SRHE Society for Research into Higher Education

Final Report: *Enhancing employability and building bridges: Evaluation of public engagement opportunities within undergraduate STEM curricula*

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The aim of this research was to determine the extent to which public engagement activities are embedded within UK STEM undergraduate curricula, the nature of these activities and to identify best practice.
To fulfil this aim, the project objectives were to:

1. Undertake a review of the educational, STEM communication and public engagement literature to identify examples of student public engagement activities in STEM undergraduate curricula, both within the UK and overseas
2. Identify credit bearing modules within UK STEM undergraduate programmes in which enrolled students undertake public engagement activities
3. Collate and disseminate good practice by inviting module managers to contribute case studies to the project.

For the purposes of this project, the following definitions were utilised.

Outreach: activity of providing services to populations who might not otherwise have access to those services.

Service learning: method of teaching that combines formal instruction with a related service in the community

Public engagement: ways in which the activity and benefits of higher education and research can be shared with the public.

Objective 1: Systematic review of the published literature

The principal publications databases for STEM subjects (BIOSIS Citation Index, BIOSIS Preview, Engineering Village, Medline, PubMed, ProQuest CSA, Scopus, SportDiscus, Web of Knowledge, Web of Science) were searched (16/5/13 – 4/6/13) for publications which described credit bearing STEM communication training, public engagement, outreach or service learning modules within STEM undergraduate curricula, either in UK and globally. Modules which provided students with experience or training in communicating within their discipline were excluded.

271 full publications were identified which, from their titles and abstracts, appeared to meet the above inclusion criteria. These were evaluated by the reading of the full paper, excluding those (n = 129) either that didn't meet the inclusion criteria (STEM, undergraduate, public engagement etc., credit bearing module) or where the abstract contained insufficient detail to evaluate it and the full paper was not available at the University of Leeds. From the remaining 127 papers (Appendix 1), details of subject, type and nature of activity, programme level, assessment methods, audience and country were extracted and this information recorded in a spreadsheet.

The majority of opportunities discovered were provided for students enrolled on science programmes (61%) followed by engineering (22%, Figure 1A). This provision was largely by North American HEIs (USA & Canada, 94%), with limited published opportunities within European (n=5, UK, Ireland & Spain) or Australian (n=2) HEIs.

Students predominantly undertook service learning (79%, combining formal learning with a related service to the community), or outreach (16%) activities, the latter typically activities in schools.

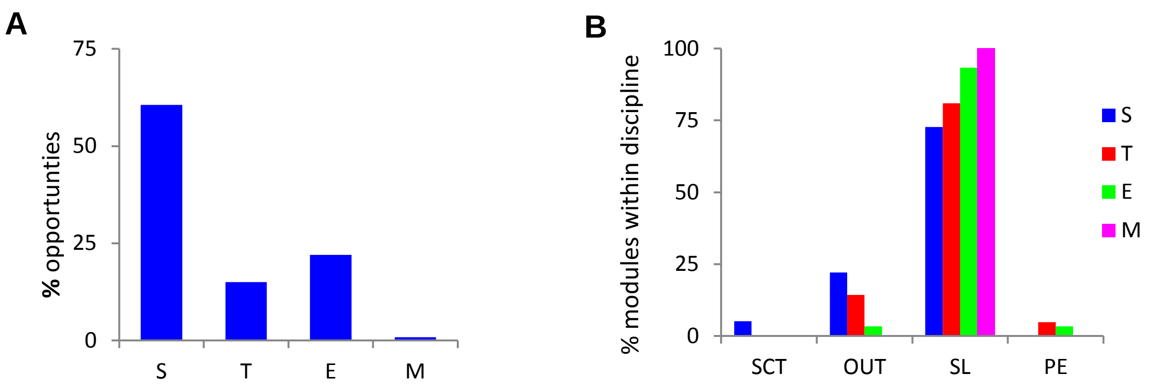

Figure 1: Evaluation of STEM undergraduate credit bearing science communication training, public engagement, outreach and service learning modules within the published literature. A: Distribution between STEM disciplines, B: Nature or type of activity across disciplines.

There was limited evidence of STEM communication training or public engagement opportunities (Figure 1B). Within individual disciplines, 93% of opportunities in engineering were service learning. In contrast, within the sciences, service learning only contributed 73% of opportunities, with 22% of opportunities being outreach (Figure 1B). Across the disciplines, 90% of all activities were actually delivered to their target audience rather than being virtual (i.e. created but not delivered). The audiences for service-learning were predominantly disadvantaged sections of the local community. In many cases the service to the community was both extensive and exceptional. It also involved substantial use of knowledge, skills and learning by the participating students. Notable examples include:

- The design and development of assistive devices for physically challenged clients (e.g. Prosthetic limb for Afghan refugee)[1]
- Designing, developing and implanting solutions to biomedical problems in the Developing World (e.g. Diagnostic Lab-in-a-Backpack)[2]
- Solving community geological, engineering, or environmental problems (e.g. designing and building a storm water management system for a local school)[3]
- Solving technology-based problems for local community service organisations (e.g. develop and construct a multimedia education centre for the local zoo)[4]

The majority (82%) of the identified opportunities or activities formed a component of a larger theory or laboratory module (82%). The remainder were stand-alone Final Year or Capstone project (9%), outreach (2%), STEM communication training (2%) or other (4%) modules. Opportunities were not restricted to upper level students (3rd/4th Level), but were available to Freshman (1st Years) up to Seniors (Final years). Given that most opportunities were from the USA, individual opportunities were available to students across multiple years and from disparate disciplines, usually working in small groups (4-12). This combination of different knowledge, skills and background provided substantial benefit to both the student learning experience and the outcomes of individual activities (i.e. what could be achieved).

Details of assessment methods were obtained from 52 publications. The predominant form of assessment being the successful creation of the project deliverables (Figure 2).

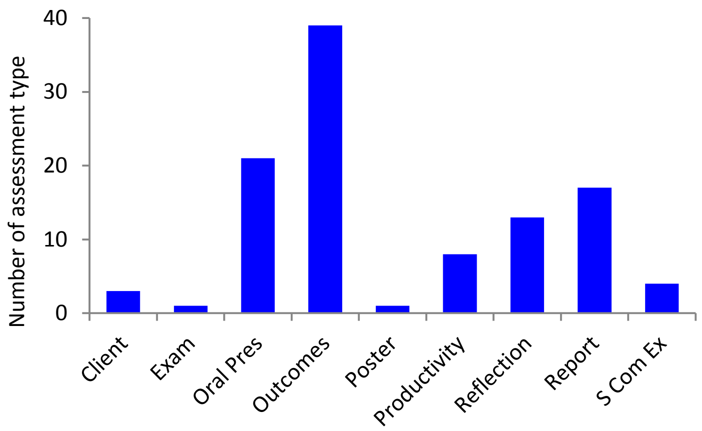

Figure 2: Methods of assessment of outreach, service-learning and STEM communication modules in the published literature. .

Objective 2: Credit bearing public engagement, outreach, service learning or STEM communication modules within UK STEM undergraduate curricula

Analysis of the UCAS directory entries[5] for the 127 English Higher Education Institutes (HEI) listed identified 94 HEIs which offered undergraduate or integrated Master's degree programmes in STEM subjects. Stand-alone taught postgraduate courses were excluded from this research. The definition of STEM subjects is not fixed and therefore, for the purposes of this research, a restrictive definition was utilised, namely those subjects coded A-K within the Higher Education Statistics Agency/UCAS Joint Academic Coding System (JACS)[6] excluding Medicine, Dentistry, professions allied to Medicine and, for example, B.Sc.'s in Planning and B.A., but not B.Sc., programmes in Geography.

In April 2013, four educational research internships[7] were advertised to all undergraduate students in the Faculty of Biological Sciences, University of Leeds; these internships to be undertaken in the 3 weeks after their June 2013 examinations so as not to interfere with their academic studies (Appendix 2). Following review of the applications received, four students who has just completed their final year were selected based on their skills and research experience (e.g. completed final year dissertation, interest in/experience of science communication and public engagement, previous internships/work experience). Training was provided for them in the form of a workshop and guidance notes. On their own initiative, the interns established a closed Facebook group for the project to facilitate collaborative working between themselves, and to enable myself to provide them with further support and guidance throughout the project. The interns evaluated the programme catalogues and underlying module catalogues of 87 out of 94 HEIs identified in the UCAS catalogue search for examples of credit bearing modules which provided student education or training in STEM communication or opportunities within the curriculum to engage in public engagement, outreach or service learning activities, putting this data into a spreadsheet. This data was reported in the project interim report (Sept 2013). An additional intern, a 2nd year neuroscience student, was employed from November 2013 to search the module/programme catalogues of the remaining 7 HEIs and re-evaluate some of the existing data

Analysis of the programme/module catalogues of these 94 HEIs identified 48 (51%) institutions which offered their students one or more opportunities to enrol on public engagement, outreach, service learning or STEM communication training modules. Whilst these Institutions represented a complete cross-section of UK HEI's (e.g. 16 Russell Group, 21 Post-92, 9 94 Group), the majority of 301 identified programmes were provided by a restricted group of Institutions (e.g. Sheffield 65; Manchester 20; Southampton Solent 17; Exeter 16; Leeds 15). Further, the availability of public engagement, outreach, service learning or STEM communication training modules within UK undergraduate STEM curricula is limited; these 301programmes comprising of only 12% of the 2542 STEM undergraduate degree programmes collectively offered by the 94 STEM HEIs.

The majority (n=146) of these 301 programmes with public engagement or similar modules were in the sciences. However, when expressed as a percentage of the total number of programmes offered across the UK in individual disciplines, students enrolled on mathematics programmes were twice as likely to be provided with this opportunity compared to other STEM disciplines (Figure 3A). These data do not fully reflect the situation within engineering in that 80% of opportunities in this discipline are provided by one Institution (University of Sheffield[8]). If this is taken into account, only 3% of students enrolled on engineering programmes at other Institutions will have the opportunity to enrol on Public Engagement or related modules.

