Bridging the Gap: Training Science Teachers in Science Museums and Other Informal Settings

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The talk outlines the work being done at Sheffield Hallam University in training secondary science teachers using the Kelham Island Industrial Museum in Sheffield. It also demonstrates how this work integrates teaching and learning in Science Education with practical work in informal settings that form a part of the National Science Week programme. The talk will also show how the students contribute to the developmental work of the museum through undertaking small-scale visitor-studies. The activity as a whole is placed into the context of the criteria for teacher-training in the United Kingdom and the need to provide experience of teaching science in settings other than schools. Some reference is also made to the international context into which this approach can be placed.

Introduction

There have long been established links between museums and teacher training establishments. In the United Kingdom a survey was conducted by Her Majesty's Inspectors of Schools into the use of museums within primary phase initial teacher training courses (DES 1990). Recent revisions of the standards and requirements for teacher training (TTA, 2002, 2003) now require that those awarded Qualified Teacher Status must demonstrate:

> "As relevant to the age range they are trained to teach, they are able to plan opportunities for pupils to learn in out-of school contexts, such as school visits, museums, theatres, field work and employment-based settings, with the help of other staff where appropriate."
> (TTA, 2002, p.9)

Formal integration of the museum experience within science teacher education at Sheffield Hallam University began some time ago with the founding of SCOPE – an interactive science and technology centre based in the Centre for Science Education – in 1990 following the annual meeting of the British Association for the Advancement of Science held in the city during the previous year. SCOPE was set up at Sheffield Hallam University with the express intention of forming close links between interactive science centres and teacher training. Since 2001 SCOPE has been located at nearby Kelham Island the local museum of science and industry.

Sheffield Hallam University is one of the leading providers of science teacher training in the United Kingdom at both primary (aged 4-10) and secondary (aged 11-18) phases. Secondary science education is based within the Centre for Science Education which is home to the Regional Science Learning Centre for Yorkshire and the Humber and also SETPOINT South Yorkshire – the regional body responsible for the non-statutory provision of Science, Technology, Engineering and Mathematics (STEM) in South Yorkshire. Science teacher training at Sheffield Hallam University is founded upon a long experience of curriculum

development, continuing professional development and underpinned by a commitment to active learning strategies.

The training of secondary science teachers takes place in all possible modes: 1year Postgraduate Certificate in Education (PGCE) for science specialists; 2 year PCGE for students whose first degree requires further science knowledge; 2 year degree for students already holding a Higher National Diploma in a science-based subject; 3 year degree in Science with qualified teacher status for post-A-level school leavers[8]. Over half of these students are considered to be mature students aged over 21 on entry. This paper focuses upon one element of the course followed by students undertaking the 2 and 3 year routes: the STEM unit. This unit was set up as the vehicle through which students would engage with the theoretical underpinning to science education through practical activity in a museum context as well as meeting the TTA requirements for QTS.

As has previously been stated the interactive gallery originally based at Sheffield Hallam University was transferred to Kelham Island Museum in 2001. The museum itself was set up in 1982 in the former premises of the Sheffield Tramway generating station on a site that has been in continuous industrial use since the middle ages. Kelham Island Museum contains a series of galleries recreating 19th century metalworking workshops together with displays and artefacts illustrating local manufacture. In addition to this, recent developments have included teaching rooms and a large space for temporary exhibitions and events. Kelham Island is one the sites forming the Sheffield Industrial Museums Trust which also includes Abbeydale Industrial Hamlet - an 18th Century Scythe making works that contains the best preserved example of the crucible steel making process - and the Shepherd Wheel – a 16th century cutlery maker's workshop.

1. The Nature of the Museum

Kelham Island Industrial museum contains elements of all four categories of museum as identified by McManus (1992) following Friedman (1989):

- **Ancestral Form Museums**

An eclectic collection of exhibits forming a cabinet of curiosities: individual displays within the museum have this feel in that they are specifically designed to show the range and diversity of Sheffield-made products or as a result of the donation of collections from companies and individuals.

- **First Generation Science Museums**

Taxonomic collections of exhibits and archives: The recent redevelopment of the museum archives has extended this function of the museum. This development has taken place in tandem with the setting up of a research space within the archive. There are a number of examples of the taxonomic organisation of products from individual firms often originating as sales and marketing materials. There has been a return to the notion of the specialised gallery with the building of a new gallery to identify the role played by Sheffield manufacture in transport-based industries.

