Institution:	University of Northumbria at Newcastle
Unit of Assessment:	10 - Mathematical Sciences
Title of case study:	Sustained Public Engagement Underpinned by Magnetohydrodynamics and Solar Physics Research: A Measured Increase In Learning Outcomes

1. Summary of the impact

This case study details the impact arising from a sustained public engagement activity with sixth-form students (16 to 17 year-olds) across two Further Education Colleges during 2012/13. The activity was underpinned by research carried out in the Unit (2010-2012). The programme resulted in multiple impacts as defined under "*Impacts on society, culture and creativity*". Specifically:

- the beneficiaries' interest in science was stimulated;
- the beneficiaries' engagement in science was improved;
- their science-related education was enhanced;
- the outreach programme made the participants excited about the science topics covered;
- the beneficiaries' awareness and understanding was improved by engaging them with the research;
- evidence of an improvement in both AS-level grades and in student retention.

These impacts are evidenced by the user feedback collected from 50 questionnaires, factual statements from the teachers and individual participants. This case study details the impact arising from public engagement as described in the recommendations of the National Co-ordinating Centre for Public Engagement (NCCPE).

2. Underpinning research

Dr McLaughlin (Senior Lecturer at Northumbria University since January 2010) is interested in problems in fluid dynamics and mathematical modelling of solar and astrophysical processes. His research involves solving nonlinear, three-dimensional, coupled systems of PDEs under various physical assumptions. He approaches this research using both analytical techniques and a variety of numerical methods, including the use of parallel computing. In 2011, he published a detailed review article on MagnetoHydroDynamic (MHD) wave behaviour within inhomogeneous magnetic media [1]. In 2012, McLaughlin reported a novel application of magnetoseismology to describe the properties of a previously unseen dark thread accompanying a solar jet [2]. Magnetoseismology is the application of MHD wave theory to magnetic wave observations to probe the plasma. In 2012 he reported new results from oscillatory reconnection (time-dependent, wave-generating reconnection) which demonstrated that oscillatory reconnection driven by magnetic flux emergence provides a natural explanation for generating the observed (transverse) solar jets [3], and investigated the sensitivity of the reconnection mechanism to various parameters [4]. In 2013, he analysed high-resolution observations from state-of-the-art solar satellites [5].

In 2012, McLaughlin constructed a five-part outreach programme of presentations: (i) Introduction to the Sun; (ii) The Sun and its effect on the Earth and Space Travel; (iii) Electromagnetism and MHD; (iv) Special Relativity; and (v) Mars. Key aspects of the presentations were based on the specific research carried out within the Unit. E.g.:

- Outreach materials covering magnetic flux emergence and magnetic reconnection were underpinned by McLaughlin's research detailed in outputs [3] and [4], respectively.
- Outreach materials explaining solar observations were underpinned by research reported in [5].
- A detailed mathematical model of the solar wind was presented as part of Presentations (ii) and (v), and this model was developed as part of US Air Force grant FA8655-13-1-3067.
- Presentation (iii) contained a discussion of MHD waves underpinned by research from [1] & [4].

The rest of the outreach materials were created from McLaughlin's body of research carried out within the Unit. The cited outputs above are specific examples of key research outputs produced within the Unit. These outputs detail the original research, whereas the outreach programme acted

as the vehicle to engage the audience with the research.

3. References to the research (* references which best indicate quality of underpinning research)

[1] McLaughlin, J.A., Hood, A.W. & De Moortel, I. (2011)
Review Article: MHD Wave Propagation Near Coronal Null Points of Magnetic Fields
Space Science Reviews, **158**, pp. 205-236. http://dx.doi.org\10.1007\s11214-010-9654-y

[2*] Morton, R.J., Verth, G., McLaughlin, J.A. & Erdélyi, R. (2012)
Determination of sub-resolution structure of a jet by solar magnetoseismology
Astrophysical Journal, **744**, 5-15. http://dx.doi.org\10.1088\0004-637X\744\1\5

[3*] McLaughlin, J.A., Verth, G., Fedun, V. & Erdélyi, R. (2012)
Generation of quasi-periodic waves & flows in the solar atmosphere by oscillatory reconnection
Astrophysical Journal, **749**, 30-40. http://dx.doi.org\10.1088\0004-637X\749\1\30

[4] McLaughlin, J.A., Thurgood, J.O. & MacTaggart, D. (2012)
On the periodicity of oscillatory reconnection
Astronomy & Astrophysics, **549**, A98. http://dx.doi.org\10.1051\0004-6361\201220234

[5*] Morton, R.J. & McLaughlin, J.A. (2013)
Hi-C and AIA observations of transverse MHD waves in active regions
Astronomy & Astrophysics, **553**, L10. http://dx.doi.org\10.1051\0004-6361\201321465

Relevant Grants

- McLaughlin, J.A. (2012-2013), £4,000,
  Northumbria University HEIF funding: Engagement Event Funding.
- McLaughlin, J.A. (2013-2014), FA8655-13-1-3067, £47.4k, "*The Hunt for the Missing Modes: Revealing the True Nature of the Solar Wind",* US Air Force Office for Scientific Research.