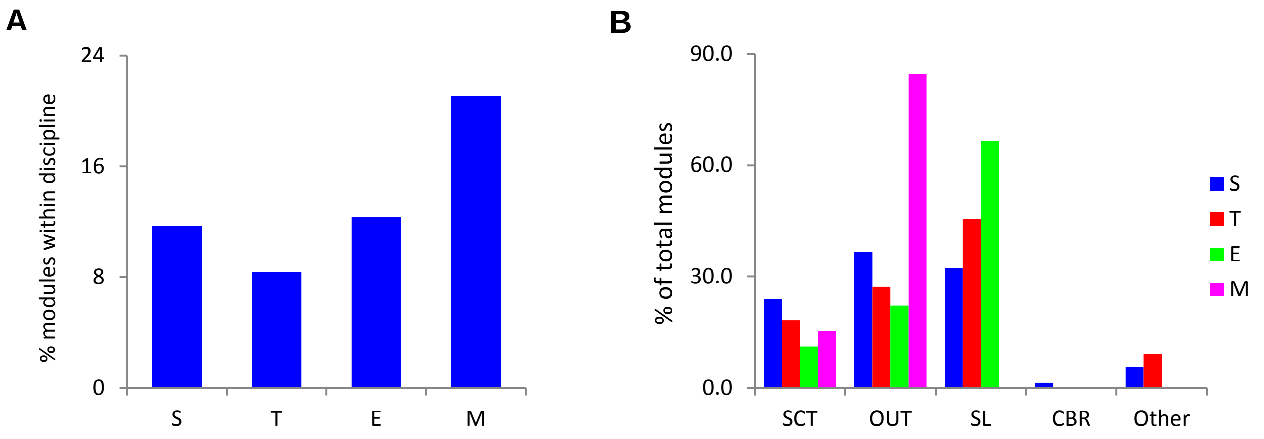

Figure 3: Evaluation of STEM undergraduate credit bearing science communication training, public engagement, outreach and service learning modules within UK degree programmes. A: Distribution between STEM disciplines, B: Nature or type of activity across disciplines.

However, many modules were offered to students enrolled on multiple degree programmes. When individual modules were only counted once, there are 104 separate outreach, service-learning or STEM communication training modules within UK STEM undergraduate curricula.

Examples of modules offered by different Institutions include:

- ***EART2002 Manchester Sustainable City project*** [9] (Faculty of Life Sciences, University of Manchester) where teams of students work on projects linked to Manchester's sustainability agenda e.g. Fuel poverty or a Community Beehive project
- ***BMS3016 Science Communication***[10] (School of Biomedical Sciences, Newcastle University) which provides science communication training including by guest lecturers, students writing blogs and workshops e.g. how to write a press release
- ***FCE2001 Engineering- You're Hired*** [8] (Faculty of Engineering, University of Sheffield), a virtual service learning activity module, were students work in multi-disciplinary teams on problems provided by industrial partners, providing both solutions to the problem and proposals for a project to develop these ideas further.

The majority of these 104 modules (40%, n=42) provide opportunities for students to engage in outreach activities, in most cases this comprises of delivering teaching activities in schools. Thirty four modules (33%) provided service-learning opportunities within the community and 22 modules (21%) training in communicating STEM subjects to lay audiences. However, there were distinct differences in the types of opportunities across disciplines (Figure 3B). For example, in mathematics, 90% of modules provide opportunities for students in outreach activities whilst engineers predominantly undertake service-learning activities (67%), possibly a reflection of the nature of their discipline. The majority of opportunities were provided later on in degree programmes, with 66% made available at Level 6 and 24% at Level 5 (Figure 4A).

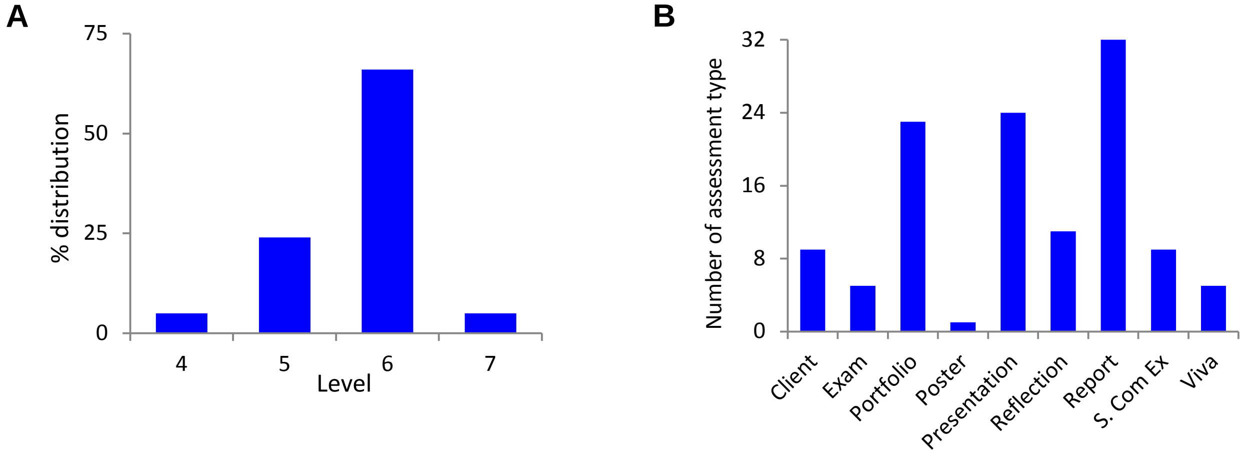

Figure 4: Evaluation of STEM undergraduate credit bearing science communication training, public engagement, outreach and service learning modules within UK degree programmes. A: Distribution of modules across programme level. B: Format of assessments

Seventy-one percent of activities were presented to their target audiences, the remainder of the activities were virtual (developed but not delivered). Traditional modes of assessment were predominantly utilised e.g. dissertations, presentations and portfolios, there was limited use of reflective blogs/journals or client-derived assessments (Figure 4B).

Objective 3: Collation and dissemination of best practice

Module managers, whose modules were identified in *Objective 2* as providing excellent examples of good practice have been contacted and invited to contribute a case study to the project. The selected case studies comprise of 4 outreach, 4 service learning and 4 STEM communication activities, with these spanning all the STEM disciplines (5 Science, 3 Technology, 2 Engineering, 2 Mathematics)(Appendix 3). A representative case study is provided in Appendix 4. Following compilation, these case studies will be disseminated as an open-access e-book.

Discussion and conclusions

The main findings of this research are:

Published literature: Examples are mainly from the USA, the opportunties are predominantly service-learning with limited public engagement or STEM communication training opportunties. These are available to students across all years of their programme. Whilst mainly in the sciences, many are interdisciplinary, involving students from disparate disciplines. Assessment is predominantly outcomes based.

UK undergraduate curricula: Opportunities are limited, wirth students studying mathematics or related programmes being twice as likely to be provided with the opportunity to enrol on public engagement modules compared to other disciplines. For mathematics students, outreach is the principal activity, whereas for engineering and technology students, it is service learning. In contrast to the USA, opportunties are more likely to be offered in the latter years of a programme, the methods of assessment are also usually more traditional (reports and presentations), with limited use/assessment of reflective practice or project outcomes.

In comparing the differences between the UK and the USA, the less formal structure of US undergraduate programmes, particularly amongst Liberal Arts Institutions, with their emphasis on broad curricula and educational experiences, may lend itself to the incorporation of service-learning opportunites within degree programmes. In addition, the requirement of Accreditation Board for Engineering and Technology[11], the US accrediting body for engineering and technology programmes, to incorporate service-learning within accredited programmes will increase provision within these disciplines.

Graduate employers are increasingly requiring graduates to posess employability skills, to be able to apply the knowledge and skills gained from their studies to the workplace, and to have relevant work experience[12]. What is clear from this scoping exercise is that UK Institutions can learn from good practice from the USA, to both increase the number of service-learning opportunities within their curricula, but also be more inventive in the nature of these so as to enable students to fully utlise their knowledge and skills. Consideration should also be given to the most appropriate means of assessing these activities, to make greater use of the assessment of outcomes and learning through engaging in reflective practice[13].

This study has also demontrated the limited STEM communication training with undergraduate curricula, both within UK and, in particular, the USA. The ability of scientists and individuals from other STEM disciplines to communicate with lay audiences is becoming increasingly important, both with regard to generating impact and also in response to public demand. Sixty-five percent of the UK public would like scientists to spend more time discussing the social and ethical implications of their work with them[14]. The provision of public engagement and outreach activities in US is less developed than the UK, for example, the first Cambridge Science Festival (MIT, Harvard[15]), didn't take place until 2007, many Learned Societies and organisations are using UK created resources/initiatives such as "FameLab"[16].

In summary, this scoping project has highlighted the need for the establishment of a global Community of Practice to share best practice and ideas for the inclusion of public engagement, outreach, service-learning and STEM communication training activities with STEM undergraduate curricula.

Problems encountered and opportunites arising

The original definition of public engagement in the original protocol was too restrictive and was expanded to include service learning (also known as community-based learning) activities; the principal formats of public engagement activities within undergraduate curricula subsequently identified by this programme of research.

The number of STEM undergraduate degree programmes far exceeded the number I expected which meant that the initial 4 interns undertook far more work than contracted for (Appendix 2). A fifth intern was employed to complete the evaluation of the programme catalogues of the outstanding HEIs and to fully analyse the data. Completion of this phase was essential before *Objective 3* (case studies, Appendix 3) could started and therefore this objective is still in progress but will be completed. Similarly, I woefully underestimated the time it would take to evaluate the published literature. As a consequence, I had to commit at least an additional 3 full weeks to the project.

