independent thinking or originality, self reflection is not apparent.
Creation and generation of project report and associated project materials.	Excellent quality, fit for purpose, show originality and effort						Poor quality, not fit for purpose, lack originality and effort
Develops attractive materials which have visual impact	Attractive with visual impact						Unattractive and lacking visual impact
Synthesises meaningful conclusions	Provides excellent interpretation and insight						Weak or lacking interpretation and insight
Management of the 5000 words length	Well organised						Not well organised
Demonstrates evidence of background reading and ability to reference well and provide appropriate citations	References are correct, appropriate and well presented						References are incorrect and incomplete, inappropriate and badly presented.
Comments and overall assessment							

Results

Student demographic and sustainability of the module

Since the introduction of the module as a pilot with nine students, in 2007/8 the numbers have increased fourfold (see Table 1). In the current academic year (2010-11) 40 students are enrolled, representing 23% of the Biological Sciences cohort. The continuing interest in this module suggests attracting sufficient student numbers to ensure the module remains financially and educationally viable in the future is unlikely to be an issue.

Apart from the 2008/9 academic year, the module seems to appeal more to females than males. Over four cohorts, twice as many females enrolled, significantly greater than the background ratio of male:female students enrolled in the School of Biological Sciences (χ^2 =5.64, df =1, $p < 0.05$).

Motivations for taking the module

Student motivations to choose various modules can be varied and there is paucity about this in the literature. In this study the pre-module questionnaire asked the students directly why they chose the module and overall 74% said that it sounded interesting, 84% recorded that they wanted to gain experience in science communication. Only 7% said it was because they couldn't think of anything else to do. This result indicates that students were genuinely interested in and were keen to gain experience of science communication. Analysis of the free text comments provided by students outlined the motivations that underpinned the students' decisions to undertake this Science Communication module. The opportunity to examine the way that scientists communicate science to the public appealed to the students. They also showed an interest in gaining an understanding of '*how science is viewed by the public'*. A preconception of the public's view of science was also indicated '*the public are generally ignorant of science*' but this was countered with the aspiration that '*this needs to change'.* As well gaining an understanding of science communication issues, other reasons for undertaking this module were captured. There were students pursuing alternative career paths to scientific research, in particular a career in teaching. These students felt undertaking this module would help them to make a more informed choice about alternative career options '*to see if (I) possibly want a career in teaching*' and they would gain valuable experience and skills that they would use in their future career '*I wanted to […] possibly learn some teaching skills*'.

A more general desire was the belief that this module would '*give an extra edge'* when it came to achieving career goals. Students had also chosen to take this module because they felt that it would '*appeal to my interests*' and that the module was providing an alternative to the purely science rich content of the other modules within the science degree programmes; it offered something '*interesting and different*'. Finally it was clear that students felt this module provided an opportunity to develop transferable skills. In particular students identified that this module would provide an opportunity to '*gain confidence in communication skills*'. Similarly, it was felt that this module would allow students to develop transferable '*organisational and presentation skills*'.

Skills development

Providing modules which develop a range of employability skills is a key component to curriculum design. An important aim embedded within the development of this module was to encourage students to develop these skills. We sought to assess how successfully this had been achieved by asking the students to provide feedback using the questionnaires. Students were asked what skills they thought they would develop prior to undertaking the module. They were then asked what skills they felt they developed after completing the module.

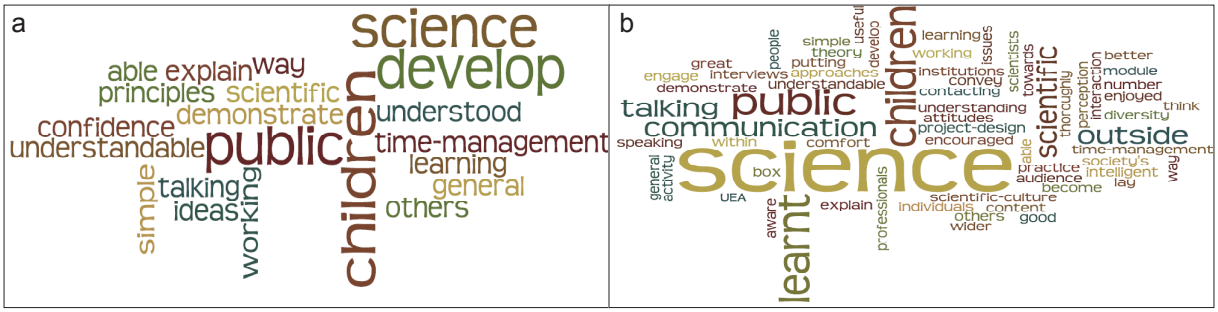
From the data in Table 5, although 88% felt they would develop skills in interacting with outside organisations, such as science centres and museums (pre-module) only 56% felt that they developed these skills post-module. This may reflect the fact that not all projects undertaken by the students involved working with outside organisations. It's interesting to note that only 25% of the students felt that they would develop independent learning before undertaking this module; however post-module 56% felt that had these skills. All projects involved a written component; this skill was felt to have been acquired by 69% of students after the module, an increase from the 44% of students that thought they would develop this skill prior to undertaking the module.