[8] A levels are the normal university entrance examinations taken at age 18.

- **Second Generation Science Museums**

Museums founded with the mission to educate and train craftsmen and designers. The Victoria and Albert Museum and the National Museum of Science and Industry set up after the Great Exhibition of 1851 (Butler, 1992) fulfilled this function. Indeed there are a number of exhibits within Kelham Island Museum that featured in the Great Exhibition but alongside these are more recent examples of good manufacture emphasising skill and precision in forging, casting and machining. The museum has a strong focus upon mass educational activity through its public programmes.

- **Third Generation Science Museums**

The third generation museum is concerned with "the transmission of scientific ideas and concepts rather than the contemplation of scientific objects" (McManus, *ibid.*). This moves the museum away from being simply a collection of authentic artefacts in that a number of interactive exhibits have been devised and produced with the aim of educating and entertaining the visitor. Two galleries specifically use the pedagogical devise of interactivity as a means of introducing young people to scientific ideas and processes. SCOPE, the interactive gallery which was formerly based at Sheffield Hallam University, gives the visitor the opportunity to engage with objects designed to "both enlighten and entertain through contemporary, participatory exhibits" (Rennie and McClafferty, 1996). In addition, the *Melting Shop* gallery was designed to give pre-school and early years pupils an environment where, through playing in a model steel plant, they could learn about the making of steel and its processing: moulding, rolling and forging.

If it were not a museum Kelham Island would remain an important site of local industrial archaeology being the one-time site of the former town armourer Homer Kelham and in almost continuous use from that time for a variety of industrial uses, finally acting as the site of the power station supplying electricity to the former Sheffield Tramway Company. There is therefore an important sense of place in the site itself; its *genius loci* has been made all the more potent by the transfer of a number of intact historic workshops and the reconstruction of a Victorian street from old shop fronts. This Victorian street formerly housed the workshops of a number of traditional craftsmen – the *little mesters* (Tweedale, 1992). Sadly only one of these – a forger of surgical instruments – remains. In bringing together real things, real people and real places Kelham Island fulfils, some of the strongest criteria for a heritage-based visitor attraction: what Moore (1997) calls the "triple power of the real". As the last of the working craftsmen finally reaches retirement a significant aspect of the museum's ethos will be lost.

2. Science Education and the Museum

From the setting up of SCOPE as an interactive gallery at Sheffield Hallam University (then Sheffield City Polytechnic) in 1990 following the 1989 Annual meeting of the British Association for the Advancement of Science held in Sheffield there has been a strong intention to link science teacher education with the development of an interactive gallery (Quin, 1990). However, the use of the museum tended to be on an *ad-hoc* basis until funding from Sheffield Hallam University - under the auspices of the HEFCE *Widening Participation* scheme[9] - to encourage greater participation in higher education from under-represented

[9] The Higher Education Funding Council for England is the government body that disburses funding to universities in England.

groups was used to fund the building of an education space within the museum. This acted as a catalyst for developing a science teacher education unit to be taught at the museum.

However, the most significant development grew out of the debate leading up to and surrounding the publication of the Roberts report (2002) *SET for Success* on the supply of people with science technology, engineering and mathematical skills. Within the Yorkshire and Humber region – and particularly the South Yorkshire Sub-region – this was set within an overall picture of enormous structural change with the decline of traditional industries such as steel making and coal mining together with the rise of new industries leading to the twin problems of pockets of high unemployment coupled with an overall skills deficit in scientific and technical careers. In addressing this problem, Yorkshire Forward – the regional development agency for Yorkshire and the Humber – set up a project to stimulate non-statutory STEM (science, technology, engineering and mathematics) coordinated through the SETPOINTs, Museums and others.

> Objective Four: To achieve a radical improvement in the development and application of education, learening and skills, particularly high-quality vocational skills. (Yorkshire Forward, 2002)

It is within this framework that the STEM unit was written to link the science teacher training work of Sheffield Hallam University with the work of SETPOINT South Yorkshire and the objectives of the Regional Economic Strategy. It should be stressed that this unit formed only part of a strategy that ultimately delivered over 1000 30-hour learning outcomes[10] and which included teacher CPD, public STEM programmes and school-based activity within its portfolio. It was, however, felt to be significant in that it targeted science teacher supply at an early stage in their work and formed a natural link between classroom–based and extra-curricular delivery of science education and so was felt to be most likely to provide a long-term influence as teachers moved into the next stage of their careers.