This project was a scoping exercise, a systematic review of the published literature and UK module catalogues using tightly defined inclusion and exclusion criteria to extract examples of public engagement and similar modules within UK and overseas STEM undergraduate curricula. Whilst many of the identified full published papers were unavailable via the University of Leeds, with the publication abstracts containing little detail or the module catalogues for UK undergraduate programmes were unavailable to external users or did not contain the details required for the purposes of this research UK, the number of full papers and modules evaluated was sufficient to provide a representative picture of the provision and characteristics of public engagement and similar modules within STEM undergraduate curricula. Thus, as a scoping exercise, this systematic review achieved its aims. However, as alluded to above, it was an extremely time-consuming process. Further, the reading of the included papers identified additional publications, not discovered in the original literature search, which provided more examples of public engagement modules. In future scoping exercises, consideration must be given as to whether to include a second (or more) phases of research, evaluating these additional sources of information and, if so, whether this would provide new information/alter the research outcomes or just increase the number of modules identified[17]. If it is solely the latter, then there is no benefit. However, if this work is to be expanded beyond a scoping exercise, then a more hermeneutic approach will have to be taken, enabling a more in-depth evaluation of the literature and modification/inclusion of new research questions, rather than just data extraction.[17,18]

Working with undergraduate students as partners in a programme of research has been a rewarding experience for all concerned and builds on previous experience I have of collaborative working with student interns in my educational research and public engagement activities[7]. There is a substantial body of evidence demonstrating the significant benefits that can be obtained through working in collaborative partnerships with students in pedagogical research, curriculum development and other activities and the outputs and outcomes of this project add to that body of evidence[19]. All five interns were extremely commited and consciencious in their work, working beyond what was agreed/expected of them and this is reflected in the project outputs. They personally gained key employability skills and valuable work experience in an area (science communication or teaching) that they all want to develop careers in (Appendix 2). Further, I have named them as co-authors on the initial output of this research (presentation at HEA STEM Biosciences summit) and will be including them in all subsequent outputs. The University has included these internships on the student's HEAR transcripts (only one of two internship schemes across the entire University deemed suitable for inclusion on HEAR transcripts). In their reflective case studies they wrote on completion of their internships (Appendix 2), they all enjoyed the internships, they recognise the employability skills gained and the benefit to their future careers. In one case, completing the internship has facilitated the student gaining employment.

Outputs

The preliminary findings of this programme of research were presented at the Higher Education Academy STEM Biosciences Summit, University of Glasgow in July 2013. The complete findings will be presented at a future SRHE conference, the forthcoming main meeting of the Physiological Society (June 2014) and submitted for publication to “Studies in Higher Education”. The e-book of case studies of good practice will similarly be disseminated and made freely available including submission to JORUM.

In addition, each student intern has written a reflective case study on their experiences (Appendix 2). These case studies will be utilised both to inform the development of the educational research internships scheme within the Faculty of Biological Sciences, University of Leeds[7] and as evidence to leverage further funding for it.

Acknowledgements

I would like to thank the Society for Research into Higher Education for the financial support to enable me to undertake this research

Bibliography

1. CARLSON, L. E. and J. F. SULLIVAN. 2004. Exploiting design to inspire interest in engineering across the K-16 engineering curriculum. *International Journal of Engineering Education,* **20**(3), pp.372-378.
2. ODEN, M., Y. MIRABAL, M. EPSTEIN and R. RICHARDS-KORTUM. 2010. Engaging undergraduates to solve global health challenges: A new approach based on bioengineering design. *Annals of Biomedical Engineering,* **38**(9), pp.3031-3041.
3. DEWOOLKAR, M. M., J. E. LENS and N. J. HAYDEN. 2012. Service-learning design projects to enhance geotechnical engineering education. *In: GeoCongress 2012 State of the Art and Practice in Geotechnical Engineering, 25-29 March 2012,* Reston, VA, USA. American Society of Civil Engineers, pp.1333-42.
4. JAMIESON, L. H., W. C. OAKES and E. J. COYLE. 2001. EPICS: documenting service-learning to meet EC 2000. *In: 31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings, 10-13 Oct. 2001,* Piscataway, NJ, USA. IEEE, pp.2-1.
5. UCAS provider’s directory. Available at: http://search.ucas.com/
6. Higher Education Statistics Agency (2012) Joint Academic Coding System. Available at: http://www.hesa.ac.uk/index.php?option=com_content&task=view&id=1776&Itemid=296
7. LEWIS, D.I. (2012) Educational internships: Extra-curricular opportunities to enhance graduate employability. Proc Physiol Soc, **27**, C107. Available at: http://www.physoc.org/proceedings/abstract/Proc%20Physiol%20Soc%2027C107%20%2526%20PC270
8. FCE2001 Engineering- You’re Hired (Faculty of Engineering, University of Sheffield). Module details available at http://www-online.shef.ac.uk:3001/pls/live/web_cal.cal_unit_detail?unit_code=FCE2001&ctype=AUT+SEM&start_date=24-SEP-12&mand=Optional
9. EART2002 Manchester Sustainable City project (Faculty of Life Sciences, University of Manchester). Module details available at: http://www.ls.manchester.ac.uk/undergraduate/courses/biology/coursemodules/module/?id=4482
10. BMS3016 Science Communication (School of Biomedical Sciences, Newcastle University). Module details available at: http://www.ncl.ac.uk/undergraduate/modules/module/BMS3016
11. ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY. Available at http://www.abet.org/home/
12. HIGH FLIERS (2013). The Graduate Market in 2013. Available at http://www.highfliers.co.uk/download/GMReport13.pdf
13. NATIONAL CO-ORDINATING CENTRE FOR PUBLIC ENGAGEMENT (2011) Embedding Public Engagement in the Curriculum: A framework for assessing student learning from public engagement. Available at: https://www.publicengagement.ac.uk/sites/default/files/Assessing%20student%20learning%20from%20PE.pdf
14. IPSOS Mori (2011) Public attitudes to science. Available at: http://www.ipsos-mori.com/Assets/Docs/Polls/sri-pas-2011-main-report.pdf
15. CAMBRIDGE SCIENCE FESTIVAL. Available at: http://www.cambridgesciencefestival.org/Home.aspx
16. INTERNATIONAL FAMELAB: TALKING SCIENCE. Available at http://famelab.org/
17. MACLURE, M. (2005) “Clarity bordering on stupidity”: Where’s the quality in systematic review? *Journal of Education Policy*, 20: 393 – 416.
18. BOELL, S.K. and CECEZ-KECMANOVIC, D. (2010) Literature reviews and the hermeneutic circle. *Australian Academic & Research Libraries*, 41: 129 – 144.
19. KAY, J, DUNNE, E and HUTCHINSON, J (2010). Rethinking the values of higher education - students as change agents?. *Quality Assurance Agency.* Available at http://www.qaa.ac.uk/Publications/InformationAndGuidance/Documents/StudentsChangeAgents.pdf

APPENDIX 1: LIST OF EVALUATED PAPERS

BARRETT, S. F. and J. R. GRAY. 2005. University of Wyoming College of Engineering undergraduate design projects to aid Wyoming persons with disabilities, a mid-program review. *Biomedical sciences instrumentation,* **41**, pp.147-52.

BAUER-DANTOIN, A. C. 2008. Using Service Learning in a Course Entitled "Biology of Women" to Promote Student Engagement and Awareness of Community Needs and Resources. *Bioscene: Journal of College Biology Teaching,* **34**(1), pp.13-19.

BENORE-PARSONS, M. 2006. A Course Designed for Undergraduate Biochemistry Students to Learn about Cultural Diversity Issues. *Biochemistry and Molecular Biology Education,* **34**(5), pp.326-331.

BONK, R. J., L. N. SIMONS, T. M. SCEPANSKY, N. B. BLANK and E. B. BERMAN. 2009. A Multidisciplinary Assessment of "Chesteropoly" as an Academic-Service Experience. *Journal of Experiential Education,* **32**(2), pp.155-177.

BROWN, G. A., F. LYNOTT and K. A. HEELAN. 2008. A fitness screening model for increasing fitness assessment and research experiences in undergraduate exercise science students. *American Journal of Physiology - Advances in Physiology Education,* **32**(3), pp.212-218.

BRUCE, B. C., S. P. BRUCE, R. L. CONRAD and H. J. HUANG. 1997. University Science Students as Curriculum Planners, Teachers, and Role Models in Elementary School Classrooms. *Journal of Research in Science Teaching,* **34**(1), pp.69-88.

BRUNDIERS, K., A. WIEK and C. L. REDMAN. 2010. Real-world learning opportunities in sustainability: from classroom into the real world. *International Journal of Sustainability in Higher Education,* **11**(4), pp.308-324.

BUDNY, D. and R. KHANNA. 2012. Designing a service learning project for Freshman Engineers. *In: 2012 15th International Conference on Interactive Collaborative Learning, ICL 2012, September 26, 2012 - September 28, 2012,* Villach, Austria. IEEE Computer Society.

CARLSON, L. E. and J. F. SULLIVAN. 2004. Exploiting design to inspire interest in engineering across the K-16 engineering curriculum. *International Journal of Engineering Education,* **20**(3), pp.372-378.

CHANGNON, D. 2004. Improving outreach in atmospheric sciences - Assessement of users of climate products. *Bulletin of the American Meteorological Society,* **85**(4), pp.601-+.

CHAPDELAINE, A. and B. L. CHAPMAN. 1999. Using Community-Based Research Projects to Teach Research Methods. *Teaching of Psychology,* **26**(2), pp.101-105.

CHRISTENSEN, K., D. RUNDUS, G. PERERA and S. ZULLI. 2006. CSE volunteers: a service learning program to provide IT support to the Hillsborough County School District. *SIGCSE Bulletin,* **38**(1), pp.229-33.

CONNOR-GREENE, P. A. 2002. Problem-based service learning: The evolution of a team project. *Teaching of Psychology,* **29**(3), pp.193-197.