Table 5 *Responses to the question "What skills will you develop", contrasting pre- and post-module surveys*

Skill	% response pre-module	% response post-module
Writing	44	69
Speaking in groups	81	44
Oral presentations	67	38
Designing display materials	70	69
Constructing an argument	59	31
Working in a team	81	63
Independent learning	25	56
Working with outside organisations	88	56

A caveat to the study was the small sample size, 27 out of the 34 (79%) students enrolled on the module in the 2008-9 academic year did the pre-module questionnaire but only 16 (47%) completed the post-module questionnaire.

Unfortunately given the low response rate to the post-module questionnaire, it's difficult to see from the responses if the module had improved skills, but the initial results suggest that skills such as '*speaking in groups*', '*oral presentations*' and '*constructing an argument* did not meet student expectations. The students were also asked to provide additional information about what other skills they expected to develop and what skills they did develop as a free text comment. A wordle of the main themes in the free text comments provided by the students prior to undertaking the module is shown in Figure 1a. Larger words represent most frequently used words; public, children, science and develop were the most frequently used prior to undertaking the module. Figure 1b shows the main themes in the free text comments provided by the students after completing the module.



Figures 1a and 1b *'Wordle' of free text responses to the questionnaire given to student pre- module (a) and post-module (b)*

It is clear that the most frequently used word was science. However the second most frequently used words were public, children and learnt. Further qualitative analysis of the free text comments received from students, prior to undertaking the module indicated that one of the skills they anticipated developing was '*working with children'*. After completing this module it was apparent that this module had been successful in allowing students to develop their

skills in this area '*I learnt to engage with children better'*. Developing science communication skills was also highlighted. However these communication skills were specifically related to interactions with the public as opposed to others within the scientific community '*learning how to develop scientific ideas/principles to be understood by the public*'. It was clear that the students recognised that for science to be communicated effectively to this audience, complex scientific ideas need to be distilled and explained to the public in 'a *simple understandable way*'. After completion of the module some of the students indicated that they had developed these skills, one example being the response '*I learnt how to convey scientific content to an intelligent lay audience*'.

Finally, one of the students indicated that they hoped to gain the transferable skill of time management. Analysis of the comments left by students upon completion of this module indicated that time management skills had been developed but, in addition, the transferable skills of project design and 'interview skills were also listed. In addition to the skills that the students had highlighted prior to undertaking the module, they reported acquiring deeper insights into the role of scientists within the scientific community, for example '*I learnt about scientists as individuals within a 'scientific culture*' and in addition '*the diversity of their approaches and attitudes towards science and the public*'. An increased awareness of '*society's perception of scientific issues*' was also described. Both the theoretical and the practical components of the module were linked by at least one student who described taking the information that they were taught about communication theory and putting this '*into practice with the activity'.* This module had also given students the opportunity to interact with different '*professionals and institutions outside of UEA'*, which they both enjoyed and valued.

The projects were chosen by the students, and their choice was probably influenced by the skills they wished to develop, for example a student wishing to train as a teacher could be more likely to choose a project associated with a school. The comments on skills post-module may also reflect the skills they developed whilst designing and delivering their projects. Students were also asked what specific subject areas they expected to learn pre-module and what they did actually learn (post-module), the results are presented in Figure 2.