3. The structure of the taught course

The link between the teacher training course and the museum can be considered as innovative in the sense that it uses the museum as a place where the content of the museum can be used to deliver aspects of pedagogy and didactics. There are of course a number of initiatives that have looked at teacher use of museums or which have formed close links between museums and education - indeed the current initiative has been reported on within a wider YMLAC[11] project *Settings other than schools* - but largely such initiavies have tended to be focussed on the better use of the museum collection or in developing more effective museum education programmes. The European project: *School-Museum cooperation for improving the teaching and learning of science* is an example of such a development in that it attempts to improve the linkage between schools, teachers and museums and particularly the manner in which collections are used by schools (Xanthoudaki, 2002). Similarly, the Exploratorium in San Francisco has engaged in teacher training programmes for many years through its direct links with schools. (Diamond, *et al.*1987).

The STEM unit is designed as a "long-thin unit" taught over two semesters to a mixed group of students including 3-year BSc+QTS students assessed at level 4 of the National

[10] These identify 30 hours of directed learning. In this case 1000 pupils would each have been engaged in 30 hours of learning.
[11] Yorkshire Museums, Libraries and Archives Council

Qualifications Framework (NQF); 2year BSc+ QTS and 2year PGCE students assessed at NQF level 6 and a small cohort of students following the unit as part of a BSc course in science communication (*Science in the Media*) at NQF level 6. The range of experience and levels of assessment posed interesting challenges for the teaching and assessment of the unit.

Ostensibly the course is two parts: the first semester concentrates upon theories of learning, and the observation of learning taking place within the museum environment. During this period the students engage in small-scale group research activity that focusses upon the observation of learning behaviour within the museum of a group of visiting primary pupils. The second semester focuses upon teaching and places the students into a teaching rôle delivering small scale teaching tasks either in the museum itself or in primary schools around the region as part of National Science Week.

Evaluation and assessment form an important part of the teaching and learning process within the unit with formative feedback being delivered after the first assignment and review points included within the course structure (see table 1).

The unit content therefore, makes a transition from teaching about cognition and theories of learning to a consideration of the nature of the museum setting and more general discussion of learning in informal situations. The course includes some teaching about research techniques prior to the students engaging in small-scale group research activity. There was also an opportunity to look at broader STEM initiatives through a visit by students to the Venturefest[12] conference in York. In the second semester the emphasis moves way from the observation of learning behaviours towards preparing the students to engage in small scale teaching tasks prior to producing reflection and evaluation.

Table 1: Science Education (STEM) unit outline

SEMESTER 1

Date	Content	3 Year Route	2 Year Route	Science in the Media
22.9.04	Introduction: Theories of Learning 1: Developmental ideas	10.00-12.00	10.00-1200	-
29.9.04	Theories of Learning 2: Constructivism	09.00-11.00	11.00-1300	-
6.10.04	Learning in Informal settings: All age learning	11.00-1300	09.00-11.00	09.00-11.00
13.10.04	The Museum Experience: Categories of museum – presentation and learning styles	10.00-12.00	10.00-12.00	10.00-12.00
20.10.04	Observational Techniques: Approaches to and methods of data gathering, validity and reliability.	09.00-11.00	11.00-13.00	10.00-13.00

[12] A regional conference that focused upon the links between business, industry and education.

3.11.04	Planning for data gathering: Group meetings to plan activity and book resources.	10.00-13.00	10.00-13.00	10.00-13.00
10.11.04	Data Gathering: Groups of 4 based around the museum.	10.00-13.00	10.00-13.00	10.00-13.00
24.11.04	School-based feedback: Opportunity for follow-up interviews.	09.00-12.00	09.00-12.00	09.00-12
8.12.04	Hand in assignment 1	By 4.00pm in Centre Office	By 4.00pm in Centre Office	By 4.00 pm in School of Science office.