CRANE, P., D. CARR, M. GUEBERT and ANONYMOUS. 2001. Protecting groundwater-source drinking-water supply through undergraduate student learning, teaching, research, and service. *Abstracts with Programs - Geological Society of America,* **33**(4), p6.

DAHLBERG, T., T. BARNES, K. BUCH and A. RORRER. 2011. The STARS alliance: Viable strategies for broadening participation in computing. *ACM Transactions on Computing Education,* **11**(3).

DEVINE, D. P. 2006. Students teach students with the west point bridge designer. *Journal of Professional Issues in Engineering Education and Practice,* **132**(3), pp.187-190.

DEWOOLKAR, M. M., L. GEORGE, N. J. HAYDEN and M. NEUMANN. 2009. Hands-on undergraduate geotechnical engineering modules in the context of effective learning pedagogies, ABET outcomes, and our curricular reform. *Journal of Professional Issues in Engineering Education and Practice,* **135**(4), pp.161-175.

DEWOOLKAR, M. M., J. E. LENS and N. J. HAYDEN. 2012. Service-learning design projects to enhance geotechnical engineering education. *In: GeoCongress 2012 State of the Art and Practice in Geotechnical Engineering, 25-29 March 2012,* Reston, VA, USA. American Society of Civil Engineers, pp.1333-42.

DOMACK, C. W. 2000. A service-learning component in a paleontology course as a model for community outreach by geology students. *Journal of Geoscience Education,* **48**(5), pp.658-661.

DONAGHY, K. J. and K. J. SAXTON. 2012. Service Learning Track in General Chemistry: Giving Students a Choice. *Journal of Chemical Education,* **89**(11), pp.1378-1383.

DUKHAN, N., M. R. SCHUMACK and J. J. DANIELS. 2009. Service learning as pedagogy for promoting social awareness of mechanical engineering students. *International Journal of Mechanical Engineering Education,* **37**(1), pp.78-86.

DVORAK, B. I., B. A. STEWART, A. A. HOSNI, S. A. HAWKEY and V. NELSEN. 2011. Intensive environmental sustainability education: Long-term impacts on workplace behavior. *Journal of Professional Issues in Engineering Education and Practice,* **137**(2), pp.113-120.

EGAN, M. A. L. and M. JOHNSON. 2010. Service learning in introductory computer science. *In: 15th Innovation and Technology in Computer Science Education Conference, ITiCSE 2010, June 26, 2010 - June 30, 2010,* Bilkent, Ankara, Turkey. Association for Computing Machinery, pp.8-12.

EKSTROM, C. L. and ANONYMOUS. 2006. Partnering with the community through SWEEP. *Abstracts with Programs - Geological Society of America,* **38**(7), p360.

ENIOLA-ADEFESO, O. 2010. Engaging k-12 students in the engineering classroom: A creative use of undergraduate self-directed projects. *Chemical Engineering Education,* **44**(4), pp.280-286.

ESSON, J. M., R. STEVENS-TRUSS and A. THOMAS. 2005. Service-learning in introductory chemistry: Supplementing chemistry curriculum in elementary schools. *Journal of Chemical Education,* **82**(8), pp.1168-1173.

EVANS, S. D., K. MALHOTRA and A. M. HEADLEY. 2013. Promoting learning and critical reflexivity through an organizational case study project. *Journal of Prevention and Intervention in the Community,* **41**(2), pp.105-112.

FANG, C. F. and D. PINES. 2007. Enhancing transportation engineering education with computer simulation. *International Journal of Engineering Education,* **23**(4), pp.808-815.

FEENEY, A. E. *Online Mapping of Campgrounds for the Pennsylvania State Parks: Student Service Learning Project.* Association of American Geographers, 1710 16th St, NW Washington, DC 20009 USA.

FELZIEN, L. and L. SALEM. 2008. Development and assessment of service learning projects in general biology. *Bioscene,* **34**(1), pp.6-12.

FERGUSON, R., M. LAST, L. CHANG and J. MERTZ. 2006. Service-learning projects: opportunities and challenges. *SIGCSE Bulletin,* **38**(1), pp.127-8.

FIORI, C. M. and A. D. SONGER. 2009. Enhancing construction education with contextual service learning. *In: 2009 Construction Research Congress - Building a Sustainable Future, April 5, 2009 - April 7, 2009,* Seattle, WA, United states. American Society of Civil Engineers, pp.1388-1397.

FRANQUESA, D., J. L. CRUZ, C. ÁLVAREZ, F. SÁNCHEZ, A. FERNÁNDEZ and D. LÓPEZ. 2010. The social and environmental impact of engineering solutions: From the Lab to the Real World. *International Journal of Engineering Education,* **26**(5), pp.1144-1155.

FROESE, A. D., V. VOGTS-SCRIBNER, S. E. EALEY and J. A. FAIRCHILD. 2003. Service Data Institute: Bridging Research and Community Service. *Teaching of Psychology,* **30**(4), pp.319-321.

FROLIK, J. and M. FORTNEY. 2006. A low-cost wireless platform for first-year interdisciplinary projects. *IEEE Transactions on Education,* **49**(1), pp.105-112.

GARNER, L. C. 2011. Meeting learning objectives through service-learning: A pomology case study. *HortTechnology,* **21**(1), pp.119-125.

GOEBEL, C. A., A. UMOJA and R. L. DEHAAN. 2009. Providing undergraduate science partners for elementary teachers: Benefits and challenges. *CBE Life Sciences Education,* **8**(3), pp.239-251.

GOGGINS, J. 2012. Engineering in communities: learning by doing. *Campus-Wide Information Systems,* **29**(4), pp.238-50.

GOLDBERG, J. R. 2007. *Capstone design courses: Producing industry-ready biomedical engineers*. Circular distributed.

GOLDWEBER, M. 2012. A day one computing for the social good activity. *ACM Inroads,* **3**(3), pp.46-49.

GOTO, K. and S. BIANCO-SIMERAL. 2009. Campus community involvement in an experimental food research project increases students' motivation and improves perceived learning outcomes. *Journal of Food Science Education,* **8**(2), pp.39-44.

GREEN, M. G., K. L. WOOD, F. T. DUDA, N. VAN GAALEN, S. H. VANDERLEEST and C. ERIKSON. 2004. Service-learning approaches to international humanitarian design projects: A model based on experiences of faith-based institutions. *In: ASEE 2004 Annual Conference and Exposition, "Engineering Researchs New Heights", June 20, 2004 - June 23, 2004,* Salt Lake City, UT, United states. American Society for Engineering Education, pp.12533-12554.

GUEBERT, M. D., M. S. CHASE and ANONYMOUS. 2009. Water resources, sanitation, and community health; an interdisciplinary, international, service-learning educational program. *Abstracts with Programs - Geological Society of America,* **41**(7), p95.

GUERTIN, L. A. and ANONYMOUS. 2006. Establishing a geoscience theme for the national annual letter-writing campaign Absolutely Incredible Kid Day! *Abstracts with Programs - Geological Society of America,* **38**(2), pp.18-19.

GUERTIN, L. A., E. T. CAO, K. A. CRAIG, A. E. GEORGE, S. T. GOLDSON, S. P. MAKATCHE, B. T. RADUSEVICH, C. W. SANDOR, A. T. TAKOS, R. TULLER, J. K. WILLIAMS and M. A. WILLIAMS. 2004. Bringing Dinosaur Science to the Junior Girl Scouts through a College Service-Learning Project. *Journal of Science Education and Technology,* **13**(4), pp.523-531.

GUERTIN, L. A. and C. NGUYEN. 2003. Combining a historical geology project with a campus student organization's fundraising efforts. *Journal of Geoscience Education,* **51**(4), pp.378-380.

GUTSTEIN, J., M. SMITH and D. MANAHAN. 2006. A Service-Learning Model for Science Education Outreach. *Journal of College Science Teaching,* **36**(1), pp.22-26.

HABASH, R. W. Y. and C. SUURTAMM. 2010. Engaging high school and engineering students: A multifaceted outreach program based on a mechatronics platform. *IEEE Transactions on Education,* **53**(1), pp.136-143.

HARBOR, J. M. 2000. A capstone course in environmental geosciences. *Journal of Geoscience Education,* **48**(5), pp.617-623.

HARK, A. T. 2008. Crossing over: An undergraduate service learning project that connects to biotechnology education in secondary schools. *Biochemistry and Molecular Biology Education,* **36**(2), pp.159-165.

HARRISON, M. A., D. DUNBAR and D. LOPATTO. 2013. Using Pamphlets To Teach Biochemistry: A Service-Learning Project. *Journal of Chemical Education,* **90**(2), pp.210-214.

HAWTHORNE, T. L. 2011. Communities, Cartography and GIS: Enhancing Undergraduate Geographic Education with Service Learning. *International Journal of Applied Geospatial Research,* **2**(2), pp.1-16.

HORENSTEIN, M. and M. RUANE. 2002. Teaching social awareness through the senior capstone design experience. *In: Proceedings of Conference on Frontiers in Education, 6-9 Nov. 2002,* Piscataway, NJ, USA. IEEE, pp.3-7.

HOSTEN, C. M., G. TALANOVA and K. B. LIPKOWITZ. 2011. Introducing undergraduates to the role of science in public policy and in the service of the community. *Chemistry Education Research and Practice,* **12**(3), pp.388-394.

JACKOWSKI, M. and L. GULLION. 1998. Teaching sport management through service-learning: An undergraduate case study. *Quest,* **50**(3), pp.251-265.

JACOBS, S. 2010. Building an education ecology on serious game design and development for the one laptop per child and sugar platforms: A service learning course builds a base for peer mentoring, cooperative education internships and sponsored research. *In: 2nd International IEEE Consumer Electronic Society Games Innovation Conference, ICE-GIC 2010, December 21, 2010 - December 23, 2010,* Hong Kong, China. IEEE Computer Society, p.IEEE Computer Society; DotAsia; IET Hong Kong; Chinese Institute of Electronics; International Engineering Consortium; Internet Society Hong Kong.