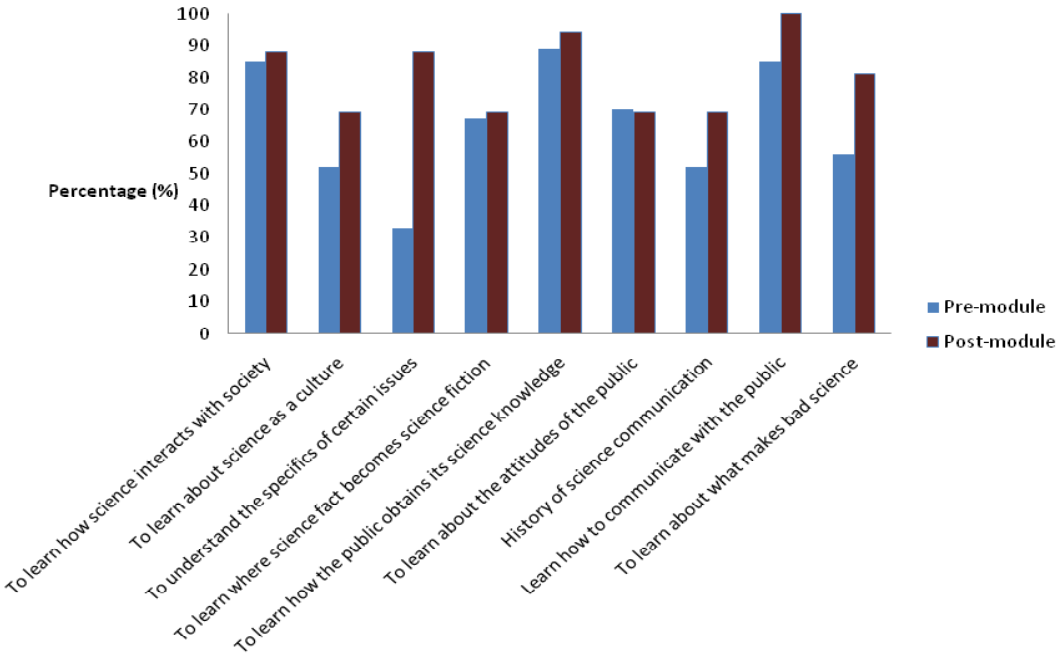


Figure 2 *Specific areas students expected to learn about on the science communication module garnered pre and post module*

From the data shown in Figure 2, it was pleasing to see that 100% of the students felt that they had learnt how to communicate with the public. Interestingly, the one area which increased dramatically post-module was their understanding of the specifics of certain issues, such as the BSE crisis, which formed the case study component of the module design. Prior to this module the students didn't expect to learn about these societal issues.

Expectations of the module

Using a 5 point Likert scale, the students were asked how much they thought they would enjoy and did enjoy the module. Students started with high expectations of the module (mean = 4.28) but we were pleased to see that they had enjoyed it even more then they expected (mean = 4.63). Using a Wilcoxon rank–sum test this difference was found to be significant (z = 2.03, df = 1, $p < 0.05$). Observations from teaching the students during the case studies (as recorded in the module organisers self-reflective diaries) indicated that students were engaged with the module and its content and willing to take part in discussions. When asked to pick one word or phrase from a list which described the module, 40% of the students said it had been 'thought provoking' and 33% 'stimulating'; 20% said 'pleasurable' and 6% 'hard work'.

First destination of students

To best uncover the first destination of our students from the 2007-10 cohorts, we stayed in touch with the majority of them through a variety of methods, including using personal contact, the UEA Alumni database and Facebook.

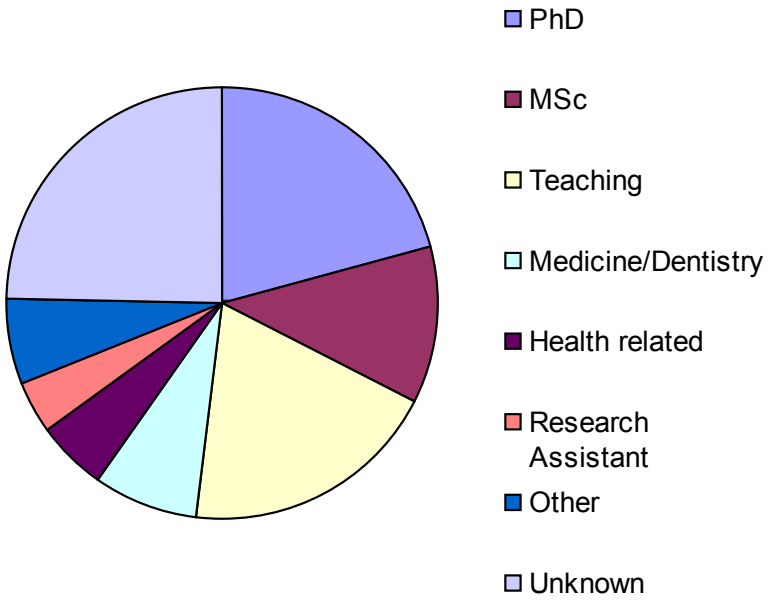


Figure 3 *First destination of every student completing the science communication module from four academic years spanning 2007-2010*