4. Details of the impact

In March 2012, McLaughlin presented his research to a general audience as part of the Newcastle Science Festival. He interviewed a subset of the audience after his presentation, and realised that such interviews, evaluation data and user feedback could be used to measure changes in knowledge and behaviour. He recognised that a one-off presentation might influence audience members on the immediate timescale, but a sustained programme with the same group was needed to embed a lasting benefit. Consequently, he devised a multiple visit, ongoing outreach programme where he interacted with the *same* group multiple times in a structured set of exercises arising from his recent research. He worked with two sixth-form/Further Education colleges: (a) Newcastle College and (b) Gosforth Academy in a collaborative outreach programme. The aim was to investigate the positive effects and benefits of public engagement at these sixth-form colleges using outreach materials underpinned by McLaughlin's research into Solar Physics and MHD since 2010.

During October 2012 to June 2013 (2012/13 school year), McLaughlin visited these sixth-form colleges on multiple, independent occasions and delivered five individual presentations (of increasing complexity) on the following topics: (i) Introduction to the Sun; (ii) The Sun and its effect on the Earth and Space Travel; (iii) Electromagnetism and MHD; (iv) Special Relativity; and (v) Mars. Each presentation session lasted for one hour, and was divided into a 20 minute oral presentation followed by 5-10 minutes of questions, followed by a second 20 minute session, again followed by 5-10 minutes of questions. This format was judged most appropriate for the audience.

Evidence gathering - Evaluation questionnaires were completed by the participants at the end of the fifth presentation and an analysis of the responses was performed. The questionnaires (available on request) were constructed using the Likert scale method (with option for free text and open questions) and were developed in collaboration with a developmental psychologist. Registers were taken at each of the five presentations to ensure that students completing the questionnaires had indeed attended the whole outreach programme. Hence, the 50 beneficiaries represent a subset of the total number of students studying AS-level Physics across both colleges. Data from the 50 evaluation questionnaires was used to evidence the impact on the change in participants' interest, knowledge, engagement and motivation. There was 100% response rate from all 50

participants who individually each answered 100% of the questions.

Impact (*on society, culture and creativity*) - The public engagement programme resulted in multiple impacts as defined under "Impacts on society, culture and creativity":

- the beneficiaries' interest in science was stimulated;
- the beneficiaries' engagement with science was improved;
- their science-related education was enhanced;
- the outreach programme made the participants excited about the science topics covered;
- the awareness and understanding of the beneficiaries was improved by engaging them with the research;
- evidence of an improvement in both AS-level grades, and student retention.

This was evidenced by questionnaire responses (user feedback), participants' quotes, AS-results and factual statements. A summary of responses is given below (e.g. 92% rated overall programme as good or very good) with full survey feedback available on request.

Specific impacts and specific evidence

The impact, **the beneficiaries' interest in science was stimulated**, was evidenced by the results of two feedback questions:

- *As a direct result of Dr McLaughlin's outreach programme, are you now more interested in science as a subject than you were before?*
  54% of responses indicated that they were more (or much more) interested.
- *Please indicate to what extent you agree or disagree with the following statement: "My interest in science has been stimulated as a direct result of Dr McLaughlin's outreach programme".*
  64% of responses agreed (or strongly agreed).

The impact, **the beneficiaries' engagement with science was improved**, was evidenced by:

- *As a direct result of Dr McLaughlin's outreach programme, are you now more likely to talk to your teacher about science?*
  32% of responses indicated that they were more (or much more) likely.
- *As a direct result of Dr McLaughlin's outreach programme, are you now more likely to consider studying science at university?*
  34% of responses indicated that they were more (or much more) likely.

The impact, **their science-related education was enhanced**, was evidenced as follows:

- *Indicate to what extent you agree or disagree with the following statement: "My science-based education has been enhanced as a direct result of Dr McLaughlin's outreach programme".*
  68% of responses agreed (or strongly agreed).