JAMIESON, L. H., W. C. OAKES and E. J. COYLE. 2001. EPICS: documenting service-learning to meet EC 2000. *In: 31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings, 10-13 Oct. 2001,* Piscataway, NJ, USA. IEEE, pp.2-1.

JAY, J. A. and K. B. MIKA. 2012. Collaborative research with K-12 students on impacts of climate change on ecosystems in an environmental engineering service-learning course. *World Transactions on Engineering and Technology Education,* **10**(2), pp.105-109.

JONES, S. R. and E. S. ABES. 2003. Developing student understanding of HIV/AIDS through community service-learning: A case study analysis. *Journal of College Student Development,* **44**(4), pp.470-488.

JORDAN, N. R., D. A. ANDOW and K. L. MERCER. 2005. New concepts in agroecology: A service-learning course. *Journal of Natural Resources and Life Sciences Education,* **34**, pp.83-89.

KAMMLER, D. C., T. M. TRUONG, G. VANNESS and A. E. MCGOWIN. 2012. A Service-Learning Project in Chemistry: Environmental Monitoring of a Nature Preserve. *Journal of Chemical Education,* **89**(11), pp.1384-1389.

KILMARTIN, L. and E. MCCARRICK. 2010. A Case Study of Enhancing Learning Outcomes for Undergraduate Electronic\Computer Engineering Students through a Service Learning Based Project Module. *In: 2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, 6-9 April 2010,* Piscataway, NJ, USA. IEEE, p.18 pp.

KOGAN, L. R. and J. A. KELLAWAY. 2004. Applied animal behavior course: A service-learning collaboration with the humane society. *Teaching of Psychology,* **31**(3), pp.202-204.

KORETSKY, C. M., H. L. PETCOVIC and K. L. ROWBOTHAM. 2012. Teaching environmental geochemistry: An authentic inquiry approach. *Journal of Geoscience Education,* **60**(4), pp.311-324.

KRANZLER, A., A. C. PARKS and J. GILLHAM. 2011. Illustrating positive psychology concepts through service learning: Penn teaches resilience. *Journal of Positive Psychology,* **6**(6), pp.482-486.

KRETCHMAR, M. D. 2001. Service learning in a general psychology class: Description, preliminary evaluation, and recommendations. *Teaching of Psychology,* **28**(1), pp.5-10.

KUMAR, S. and J. K. HSIAO. 2007. Engineers learn "soft skills the hard way": Planting a seed of leadership in engineering classes. *Leadership and Management in Engineering,* **7**(1), pp.18-23.

LAPP, J. and K. A. CALDWELL. 2012. Using food ethnographies to promote systems thinking and intergenerational engagement among college undergraduates. *Food, Culture and Society,* **15**(3), pp.491-509.

LAWSON-WILLIAMS, B. 2013. Touchdown: The impact of a sport management service-learning project. *Psychology and Education,* **50**(1-2), pp.32-35.

LAZAR, J. 2011. Using community-based service projects to enhance undergraduate HCI education: 10 years of experience. *In: 29th Annual CHI Conference on Human Factors in Computing Systems, CHI 2011, May 7, 2011 - May 12, 2011,* Vancouver, BC, Canada. Association for Computing Machinery, pp.581-588.

LEIDIG, P. M., R. FERGUSON and J. LEIDIG. 2006. The use of community-based non-profit organizations in information systems capstone projects. *SIGCSE Bulletin,* **38**(3), pp.148-52.

LESTER, C. Y. 2008. An innovative approach to teaching an undergraduate software engineering course. *In: 2008 The Third International Conference on Software Engineering Advances (ICSEA), 26-31 Oct. 2008,* Piscataway, NJ, USA. IEEE, pp.301-6.

LIU, L., A. R. PHILPOTTS and N. H. GRAY. 2004. Service-learning practice in upper division geoscience courses: Bridging undergraduate learning, teaching, and research. *Journal of Geoscience Education,* **52**(2), pp.172-177.

LOPEZ, R. R., K. B. HAYS, M. W. WAGNER, S. L. LOCKE, R. A. MCCLEERY and N. J. SILVY. 2006. Integrating land conservation planning in the classroom. *Wildlife Society Bulletin,* **34**(1), pp.223-228.

MACFALL, J. 2012. Long-Term Impact of Service Learning in Environmental Studies. *Journal of College Science Teaching,* **41**(3), pp.26-31.

MANKOFF, J. 2006. Practical service learning issues in HCI. *In: Conference on Human Factors in Computing Systems, CHI EA 2006, April 22, 2006 - April 27, 2006,* Montreal, QC, Canada. Association for Computing Machinery, pp.201-206.

MEAD, K. S. 2010. Neural Networks: Making Connections about the Brain and about College while Monitoring Student Engagement in Second Graders. *Journal of Undergraduate Neuroscience Education,* **9**(1), pp.A57-A61.

MEANEY, K. S. and K. KOPF. 2010. C.P.R.: Promoting Cooperation, Participation and Respect in Physical Education. *Strategies: A Journal for Physical and Sport Educators,* **24**(2), pp.29-32.

MIKA, K. B., T. Y. LIN, M. FERREIRA, J. LACSON, C. M. LEE, C. C. LIN, K. O'BYRNE, W. SANDOVAL, V. THULSIRAJ and J. A. JAY. 2012. Incorporating service learning in traditionally lecture-based environmental engineering courses through researching bacterial contamination at a local beach. *Global Journal of Engineering Education,* **14**(2), pp.155-162.

MIKIC, B. and D. GRASSC. 2002. Socially-relevant design: The TOYtech project at Smith college. *Journal of Engineering Education,* **91**(3), pp.319-326.

MONI, R. W., D. H. HRYCIW, P. PORONNIK and K. B. MONI. 2007. Using explicit teaching to improve how bioscience students write to the lay public. *American Journal of Physiology - Advances in Physiology Education,* **31**(2), pp.167-175.

MOOSAVI, S. C., M. T. BROWN, L. LOVING, J. SICHEL and ANONYMOUS. 2011. The impact of BP Deepwater Horizon oil spill clean up activities on a recently nourished barrier island beach, Grand Isle, Louisiana. *Abstracts with Programs - Geological Society of America,* **43**(3), p11.

MORGAN THEALL, R. A. and M. R. BOND. 2013. Incorporating professional service as a component of general chemistry laboratory by demonstrating chemistry to elementary students. *Journal of Chemical Education,* **90**(3), pp.332-337.

MUIR, G. M. and G. J. VAN DER LINDEN. 2009. Students teaching students: An experiential learning opportunity for large introductory psychology classes in collaboration with local elementary schools. *Teaching of Psychology,* **36**(3), pp.169-173.

NAFALSKI, A. and Z. NEDIC. 2008. Final year projects with involvement of industry and high schools. *In: 38th ASEE/IEEE Frontiers in Education Conference, FIE 2008, October 22, 2008 - October 25, 2008,* Saratoga Springs, NY, United states. Institute of Electrical and Electronics Engineers Inc., pp.T4C7-T4C11.

NAGCHAUDHURI, A. and H. M. CONWAY. 1999. 'Teaching tools for teachers'-an engineering design project to enhance science and mathematics education for middle/high school students. *American Society of Mechanical Engineers, Design Engineering Division (Publication) DE,* **102**, pp.37-42.

NICHOLS, K. K., P. R. BIERMAN, L. PERSICO, A. BOSLEY, P. R. MELILLO and J. KURFIS. 2003. Quantifying urban land use and runoff changes through service-learning hydrology projects. *Journal of Geoscience Education,* **51**(4), pp.365-372.

NUNN, J. A. and J. BRAUD. 2013. A service-learning project on volcanoes to promote critical thinking and the Earth science literacy initiative. *Journal of Geoscience Education,* **61**(1), pp.28-36.

ODEN, M., Y. MIRABAL, M. EPSTEIN and R. RICHARDS-KORTUM. 2010. Engaging undergraduates to solve global health challenges: A new approach based on bioengineering design. *Annals of Biomedical Engineering,* **38**(9), pp.3031-3041.

OLSON, M. L. 2011. Practical experience with age-related dementia: Implementation and outcomes of a semester-long service learning project in neuropsychology. *Journal of Undergraduate Neuroscience Education,* **10**(1), pp.A58-A64.

OSBORNE, R. B., A. J. THOMAS and J. R. N. FORBES. 2010. Teaching with robots: A service-learning approach to mentor training. *In: 41st ACM Technical Symposium on Computer Science Education, SIGCSE'10, March 10, 2010 - March 13, 2010,* Milwaukee, WI, United states. Association for Computing Machinery, pp.172-176.

OWENS, K. and A. FOOS. 2007. A course to meet the nature of science and inquiry standards within an authentic service learning experience. *Journal of Geoscience Education,* **55**(3), pp.211-217.

PAIN, R., M. FINN, R. BOUVENG and G. NGOBE. 2013. Productive tensions-engaging geography students in participatory action research with communities. *Journal of Geography in Higher Education,* **37**(1), pp.28-43.

PEZDEK, K. 2002. Teaching Psychology in the Context of a University-Community Partnership. *Teaching of Psychology,* **29**(2), pp.157-159.

PIKET-MAY, M. and J. AVERY. 2001. Service learning first year design retention results. *In: 31st Annual Frontiers in Education Conference- Impact on Engineering and Science Education-, October 10, 2001 - October 13, 2001,* Reno, NV, United states. Institute of Electrical and Electronics Engineers Inc., pp.F3C/19-F3C/22.

PROKOPY, L. S. 2009. Looking at the big picture: Engaging natural resource students in landscape level planning through a capstone course. *Journal of Forestry,* **107**(2), pp.90-94.