The data were collected from three cohorts of students from academic years 2007-2010 (Fig 3). Those that completed the science communication module (n = 77) and indicates that the majority of students (60%) do further study after completing their degrees, most often a PhD. MSc or PGCE (teaching qualification). One student went on to do a Science Communication MSc programme and has since graduated successfully and another gained employment on a science communication project funded by The Wellcome Trust. Students reported that during PhD interviews, they were able to talk with confidence about the importance of public engagement with science and were able to use their projects as useful discussion material. Interestingly there were several students who applied for PhD studentships within the School of

Biological Sciences at the UEA. The interview panel noted that students who had undertaken the science communication module did well and 'better than average' during the interviews. It has been recorded that '[science communication students] *have done very well and better than average during PhD interviews when we ask them about general science topics they are interested in and particularly when we ask them about communication – e.g. how do scientists do that (trying to get at the full range of communication) and what experience do they have of doing it. This is a marked feature of these interviews and we all have noticed it*.' BIO PhD interview panel at UEA.

Discussion

It is crucial that interdisciplinary modules such as the one described in this paper, have academic rigor. A study by Mulder *et al.* (2008) examined the content of postgraduate science communication courses from 19 universities across ten countries. They identified four areas of study common to all courses which supported the teaching of science communication. Firstly, the area of science; many of the courses were part of science departments (especially in Europe), there is scientific knowledge which is needed and courses require a first degree in a science discipline. Secondly, educational studies; students were taught how to explain scientific issues to a non-scientist. Many of the courses also covered theories of learning. Thirdly, social studies of science; here the material covers the transition of a 'deficit' model of science communication to a 'dialogue' model. Many courses also covered risk analysis and scientific controversies. Finally, communication studies covered the interpretation and communication of scientific issues. Several science communication courses examined the role of the media.

The module discussed in this paper, which was designed for level three undergraduate degree students from the Science Faculty does address all four major content areas however it is delivered at an earlier time point within a student's career. Students enter the module with a strong science background, coming from a variety of degree programmes across the Science Faculty, including biological sciences, biomedicine, chemistry, ecology and environmental sciences. However the finding that significantly more females have taken the module over the last four years, is perhaps not a surprise. It is documented that science communication is a female dominated profession (Metcalfe and Gasgoine, 2004). Bubela *et al*. (2009) state that graduate science students should be trained in communication with the media and diverse publics and that as potential future spokespeople of science they should be aware of the political and societal contexts of science. A good example is the science communication module at the University of Edinburgh which offers post graduate PhD students an opportunity to learn about the ethical, educational and political issues surrounding science communication. At Edinburgh University PhD students are also encouraged to become involved in diverse public engagement events, including workshops and after school clubs for primary schools (King, 2004). We have taken this approach further by embedding science communication opportunities at an earlier stage; in the undergraduate degree curriculum reflecting the statements of the QAA that students should be offered these opportunities as part of a science undergraduate degree programmes (QAA, 2007).

The literature concerning the teaching of science communication to science undergraduates is scanty. In a paper by Edmonston *et al*. (2010) undergraduate biotechnology students in Australia were canvassed for their views on science communication. The results suggested that the students didn't value communication with non-scientists or science communication training. However, the authors point out that there was little communication training embedded within the degree programme and that more needs to be done to incorporate science communication training within the undergraduate curriculum and to enable students to become aware of its importance. This is a view shared by Bonfiglioli *et al.* (2009), who introduced

science communication skills into a first year undergraduate physics course. In this initiative students were given audio and visual material based on the physics research at the University of Sydney and the students were then asked to write their own perspective on the research based on this material. This not only allowed the development of written communication skills, but also enhanced the teaching research symbiosis by allowing students early access to research.

The projects offered on our module also contribute towards research-led teaching. This is defined as teaching which is heavily informed by recent or cutting edge research, and research with or by students (Zamorski, 2000; Griffiths, 2004). This is illustrated by a project in which images generated through the research in the school were turned into postcards, promoting BIO's research and degree programmes, enabling not only the student who designed the cards, but other undergraduates to feel more in touch with the research in the school. Another example is the 'Science Gossip Magazine' designed and edited by undergraduate students. It carries research articles written by staff and students, again enabling dissemination of research to a wider undergraduate audience. In a project at Manchester Metropolitan University, undergraduates are encouraged to link science and art (Verran, 2009). The assignment was to work on a 'product' that links microbiology with art; showcasing the beauty of microorganisms. The displays are then used in exhibitions for the public. The evaluation of this teaching initiative suggests that students develop many employability skills, such as time management, negotiation, oral and visual communication. Similarly the work produced by our students provides useful examples of skill development for CVs, portfolios and job interviews and indeed, the usefulness of being able to demonstrate involvement in science communication in interviews was apparent in our study.