SEMESTER 2

Date	Content	3 Year Route	2 Year Route	Science in the Media
26.1.05	STEM Session (City Campus)	11.00	11.00	
2.02.05	Trip to YORK - Venturefest	10.00-12.00	10.00-12.00	10.00-12.00
9.02.05	Role-play and Drama	09.00-11.00	11.00-13.00	11.00-13.00
16.02.05	Games and simulations 3311	11.00-13.00	09.00-11.00	09.00-11.00
23.02.05	Practice week: Opportunity to run through your activity 3311	10.00-12.00	10.00-12.00	10.00-12.00
9.03.05	Informal Group meetings 3311	TBA	TBA	TBA
16.03.05	Science Week: Activities	TBA	TBA	TBA
6.04.05	Debriefing 3311	09.00-11.00	11.00-13.00	11.00-13.00
28.4.05	Hand in assignment 2	By 4.00pm in Centre Office	By 4.00pm in Centre Office	By 4.00 pm in School of Science office.

Differentiation for this rather diverse group was addressed by means of some separate teaching for the constituent groups but mostly through the differentiation of assessment by outcomes as defined by the NQF level criteria. There were two assessment tasks: the first focussing upon the observation of learning and the second on the evaluation of teaching (Table 2).

Table 2.
Comparison of assessment tasks and criteria for Assignment 1 at levels 4 and 6.

Assessment: BSc (Hons) 3 Year / Year 1 (level 4)

Assignment 1

Produce a log of observations made upon pupils working in SCOPE the interactive science centre based at Kelham Island Museum, Sheffield. The observation log will use a range of techniques to map out the activity of children working in an interactive gallery.

Your observations will be made as part of a team and will include follow-up activity with pupils in school. You will use the data collected as the basis for an individual report.

Marking Criteria (Individual Report)

Criteria	Mark
1. Identify the group under observation and the observation techniques to be used.	10
2. As a group make observations and record the data collected.	15
3. Produce a brief report (1000 words) Describing the behaviour and learning of the pupils under observation	20
4. Correct use of spelling, grammar, referencing and citation.	5
Total	**50**

Assessment: BSc (Hons) 2 Year / Year 1; (PGCE 2 Year / Year 1 (level 6)

Assignment 1

a. Working in groups, you are to produce a log of observations of pupils in a museum or science centre. Your log will be based upon a range of data collection techniques. (25%)
b. Write an individual report showing analysis of the data produced by the observation. (25%)

Marking Criteria (Individual Report)

Criteria	Mark
1. Identify the group under observation and the observation techniques to be used.	5
2. As a group make observations and record the data collected.	10
3. Produce a brief log (500 words) of the observations made by your group.	10
4. Write an individual report (1000 words) analysing the behaviour and learning of the pupils observed.	10
5. Write a summary recommendation (500 words) reflecting upon the effectiveness of this aspect of the museum's work.	10
6. Correct use of spelling, grammar, referencing and citation.	5
Total	**50**

Similarly, the second assessment - which took place in semester 2 – had assessment criteria which were differentiated according to the national qualification framework for levels 4 and 6 (Table 3). A separate second assessment was devised for the small number of science communication students.

Table 3:
Comparison of assessment tasks and criteria for Assignment 2 at levels 4 and 6.

Assessment: BSc (Hons) 3 Year / Year 1 (level 4)

Assignment 2

In small teams, select a STEM teaching activity: *Becky Boyle, Who Polluted the River?, Science Suitcase, The Scout Packs.* Deliver this activity to a group of children. Write an individual report (1500 words) through which you reflect upon the learning that has taken place and upon your own teaching.

Criteria	Mark
1. Description of the activity and of how it was used.	10
2. Reflection upon the pupils' learning in terms of skills, attitudes and knowledge	20
3. Personal reflection upon the effectiveness of your own teaching.	15
4. Spelling, structure, grammar, referencing and citation	5
Total	**50**

Assessment: BSc (Hons) 2 Year / Year 1; (PGCE 2 Year / Year 1 (level 6)

Assignment 2

a. As a group, you are to devise and deliver a teaching activity that could be used at Key Stage 2 or 3 as a means of popularising one aspect of Science, Technology, Engineering or Mathematics (STEM) during Science Week. (25%)
b. You are to produce an individual evaluative report of the teaching and learning that took place as a result of the STEM activity. (25%)