RENAUD, J., C. SQUIER and S. C. LARSEN. 2006. Integration of a communicating science module into an advanced chemistry laboratory course. *Journal of Chemical Education,* **83**(7), pp.1029-1031.

REVETTA, F. A., K. PECK and ANONYMOUS. 2001. A case study that demonstrates the effectiveness of teaching environmental geophysics as service learning. *Abstracts with Programs - Geological Society of America,* **33**(1), p75.

RIEK, L. D. 2013. Embodied Computation: An Active-Learning Approach to Mobile Robotics Education. *Ieee Transactions on Education,* **56**(1), pp.67-72.

ROMERO-CALDERÓN, R., E. D. O'HARE, N. A. SUTHANA, A. A. SCOTT-VAN ZEELAND, A. RIZK-JACKSON, A. ATTAR, S. K. MADSEN, C. A. GHIANI, C. J. EVANS and J. B. WATSON. 2012. Project brainstorm: Using neuroscience to connect college students with local schools. *PLoS Biology,* **10**(4).

RUSSOMANNO, D. J., D. R. FRANCESCHETTI, A. L. DE JONGH CURRY and A. PHILLIPS-LAMBERT. 2006. The development of an interdisciplinary data visualization course with an ongoing community-based project component. *Computers in Education Journal,* **16**(3), pp.29-39.

RUSU, A. and J. LAWLOR. 2010. Connecting campus and community through Web Development service-learning projects. *In: 40th Annual Frontiers in Education Conference: Celebrating Forty Years of Innovation, FIE 2010, October 27, 2010 - October 30, 2010,* Arlington, VA, United states. Institute of Electrical and Electronics Engineers Inc., pp.F4D1-F4D6.

SAITTA, E. K. H., M. A. BOWDON and C. L. GEIGER. 2011. Incorporating Service-Learning, Technology, and Research Supportive Teaching Techniques into the University Chemistry Classroom. *Journal of Science Education and Technology,* **20**(6), pp.790-795.

SALAZAR, K. A., L. P. TEDESCO and ANONYMOUS. 2004. Environmental service learning and community partnerships; applying science-based solutions to urban environmental problems. *Abstracts with Programs - Geological Society of America,* **36**(5), p162.

SANTAS, A. J. 2009. Reciprocity within biochemistry and biology service-learning. *Biochemistry and Molecular Biology Education,* **37**(3), pp.143-151.

SAPP, D. A. and R. D. CRABTREE. 2002. A laboratory in citizenship: Service learning in the technical communication classroom. *Technical Communication Quarterly,* **11**(4), p411.

SCHAAD, D. E., L. P. FRANZONI, C. PAUL, A. BAUER and K. MORGAN. 2008. A perfect storm: Examining natural disasters by combining traditional teaching methods with service-learning and innovative technology. *International Journal of Engineering Education,* **24**(3), pp.450-465.

SCHLOSSBERG, M. and D. WYSS. 2007. Teaching by doing: PPGIS and classroom-based service learning. *URISA Journal,* **19**(1), pp.13-22.

SCHWARTZ, D. R. 2009. The Benefits (and Drawbacks!) of "Real World" Software Engineering Semester Projects: A Case Study. *In: 2009 International Conference on Frontiers in Education: Computer Science & Computer Engineering. FECS 2009, 13-16 July 2009,* Las Vegas, NV, USA. CSREA Press, pp.95-101.

SENIOR, B. A. 1999. Service-learning: A win-win resource for construction education. *Journal of Construction Education,* **4**(1), pp.17-25.

SHARON, T. 2012. Learning times two: Creating learning through a children's museum exhibit. *Teaching of Psychology,* **39**(1), pp.24-28.

SHEMYAKIN, A. and B. TIEFENBRUCK. 2009. Community-oriented projects in calculus-based statistics courses. *Model Assisted Statistics and Applications,* **4**(4), pp.253-264.

STANLEY, L. and T. HOYT. 2011. A service learning case study for the ergonomics classroom. *In: 55th Human Factors and Ergonomics Society Annual Meeting, HFES 2011, September 19, 2011 - September 23, 2011,* Las Vegas, NV, United states. Human Factors an Ergonomics Society Inc., pp.525-529.

STEVENS, C. 2011. Integrating community outreach into the undergraduate neuroscience classroom. *Journal of Undergraduate Neuroscience Education,* **10**(1), pp.A44-A49.

TSANG, E., J. VAN HANEGHAN, B. JOHNSON, E. J. NEWMAN and S. VAN ECK. 2001. A Report on Service-Learning and Engineering Design: Service-Learning's Effect on Students Learning Engineering Design in 'Introduction to Mechanical Engineering'. *International Journal of Engineering Education,* **17**(1), pp.30-39.

WADSWORTH, L. A., C. JOHNSON, C. CAMERON and M. GAUDET. 2012. (Re) focus on local food systems through service learning, empowering pedagogy in a Human Nutrition Degree Program. *Food, Culture and Society,* **15**(2), pp.315-334.

WAGNER, L. K. and S. W. FONES. 1999. Enhancing science education experiences through Garden Explorations: An inquiry-based learning opportunity at the South Carolina Botanical Garden. *HortTechnology,* **9**(4), pp.566-569.

WALCZAK, M. M. 2007. Using news assignments to develop skills for learning about science from public information sources. *Journal of Chemical Education,* **84**(6), pp.961-966.

WALICZEK, T. M. and J. M. ZAJICEK. 2010. The benefits of integrating service teaching and learning techniques into an undergraduate horticulture curriculum. *HortTechnology,* **20**(5), pp.934-942.

WELCH, C. and B. OSBORNE. 2012. Kuspace: Embedding science, technology, engineering and mathematics (STEM) ambassador activities in the undergraduate engineering curriculum. *JBIS - Journal of the British Interplanetary Society,* **65**(2-3), pp.105-108.

WHITBOURNE, S. K., K. J. COLLINS and K. M. SKULTETY. 2001. Formative reflections on service-learning in a course on the psychology of aging. *Educational Gerontology,* **27**(1), pp.105-115.

WILLIAMS, K. and C. KOVACS. 2001. Balance and Mobility Training for Older Adults: An Undergraduate Service-Learning Experience. *Journal of Physical Education, Recreation & Dance,* **72**(3), pp.54-58.

WILLIAMS-LAWSON, B. 2009. Power play: The impact of a physical education service-learning project. *Psychology and Education,* **46**(1), pp.26-30.

WOLCOTT, M., S. BROWN, M. KING, D. ASCHER-BARNSTONE, T. BEYREUTHER and K. OLSEN. 2011. Model for Faculty, Student, and Practitioner Development in Sustainability Engineering through an Integrated Design Experience. *Journal of Professional Issues in Engineering Education and Practice,* **137**(2), pp.94-101.

WYSS, V. L. and R. H. TAI. 2012. Service Learning in High School Biology and College Major Choice. *College Student Journal,* **46**(2), pp.459-464.

YILMAZ, M., S. OZCELIK, N. YILMAZER and R. NEKOVEI. 2013. Design-Oriented Enhanced Robotics Curriculum. *Ieee Transactions on Education,* **56**(1), pp.137-144.

ZOGHI, M. and M. PINNELL. 2005. Service-learning opportunities at the University of Dayton. *In: 2005 ASEE Annual Conference and Exposition: The Changing Landscape of Engineering and Technology Education in a Global World, June 12, 2005 - June 15, 2005,* Portland, OR, United states. American Society for Engineering Education, pp.12637-12644.

APPENDIX 2: STUDENT INTERNS REFLECTIVE CASE STUDIES

INTERN 1

Initial reflections on starting:
I am excited to research the extent to which university students of STEM degree courses have access to study modules which support public engagement activities. Experience gained through the completion of my 'science and society' dissertation project initially sparked my interest in this area, and I hope that this project can further increase both this interest and my understanding. I feel that communication between practitioners and 'the public' is of upmost importance for two major reasons. Firstly, research is often publicly funded and should therefore be accountable to the public, and secondly, effective communication and engagement can encourage higher levels of involvement within STEM fields by young people. This is essential to the further the development of new life-enhancing innovations. I aim to enthusiastically contribute to this project throughout the duration of this internship, whilst also improving both my data mining/collection and analysis techniques and my communication skills. I also hope to enhance many transferable skills through my long term involvement with this project, examples of these include; report writing and presentation skills.

Post internship reflections:
Why did you apply for an educational internship?
Upon first hearing of this educational internship opportunity I was very excited to learn of the extent to which STEM students had access to public engagement activities within their studies. I thought that this would be both informative and educational, and would build upon the knowledge of public engagement with science, which was built during my ‘Science and Society’ dissertation research project. I also applied to this internship with thoughts to being better prepared in understanding the level STEM knowledge found in today’s society, as I thought this would undoubtedly help me in my future career.

What did you hope to get from the internship before you started?
As previously mentioned I hoped that this internship would give me a greater understanding of the knowledge held by, and opportunities provided to, other STEM undergraduates. I hoped that this internship would build upon the work I had done with my final year research project, and could help me put into practice techniques for communicating science. I also hoped that this internship would allow me to demonstrate, and enhance, my data mining and computer literacy skills.

What did you enjoy/dislike about the project?
Overall, I really enjoyed this project. I enjoyed researching the modules and courses available at the many different universities we examined. I enjoyed seeing the variation in activities that were available to different undergraduates, and the innovative ways in which the public were engaged. I also enjoyed the collaborative nature of the project, which allowed a better level of research as a result of the reduced volume.
Despite this, I did find the volume of the work to be higher than I had initially expected (however this was not a problem). I also found that communication with the other collaborators was a little forced at times, particularly with regards to the final report, but again this resolved itself with time.

What skills have you gained from doing the internship?
As a direct result of my involvement with this internship I have found that my data mining skills have increased to no-end. I am now much more proficient in terms of researching different themes. I also feel that my communication and organisational skills have only been enhanced by this opportunity. All these bettered skills combined have contributed to me gaining employment this summer in a similar project role.