The impact, **the outreach programme made the participants excited about the topics covered**, was evidenced by the results of the following feedback question:

- *Did the outreach programme make you excited about the science topics covered?*
  80% of responses indicated yes (or yes to a strong extent).

The impact, **the awareness and understanding of the beneficiaries was improved by engaging them with the research**, was evidenced by the following illustrative feedback, i.e. participants' quotes from survey (quotations may also evidence the other impacts):

- "*It inspired me to do a space based EPQ (about Mars)*". [Extended Project Qualifications are part of level three of the National Qualifications Framework].
- "*I would like to take geology at university and am now going to look at the courses to see if they include geology on other planets*".
- "*It has extended my knowledge of science and gave me more motivation to do well in science. I am much more enthusiastic about it now*".
- "*It did make me more enthusiastic about physics, discovering new things, and realising that there are so many things that you don't know*".
- "*It's given me more knowledge on the subjects discussed. It's made me more interested in learning physics in more detail, rather than just what is learnt in lessons*".

- "*I realise that I can research topics myself in order to increase my knowledge*".
- "*I feel more happy going into A2 with a higher knowledge about space. A lot of the topics discussed I wasn't confident on beforehand*".

Additional Significance - This was a sustained and ongoing engagement with the groups (*sustainability* as well as *secondary reach*). Specifically, the same group of students was seen at five individual points over the period October 2012 to June 2013 (i.e. 50 students had attended all five presentations). It was believed that the information, knowledge and benefits of the outreach programme 'take time to really sink in', and so an outreach programme spread across a school year seemed appropriate. Moreover, McLaughlin's research (which underpinned the outreach material) is specialist material, and it took time to build the knowledge and context for the audience to a mature level in order to engage properly with and understand the underpinning research.

A factual statement from the Head of Physics at Newcastle College states: *"The topics covered encouraged several students with a lower than average ALIS* (Advanced Level Information System) *predicted grade to attend the presentations. Engaging some of these students was an achievement in itself and from the discussions that followed it seemed to have a motivational effect. Statistically speaking these students have a lower than average chance of achieving the high grades required in order to gain a place at university making engaging and motivating them to learn even more important".* A comparison of the AS-level Physics predicted grades versus actual grades across the Newcastle College students showed a clear increase in grades, specifically:

- **Predicted grades**: A= 0%, B=18%, C=23%; D=14%; E=45%
- **Actual grades**: A=18%, B=27%, C=18%; D=9%; E=27%

with an average increase of +0.86 grade per students (not uniform increase). Thus, from the factual statement and grade comparison, there is evidence that the programme contributed to an improvement in AS-level grades, i.e. improved attainment.

A factual statement from Gosforth Academy states: *"This year 60% of students have continued from AS level Physics to A2 level Physics compared to an average of 50% over the last few years. I would not be able to hold Dr McLaughlin completely responsible for this, but do believe that his delivery of lectures through the year has indeed partially contributed to this success",* i.e. there is some (indirect) evidence of increased retention and progression.

Beneficiaries and Additional Reach - The target audience was the first year of sixth form of AS-level Physics. Across the two colleges, data was collected from 50 AS-level students (16-17 year olds), consisting of 39 males and 11 females where, for STEM subjects, the NCCPE (National Co-ordinating Centre for Public Engagement) defines female students as a 'hard to reach' audience.

This case study details the impact arising from public engagement activity and follows the recommendations of the NCCPE and their guidance for assessing REF impact arising from public engagement with research. The NCCPE is part of the Beacons for Public Engagement project, funded by the UK Funding Councils, Research Councils UK and the Wellcome Trust, and the NCCPE is at the forefront of the national debate on public engagement. The Director of the NCCPE has described McLaughlin's public engagement programme as "*an impressive and thoughtful project*". In 2014, the NCCPE will be drafting guidelines of best practice and useful tools to apply to the next REF exercise. As a direct result of his public engagement programme, the Director of the NCCPE has invited McLaughlin to be part of this process.

5. Sources to corroborate the impact

- Summary/breakdown of responses (*corroborating all impacts*).
- Selected participants' quotations (*corroborating all impacts*).
- Predicted & actual grades of Newcastle College AS-level students (*showing grade increases*).
- Factual statement from Newcastle College (*corroborating positive impact on beneficiaries' interest, educational enhancement, and engagement*).
- Factual statement from Gosforth Academy (*corroborating impacts on beneficiaries' interest and engagement, educational enhancement, and evidence of improved retention and progression*).
- Invitation from the Director of the NCCPE.

Copies of these documents are available on request.