Marking Criteria (Individual Report)

Criteria	Mark
1. Identify the group to be taught and the material to be covered.	5
2. Produce appropriate teaching materials.	10
3. Produce an outline of the activity together of your group in action	10
4. Write an individual report (1000 words) analysing the behaviour and learning of the pupils observed.	10
5. Write a personal account evaluating your role in planning and executing the activity	10
6. Correct use of spelling, grammar, referencing and citation.	5
Total	**50**

4. Students as Researchers

The approach to teaching educational theory required that the students should undertake small scale research in the museum. This has benefits not only for the students but also for the museum as well as enabling a primary school group to engage with the museum free of charge. The intended benefits for the students was that it enabled a practical approach to be taken to the teaching of educational theory in which students could observe learning at first hand. It also allows students undertake fieldwork in a controlled manner. Working in groups of between 4 and 6, the students were encouraged to use a range of observational techniques (Table 4) and were required to pool their data as a means of using triangulation to achieve a measure of validity to their individual analyses. Museum staff contributed to the research aspect of the unit by suggesting which areas might be used for observation in order that the data collected could be used as part of the museum's own research and evaluation strategy. In general three main areas have been used for observation:

- **SCOPE** – an interactive science and technology centre focussing upon physics based phenomena.
- **The Hattersley Gallery** – a collection of varied exhibits demonstrating the range of products made in Sheffield. This gallery also contained a few interactives.
- **The Melting Shop** – an interactive gallery designed for pre-school and early years pupils where, through the use of playground exhibits, the children could learn about steel production and processing.

Students took part in a follow up visit to the school two weeks later to enable further interviewing of the pupils to take place. On the basis of this, students prepared individual reports using data collected within each of their groups. The reports were made available to the museum staff.

Table 4: Data collection techniques.

Data collection technique	Intended purpose
Video Recording of individual exhibits	To examine in depth the range of interactions with a single exhibit.
Video recording of large areas	To map general movement around the space. To map use of individual exhibits
Audio recording of pupil interaction	To record and analyse pupil discussion of exhibits
Interviews	To gain an understanding of individual perceptions of the exhibits and of the museum as a whole.
Pupil shadowing	To identify the individual experience of the museum
Timing	To analyse the time spent at individual exhibits.
Focus group discussion in school	To enable pupils to reflect upon their experience of visiting the museum

The museum has proved to be a very data rich environment. The use of students to collect and analyse data has enabled significant visitor research to take place which would normally be beyond the resources of a provincial museum such as Kelham Island.

5. Teaching in the Museum

The second semester of the unit concentrated upon giving the students the opportunity to perform small scale teaching tasks and reflect upon these. In the case of the students working at level 6 this involved devising and carrying out microteaching activities in the museum. For the students working at level 4, the teaching task was presented to them in the form of a suitcase of interactive exhibits which was taken out into local primary schools.

For the majority of students this teaching task formed their first real experience of directing the work of children. Although these students ultimately intend to teach at secondary level, the use of small groups of upper primary pupils gave the students an opportunity to concentrate upon communicating scientific ideas with which they generally felt secure without having the added pressure of maintaining discipline. Within this framework students working at level 6 would devise an activity to be delivered as a group of 4 or 5 repeatedly to small groups of pupils.

From the museum's perspective this provided an opportunity to organise themed activity for schools within the education spaces of the museum as part of National Science week[13].

6. So, did it work?

When considered from the point of view of teaching and assessment within the University, the approach outlined in this paper presents a number of novel features:

- it introduces undergraduate students not only to a theoretical understanding of educational ideas but also, through small scale research, to an empirical engagement with teaching and learning;
- it provides an innovative approach to the teaching of a generally unpopular aspect of the teacher education curriculum;
- it places learning and assessment more closely together in that students are encouraged to learn through assessment;
- it places teaching and learning into a real situation.

For the museum the activity provides a number of benefits:

- it enables a significant level of visitor study data to be collected in a controlled way;
- it enables initial data analysis to be undertaken by the students with the presentation of initial recommendations;
- it enables the museum to expand its range of public programmes;
- it provides a means of recruitment of volunteers, explainers and casual staff.