How would you describe the internship to a prospective employer?
As alluded to, I have mentioned my experience of this internship to an employer, and they were impressed with the opportunity. I described it as a short, online-based research project that focused upon both qualifying and quantifying the access that current UK university STEM undergraduates had to ‘science engagement activities’ within their degree courses. I also mentioned the tasks of researching, data compiling, and report writing which were involved with the internship.

Do you think internships are valuable for UG students? Why?
I think that internships are very, very valuable to undergraduate students, as they can shed light upon certain areas of research or work that they may then wish to pursue upon graduation. The short duration of such internships can provide a valuable experience of something that may have otherwise been unknown, whilst not being to taxing on the undergraduates’ timetables. I think they are invaluable, and I would hope that such opportunities could continue for others.

What would you do differently if you were to do another internship?
Despite my enjoyment of this particular internship I would have liked to participate in a more ‘bench science’ related project, so I could have further honed the scientific skills learnt in my degree. I would have also liked to

participate in an internship slightly earlier in my academic career, however the timing of this particular project was ideal just before graduation.

INTERN 2

Initial reflections on starting:
I am excited to start this internship to investigate the modules available to undergraduate students studying STEM subjects which enable them to engage with the public. As I have recently carried out a "science and society" project, I have seen how university modules which incorporate public engagement can benefit both the public and the undergraduate students undertaking the module. I personally believe that educating and informing the public of current scientific findings and research is of importance. This is because surveys have revealed that the public would like to be informed more about the scientific world. I also believe that engagement with the public, especially school students, can increase interest in science which could ultimately increase interest in STEM subjects in schools. I think this internship will enable me to enhance my data retrieval/ analysis skills and will also provide me with the opportunity to improve my communication skills.

Post internship reflections:
Why did you apply for an educational internship?
I applied for an educational internship as I was interested to learn about other types of public engagement activities other universities provided within their course. Within my final year project I carried out a science and society project which involved public engagement with secondary school students. Therefore I had knowledge of the modules that the University of Leeds provided to students to allow them to be involved in public engagement. Therefore I was intrigued to see whether other STEM subject courses at other universities provided the same or similar opportunities to their students.

What did you hope to get from the internship before you started?
I hoped that I would increase my understanding of how universities encouraged and accommodated public engagement within STEM university degrees. I also thought that this would enable me to understand which universities were particularly good providers of public engagement activities. I thought that this could help me when pursuing my career as a teacher, as I could try to link up with these universities so that my students would benefit from these activities. I also hoped to enhance my data retrieval/ analysis skills and to improve my communication skills.

What did you enjoy/dislike about the project?
I most enjoyed finding out about the variety of public engagement activities which different university STEM courses provided. It made me aware of the variety of ways in which public engagement can be achieved. However I did find that there was more work than I anticipated and I spent more than the allocated number of hours researching for this internship.

What skills have you gained from doing the internship?
I believe that I have gained knowledge about the public engagement activities that universities provide in their STEM subject courses, which has been insightful. I have also enhanced my data retrieval/collection skills. I am also now familiar with a wide variety of STEM degree courses that are available to students. This will be useful when teaching to encourage and inform students of the variety of STEM degrees available for them. This is gained knowledge which I hadn’t anticipated. I also believe I have further strengthen my communication and organisational skills.

How would you describe the internship to a prospective employer?
I would describe this internship as a research project which aimed to explore the science engagement activities which universities provided within STEM undergraduate degree programmes. I would explain that my role was to compile data by researching STEM undergraduate degree programs provided at 25 Universities and the public engagement activities included within these STEM subjects. I worked collaboratively with three other individuals to collect data from 99 universities.

Do you think internships are valuable for UG students? Why?
I believe that internships are valuable to undergraduate students, as they give students the opportunity gain experience in something which they are particularly interested in. This can help students to develop an understanding of what area of research or career they wish to pursue.

What would you do differently if you were to do another internship?
I would perhaps choose an internship with more collaborative work, as I often felt as though even though there were others doing the same internship we worked separately. However this couldn’t have been prevented in this internship due to the nature of the task and the timing of the internship. This wasn’t a problem however if I was going to do another internship I would like to work closer with the others members of the group, to gain more from the experience by sharing ideas and findings.

APPENDIX 3: MODULES WHERE CASE STUDIES WILL BE REQUESTED

STEM	Activity	Module code	Module Title	Weblink	Contact	Email
E	Placement within a local school (primary, secondary or tertiary). During the placements, the student initially observes teaching but gradually becomes more involved in the classroom, ultimately carrying out a special project with pupils.	SESG3017	Teaching and Communication and the Undergraduate Ambassador Scheme	http://www.southampton.ac.uk/engineering/undergraduate/modules/sesg3017_teaching_and_communication_and_the_undergraduate_ambassador_scheme.page#overview	Joy Moloney	jmlm@soton.ac.uk
E	Interdisciplinary teams work on a real-world problem provided by industrial partners. Provide solutions & proposals for a project to develop these ideas further	FCE2001	Engineering- You're Hired	http://www-online.shef.ac.uk:3001/pls/live/web_cal.cal_unit_detail?unit_code=FCE2001&ctype=AUT+SEM&start_date=24-SEP-12&mand=Optional	Rebecca Swift	r.m.swift@sheffield.ac.uk
M	Communicating and Teaching Mathematics in School	MTH6110	Communicating and Teaching Mathematics: the Undergraduate Ambassadors Scheme	http://www.maths.qmul.ac.uk/undergraduate/modules?module=MTH6110	Dr R J Harris	
M	Knowledge of public engagement of science and development of own communication skills	H3	Communicating Science: The Public and the Media	https://www3.imperial.ac.uk/humanities/undergraduate/humanitiescourses/communicatingscience	Ms Giskin Day	
S	Development and delivery of interactive teaching session in either primary or secondary school	BMSC3301	Research project in Biomedical Sciences	http://webprod3.leeds.ac.uk/catalogue/dynmodules.asp?Y=201314&M=BMSC-3301	Dr D Lewis	d.i.lewis@leeds.ac.uk
S	Work on projects set out by local organisations linked Manchester's sustainability agenda eg fuel poverty, community bee project, car parking issues, waste management, ecology and land use.	EART 20002	Manchester Sustainability City Project	http://www.ls.manchester.ac.uk/undergraduate/courses/biologywithscienceandsociety/coursemodules/	Prof Colin Hughes	colin.hughes@manchester.ac.uk
S	Design, develop and implement a 'real life' intervention and host it on the University campus	No Information	Exercise and Health Interventions	http://www.salford.ac.uk/ug-courses/exercise,-physical-activity-and-health	Paul Wilson	p.s.wilson@salford.ac.uk
S	Science communication module. How to write for the web, regular practice in producing web-based content, science communication and the public, science communication in the classroom, science communication in the media, science communication within science and science communication and policy. By lectures, practicals, small group teaching and workshops.	BMS3016	Science Communication	http://www.ncl.ac.uk/undergraduate/modules/module/BMS3016	Dr Vanessa Armstrong	vanessa.armstrong@ncl.ac.uk 0191 2227545
S	Introduction to Science Communication and the importance of public engagement, gaining the ability to evaluate forms of science communication and write to target a wide audience	6BY506	Science Communication	http://www.derby.ac.uk/media/derbyacuk/contentassets/coursefiles/modulespdfs/undergraduate/babiology/SCIENCE-COMMUNICATION.pdf	Overall course contact: Dr Grahame Rowe	
T	design, deliver and reflect on a series of sessions in which you support others to learn about your subject. May be academic tutoring, peer mentoring, outreach	EMP2001	Ambassadors for Science	http://emps.exeter.ac.uk/computer-science/undergraduate/degrees/computer-science-mathematics/structure/EMP2001?year=2013	Dr Barrie Cooper	
T	practical work experience in a business or commercial setting. Apply knowledge and skills to authentic problem solving in the work place		Commercial and Industrial Experience	http://emps.exeter.ac.uk/computer-science/undergraduate/degrees/computer-science/structure/EMP3001?year=2013	Mr Stephen Rose	
T	Write a magazine article on either learning to computer programme, or the suitability of a particular language, platform or technique for beginner programmers	4CC516	Programming Principles	http://www.derby.ac.uk/media/derbyacuk/contentassets/coursefiles/modulespdfs/bcl/computing/bscinformationtechnology/PROGRAMMING-PRINCIPLES.pdf	Not given	

	Outreach
	Service learning
	STEM communication training

APPENDIX 4: REPRESENTATIVE CASE STUDY

Public Engagement, Service Learning and Science Communication training and activities within UK STEM Undergraduate curricula

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1. Example title *(To convey to others the central aspects)*: "*Science and Society*" Final Year Research Projects

2. Contact details and context

Name: Dr Dave Lewis
Institution: University of Leeds
Email: d.i.lewis@leeds.ac.uk

Degree Programme (s): BSc Human Physiology; BSc Medical Sciences; BSc Neuroscience; BSC Pharmacology
Module title & code: BMSC3301 Research Project in Biomedical Sciences
Class size: 180-220 (5-8 p.a. undertake "Science & Society projects

3. Please describe the main features of the module:

Final year students within the Biomedical Sciences group of programmes (Human Physiology, Medical Sciences, Neuroscience, Pharmacology) have the opportunity to undertake one of the following ten types of Final Year research project (Individual or group laboratory; critical review; therapeutic audit; bioinformatics; computer modelling; public health survey; science and Society; educational research; digital resources). Each project is of 8 weeks duration, with students expected to commit 3.5 days per week to their project. "*Science and Society*" projects enable students to undertake outreach activities as their research project.