In 2010 there was a Eurobarometer survey (2010; N^{o} 304) looking at employers' perception of graduate employability. In rating skills and capabilities, team working skills were highlighted as the most important (67%), followed by sector specific skills and communications skills at 62% and 60% respectively. A review of the literature surrounding student engagement with the community shows that this type of engagement provides students with opportunities to develop citizenship, employability, resilience, problem-solving and self-motivation (Mason O'Connor *et al.* 2011).We agree with Miller's' view that scientists need to engage with the public. *"This century will bring exciting biomedical advances thanks to stem cells and genetic engineering. If scientists want the public to grasp the meaning of these developments, they need to start getting personally involved in improving the education system".* From Miller (2011).

Taking science to local schools and to the community is receiving recognition within Higher Education (HE), with the funding of the university Beacons of Public Engagement. It's important that future scientists see engagement as an activity that is part of their role alongside research and if in an academic environment, teaching, although it is recognised that there are barriers to engagement as outlined by the National Co-ordinating Centre for Public Engagement (NCCPE, 2010). The funders of research in the UK have recently drawn up a set of principles for engaging the public with research: the Concordat. *"The signatories of the Concordat recognise the importance of public engagement to help maximise the social and economic impact of UK research"* (Concordat, 2011). In addition the recent manifesto for public engagement drawn up by the National Co-ordinating Centre for Public Engagement (NCCPE) specifically mentions the importance of students in this process and how engagement can enrich the curriculum. Mason O'Connor *et al.*, (2011) found that student community engagement enhances graduate attributes and they suggest it is an important component of the modern university.

The module described in this paper not only trains potential young scientists and teachers as communicators it uses science communication as a vehicle to enhance transferable skills.

According to Murphy (2001) and Scott (2004) transferable skills can be divided into the following areas, communication, application of number, information technology, problem solving, working with others and improving own learning and performance. As a final year student in a science-based degree programme students have already acquired experience in these areas. It is clear that their motivations for choosing the module included the desire to improve transferable skills. Communication, interaction with the public, teaching skills, work experience and time management were all mentioned as drivers for module choice. The responses given post-module on skills acquisition indicated that students felt they had benefited from the module and gained valuable practical experience in communication. In addition, where the project was appropriate, they had gained experience in working with outside organisations. In undertaking their project, students had to reflect upon the design and delivery of their project and time management skills as well as consider the needs of their audience. These are important employability skills as determined by the Eurobarometer Survey (2010).

The self-reflection section of the assessed report on the project encouraged students to think about how they had developed themselves and their skills through the process. Initial observations of the module organiser with the first two cohorts of students, was that the self reflective aspect of the module could be improved; more structure was needed to enable students to gain self reflective skills. To aid with encouraging self reflection the method of action learning as described by Marquardt (1997) was introduced in 2009. The students were divided into action learning sets and each student took a turn at being the 'problem holder', where they shared issues and or concerns related to their project. They listened to questions and explored the implications of what was suggested by their action learning set. This method generated ideas and encouraged reflection using the power of questioning, rather than by giving advice. The questions are not a quest for solutions but aim to encourage a deeper understanding of the issues involved a reflective reassessment of the problem and an exploration of the ways forward for the problem holder.

The number of undergraduates from our cohorts going on to do science-based MScs, PhDs and research assistant positions post module is 36%. Science communication modules, such as the one described in this paper, can positively influence how students perceive the important of public engagement. It would be of benefit if all young scientists enter their scientific career with a mindset that would enable them to be more confident about being involved in science communication. Modules such as the one described in this paper could give confidence to design their own quality communication events in the future. It is also recognised that communication is a more general employability skill (Eurobarometer 2010) and it would be beneficial if all students graduated with experience in this area. A difficulty in achieving this however, is being able to offer such a module to a entire cohort which has a large number of students (n>100). The module described in this paper is capped at 40 students, if it were to become a core component of study, more projects would have to be offered and more staff would need to become involved.

Currently the projects are the most time consuming and time intensive strand in the module. The projects are principally supervised by one individual with expertise in the area of science communication. In order to enrol more students onto the module, students would have to be split into smaller seminar groups to discuss the case studies, more project supervisors would be required and this would involve the investment of more faculty time and resources. A different module structure and the assessment strategy would also need to be reviewed. The new Science Communication module at Exeter University, does not include a project component (pers. comm., Dr Nicola King), and this could be explored as an alternative model. This would ensure the sustainability of the module, but would not provide the breadth of experience offered by this module at the present time. In its current format this module successfully delivers the

areas of common study to all courses which teach science communication (Mulder *et al*., 2008). Students demonstrate that they have gained transferable skills and their motivations to enrol on this module are linked to the development of these skills.

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