Student evaluations of the course are generally supportive of this approach. The students' view of using the museum as a venue for teaching were generally positive with typical responses being:

[13] National Science Week is organised by the British Association for the Advancement of Science in March each Year. The activities organised in South Yorkshire engaged with over 18000 pupils aged 5-16 taking part in over 300 events. Making it one of the largest regional programmes in the UK. These events included public lectures, visits into schools by experts, problem solving, museum based activity, industrial visits.

A good environment
Very good. There are extensive facilities on site that enhance lectures
The museum was an excellent location although I would have preferred more chances to be in the museum with the children.

This latter comment identifies a distinction in some students thinking between the museum as a venue for lectures and the museum as a venue for undertaking activities with children. When asked to reflect upon the best aspects of the taught part of the course, some students expressed the view that lectures could have taken place at the university with visits only being made for microteaching and research. The lectures themselves were generally valued with typical comments being:

It was very enjoyable and proved how children learn and think (Piaget and Vygotsky)
The taught part was more like a lecture than a lesson and was given in a relaxed manner so you felt like you could join in.
Thinking about different methods of learning was something I'd not done before.

A utilitarian theme runs through student comments in which the emphasis upon practical teaching is valued:

The demonstrations of teaching methods using volunteers from the audience – very entertaining as well as informative.
The actual visits of school children visiting the museum memory retention by visiting the school and invaluable experience gathered in science week.

7. General Benefits

It is clear that the schools involved in working with the museum benefit:

- the visit is free to the school including travel costs;
- the pupils focus directly upon science and technology in an environment they way they could not in school;
- teachers learn from the visit and carry their ideas back to the school;
- primary pupils have scientific ideas taught to them by a specialist;
- a generally high level of excitement and enthusiasm for science and technology is generated motivating the pupils to learn.

However, the regional development STEM project as a whole has had a significant effect for schools in South Yorkshire. External evaluation of the project has revealed that schools engaged with SETPOINT South Yorkshire have shown remarkable levels of improvement in SATS performance (Table 5.)

Conclusions

This museum based activity is one aspect of a wider raft of activities co-ordinated by SETPOINT South Yorkshire in conjunction with other partners in South Yorkshire. This, in turn, forms part of a broader project covering the whole of Yorkshire and the Humber Which attempts to improve the general level of scientific and technical knowledge and skill for the workforce. Independent evaluation of the project has demonstrated particularly high levels of improvement for primary schools in the South Yorkshire region. Although direct causal links

are difficult to establish, the evidence points strongly to the significant influence that engagement with projects such as this has upon schools.

Table 5: SATS performance in South Yorkshire (Source Hoshin Report 2005)

		South Yorkshire			Yorkshire and the Humber		
		2003	**2004**	**Change**	**2003**	**2004**	**Change**
KS2 Maths Level 4+	**Pearson/ANOVA**	-0.027	0.047	**9.981**	-0.21	-0.11	**4.43**
	Significance	0.302	0.183	0.002	0.203	0.338	0.035
KS2 Maths Level 5	**Pearson/ANOVA**	-0.16	0.029	**7.687**	-0.054	-0.029	**4.041**
	Significance	0.381	0.288	0.006	0.018	0.129	0.045
KS2 Science 4+	**Pearson/ANOVA**	-0.034	0.082	**10.058**	0.014	0.027	**0.895**
	Significance	0.262	0.057	0.002	0.296	0.142	0.344
KS2 Science 5	**Pearson/ANOVA**	-0.027	0.047	**7.508**	-0.026	-0.009	**3.216**
	Significance	0.306	0.184	0.006	0.153	0.362	0.073

In conducting this evaluation comparison was made between those schools involved with SETPOINT South Yorkshire and other schools which had not had such involvement. Also comparison was made with school performance in non science and technology subjects (English) across the same authorities. In summary, the key points that this study reveals are:

- Involved schools show improvement
- The same change not seen in other subjects
- Raft of regional development projects stimulates improvement
- Schools look to SETPOINT when planning for improvement
- Linkage between Teacher Training, CPD and STEM I seen as an important feature.

It would seem therefore that in influencing teacher training through enabling teachers to make better use of informal settings, a significant contribution is being made to the enhancement of academic performance of pupils evidence for which can be found in a rise in public examination grades.

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