Students undertaking "*Science and Society*" projects create, deliver and evaluate an interactive, curriculum enhancing teaching in local primary (students aged 7-11) and secondary (students aged 13-18) schools. Students design a teaching session on their allocated topic (e.g. *Making sense of our senses* (primary); *Creating super humans: Curing disease or enhancing performance?* (ethics discussion, secondary). It must be interactive (i.e. not a didactic lecture) and curriculum enhancing (i.e. be part of the national curriculum), but something the teachers themselves can't deliver (e.g. though lack of equipment, recent advances in science etc.). The session must be modifiable for different year groups or session lengths. It must also incorporate a means of evaluating student's acquisition of knowledge, and feedback from both students and staff. Prior to delivery in schools, focus groups are utilised to provide feedback on the suitability, content and format of the session. The sessions are then delivered at the University during National Science Week, or in a carousel of such sessions which tours either local primary or secondary schools. Students deliver their session up to 15 times, and to more than one year group.

4. What employability or transferable skills and graduate attributes do the students develop and utilise?

Science communication, curriculum development, teaching practice, data collection and analysis, time & project management, ethical awareness, pedagogical literature review, report writing, interpersonal skills, resilience.

5. What are the learning outcomes for the module?

On completion of their project, students should have:

- acquired an in-depth knowledge and understanding of a research topic in the Biomedical Sciences;
- gained experience in the collation, critical analysis, interpretation and presentation of data;
- practised basic laboratory skills and acquired new laboratory skills or acquired skills associated with the design and interpretation of surveys or acquired skills associated with the design and delivery of educational or science and society activities or practiced skills associated with the critical analysis of the literature or acquired skills associated with the writing of grant applications;
- developed skills in the appropriate and selective use of library and other resources;
- expanded their ability to produce a written report on an investigation in the style of a scientific paper;
- improved their skills in preparing and delivering a scientific oral communication;
- improved their time management and organisational skills;
- improved their interpersonal skills.

6. **How do you assess the work and what evidence do you have that standards are comparable with more traditional formats?**

The assessments for all project types are similar. Students are required to write a 30 page dissertation (25 pages for critical review projects) and deliver an oral presentation. There is also a supervisor allocated "productivity" mark. The final module marks is derived as follows:

Dissertation 70%, oral communication 10%, productivity 20%

Whilst the dissertation for "*Science and Society*" projects follows the same format as traditional laboratory projects (Introduction, methods, results, discussion), the introduction focuses on the pedagogy, place within the curriculum and available resources for teaching the topic rather than the science. Feedback from the focus groups, materials or work produced by students in the session, evaluations of student knowledge acquisition, and feedback from both students and teachers form the results section. Teaching materials and blank feedback questionnaires are included as appendices. The novelty and appropriateness of the teaching session are assessed both as a component of the "productivity" mark and in the results section of the dissertation.

To ensure that all project types are academically equivalent and assessed to the same standards, there are detailed qualitative assessment criteria for all assignments, with the same criteria used for all project dissertations except critical review projects. All dissertations are independently double marked. If the first (supervisor) and second marks differ by 10 or more marks, the two markers discuss the marks they have allocated and come to an agreed mark. If they cannot come to an agreed mark, the assignment is third marked, with the final mark being the average of the nearest two out of the three marks. Most supervisors offer more than one type of project and are therefore used to supervising/assessing multiple different types of project. Furthermore, all "*Science and Society*" projects are second marked by colleagues who supervise laboratory projects.

Oral presentations are independently assessed by two members of academic staff (neither of whom are the supervisor) and by a minimum of 16 students using defined qualitative assessment criteria. The two academic staff marks each contribute 25% to the overall mark awarded, with the average student (peer) mark contributing 50%.

To further ensure comparability in academic standards, both between different project types and with other final year taught modules, a selection of calibration (top, middle and bottom of the mark range) dissertations are made available to the four External Examiners prior to the Examination Board. This selection includes examples of dissertations from all of the different project types.

7. Hot tips and things to look for: (*Guidance for colleagues who may wish to develop a similar activity*)

The key to success in the delivery of "*Science and Society*" projects is to:

- Offer *Science and Society* projects alongside other different project types, with limited numbers of the former to ensure that only students who definitely want to do these are allocated one.
- Provide students with a clear brief: Interactive, year group(s), session length etc.
- Provide suitable support and feedback during development of the session e.g. content, level, what can be achieved in a lesson
- Provide sufficient opportunities for students to rehearse their sessions before delivery in schools and gather feedback
- Ensure effective time management by having defined deadlines at distinct time points throughout the project and for the session itself
- Retain the right to prevent students delivering their sessions in schools if they are not of a sufficient standard
- Maintain regular contact with schools (delegating this to students as the time for delivery approaches), arranging times/dates of sessions 2-3 months in advance.
- Require students to reflect (and blog these reflections) at the outset of their project and regularly throughout its duration including after delivery of each session.
- Provide mechanisms for all students or supervisors meet informally to collectively discuss any problems as they arise.
- Gather feedback from participating schools and students and use this to inform the content of next year's sessions

8. How well does it work?

Extremely well! "*Science and Society*" projects enable students interested in education or science communication to undertake a project in this area; to develop valuable skills and gain work experience more closely matched to their final career destinations. Past graduates actively promote the outstanding educational experience and impact on employability of these projects to their peers.

"*Incredibly invaluable experience which enabled me to develop the skills that I am currently using in my teacher training"*

They have been recognised as an excellent example of good practice in a National Teaching Fellow's report on Final Year projects

"*Excellent example of good practice. It demonstrates how students can be given a range of options, which enables them to consider what they want to accomplish by completing a Final Year Project*"

External examiners are also very supportive of the high quality of "*Science and Society*" projects and their academic equivalence to other project types:

"A truly exceptional project, a delight to read"

They are extremely well received by Schools:

"Thank you for organising the science visits again. As always, a great success and the children really enjoyed them; exciting practical activities, high quality resources, impeccable planning and incredible levels of enthusiasm"

"*A credit to the Uni - very professional, sought and heeded advice willingly and all 3 were full of enthusiasm. Please pass on my thanks to them. We would be delighted to continue next year*"

They are an invaluable means to develop links between the Faculty and local schools and to promote the Faculty's education and research activities. All schools have invited us back in subsequent years. Indeed, we cannot meet the demand for these sessions from our partner schools.

9. What problems / issues have arisen?

Academic equivalence of different project types: Initially, on first offering "alternative" projects, some colleagues had concerns about their academic equivalence to traditional laboratory-based and literature review projects. To address these concerns, staff were invited to second mark these non-standard projects so they could see for themselves their high quality and depth of understanding. External examiners were also invited to comment on the suitability and academic equivalence of these non-traditional projects.

Time management: Students undertaking Science and Society projects only have 4 weeks to develop their activity before they are required to deliver the teaching session, leading to time management issues. To ensure that sessions are developed and delivered on time, students are now required, within 1 week of starting their project, to provide their supervisors with a Gantt chart outlining the key timelines/milestones throughout the project.

10. What is the feedback from your students?

Student feedback has been excellent. They appreciate the opportunity to be able to choose a project which both matches their research interests and their career destinations. These "alternative" (i.e. not traditional laboratory or critical review) projects are extremely popular with students, 35% opting for them as their first choice of project in 2013-14. Graduates recognise the employability skills gained and the benefits of undertaking them to their subsequent careers.

"*An incredibly invaluable experience which enabled me to develop the skills that I am currently using in my teacher training"*

"Challenging, highly interesting and rewarding"

"Communicating & engaging with children, thinking diversely and reasoning- transferable into medical career"

11. How resource-intensive is it?

Supervisors are required to commit one hour per week to meeting with project students during the 8 week duration of the project. They are also required to provide general feedback on draft dissertations within a two week time window, to listen to/provide feedback on a rehearsal of the student's oral presentation and to be available to assess at least one 3 hour oral presentation session.

Supervisors of students undertaking "Science and Society" projects may have to provide additional time to listen to/advise on the development of their students teaching sessions. The module manager also has to commit additional time to make arrangements with local schools for these sessions to take place.

In comparison to other project types, they are a low cost alternative. £100 will cover the cost of the development of resources, workbooks etc. and student travel to schools.

12. Details of support material / course work / assessment methods:

Students and Staff are provided with the following guidance documents:

- Module outline including details of deadlines
- Guidance for staff and students for each project type
- Guidance for oral presentations
- Document outlining the roles and responsibilities of students and staff

The following assessment criteria are utilised:

- Qualitative criteria for the assessment of all projects except critical review projects
- Qualitative criteria for the assessment of critical review projects
- Qualitative criteria for the assessment of oral presentations

Feedback on draft dissertations is provided a minimum of 2 weeks prior to the final deadline using specific feedback forms.

All of the above are available on the University's virtual learning environment module pages. These pages also include areas where students can provide feedback on the module as it progresses, a discussion forum and individual personal reflective blogs.

In addition to the above, additional training in the searching and critical review of the literature, writing grant proposals, and evaluating the ethical issues and long term societal impact of a programme of research is provided through seminars and linked tutorials in an "Advanced Scientific Skills" module in semester 1 of the final year, with projects starting in semester 2. The module manager also provides a seminar on questionnaire design and analysis for students undertaking science and society projects, and regular informal group drop-in sessions for both students undertaking science and society projects and their supervisors. Training in working in schools and with young people is provided by the University's Students into Schools Officer.

13. Relevant references and Web sites:

D.I. Lewis (2011) Enhancing Student Employability through Ethics-based Outreach Activities and Open Educational Resources. *Bioscience Education* Vol 18-7SE. Available at http://www.bioscience.heacademy.ac.uk/journal/vol18/beej-18-7SE.aspx

D.I. Lewis (2010) ***"Science and Society in schools; an alternative to laboratory based final year Research projects*"**. HEA Centre for Bioscience Conference **"Final Year Projects: Maximising the Learning", Newcastle.** Available at http://www.bioscience.heacademy.ac.uk/events/newcas130510.aspx

D.I. Lewis (2009) Case-study: Science and Society projects as alternative final year research projects. Available at http://www.sddu.leeds.ac.uk/casestudies/casestudy.php?ID=59