Marvellous Microbes & Microscopes: Reflections on a 'Multi-Way' Learning Experience

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1. Introduction

This report is a story about my development as a science communicator. It includes a consideration of science communication and learning theory, and how these were incorporated into my public-engagement event, which involved learning about the water mould *Saprolegnia* along with other organisms with which it associates, such as *Paramecia*, *Rotifers* and *Vorticella*, and it was also about having fun with microscopes. The most important point, in planning the event, was that my activity was *accessible* to every type of learner (pragmatist, activist, reflector, theorist), and that it was a dynamic, creative and open learning experience. I will finish by critically reflecting on my experience conveying science to the public, and on what they thought of my project judging by their feedback.

2. The Theory of Science Communication

2.1 Two Models of Science Communication

This section aims to provide a critical overview of science communication focusing on the original one-way 'deficit model' which led onto an 'engagement model' of two-way communication. This is important because, as I will explain, 'two-way' communication was central to my project. Science communication is a multi-disciplinary field incorporating science, psychology, sociology, philosophy, economics, and education/ communication theory [1]. Science communication concerns itself with the social and cultural implications of science, in the media, in popular opinion, in fiction, in myth, in philosophical and moral discourse – in just about any aspect of culture upon which scientific-endeavour has left its mark [1]. The value of this discipline arises from the need to understand the profound effect that science has on our lives: be that economic/ utilitarian (the wealth, growth or benefits that science has bestowed to humanity), democratic (scientific knowledge empowers individuals to make more informed contributions to society), cultural (science, like art, can provoke wonder), or evolutionary (every historical epoch has been defined, in some way, by the growth of scientific knowledge) [1].

From the 1960-80's Science communication research was concerned with 'Scientific literacy,' founded on Jon D Miller's deficit principle [2]. According to the deficit model, people without sufficient 'textbook' knowledge of science excluded themselves from intelligent discussion regarding science [2]. An ignorant public required 'topping up' with knowledge of scientific method (induction in this case) and would thus be liberated from superstition [2]. In the mid 1980's research conducted by the Public Understanding of Science (PUS) shifted the emphasis of the deficit model from ignorance to public attitudinal groups [2]. According to PUS, people did not approve of science because they did not know enough about it; if people knew more, they would love science more [2]. Contemporary Science Communication research regards the deficit model as archaic, and one-way [2]. To assert that all non-scientific members of society require drip fed knowledge is condescension; furthermore, knowledge of science does not necessitate a love of it. An appreciation of science is more likely rooted in someone's private history, than in textbook facts.

The current 'two-way' model of scientific engagement shows more regard of the publics' thoughts and concerns than its 'deficit' precursor. Two way communication places emphasis on the value of *dialogue*, and asserts that the responsibility for future developments in science do not lie solely with scientists, and that such developments should be guided by a reciprocal discourse between science and the wider social network in which it exists [3]. Dialogue empowers the non-specialist by enabling them to influence policy with informed opinion which thereby instils greater trust in science; science also benefits from dialogue because the local knowledge and experience of the layperson can provide an element of realism in research that might otherwise elude a scientist due to her scholarly distance [3]. Current models of communication promote 'upstream' engagement whereby the public is made aware of a given research agenda and their opinions are taken into account; such upstream communication has been successful in the cognitive sciences [3]. Furthermore, the need for 'upstream' communication is thought to facilitate more 'mutual understanding' between scientists, stakeholders, government and lay persons prior to the emergence of a potentially controversial field of science. The importance of this was made patently clear by the emergence of GM technology, whereby the public were not made aware of the research until much of the procedures were developed and being implemented within agriculture [3-4]. This was thought to have contributed significantly to the mass-disapproval of GM research that ensued. In 2003, as a consequence of new government drives toward greater transparency and consultation of stakeholders, a series of programmes brought together 36,000 people in the 'GM Nation?' debate: unfortunately, the debate came very far 'downstream' in terms of development - GM tomato paste was introduced by Sainsbury's and Safeway as far back as 1995 – and this was thought to have made the matter more divisive [5]. From a communication perspective, the technology is so controversial because it left the public in the dark until it was too late. Indeed, the polarity of opinion regarding GM technology was apparent long before the debate came into being, and is probably responsible for the ambiguity as to whether any direct or useful political consequences were drawn from the debate [5].

Such examples serve to illustrate the importance of *communication* in science. A scientific community that shrouds itself in technical jargon might appear self-sufficient, but however much, out of vanity, we might wish to keep science the preserve of special 'enlightened individuals', we cannot escape the fact that science exists, and is dependent upon, a wider social framework for its basic subsistence. Viewing science as socially related to 'everything else' in society should give us the humility to embrace our ethical responsibility to disseminate our scientific understanding. Such a stance is anti-elitist, and places great value on openness and *learning*. The value of learning, and a consideration of learning theory with regard to public-engagement, is the focus of the next section.

2.2 Learning Theory

There are five main learning theories that will be discussed: behaviourism, constructivism, cognitivism, humanistic and experiential learning theories [6]. Behaviourism was largely influenced by the logical positivists or Vienna circle, a group of philosophers influential in the early 20th century who asserted that a statement is only meaningful if it is verifiable, either by exhibiting some sort of logical/ grammatical consistency (an analytically true proposition), or by making a direct appeal to observation (a synthetically true proposition) [7]. The positivists were famous for suggesting that non-scientific propositions, such as ethical or metaphysical statements were meaningless - today this view is often referred to derogatively as 'scientistic' [8]. It is not surprising, then, that behaviourist learning theory concerns itself with what can be *empirically verified*: the learner is considered to be a passive *tabula rasa* and the learning is shaped by reinforcement or punishment which brings about a change in the behaviour of the learner, a change that is verified empirically – such as Pavlov's dogs salivating in response to a bell ringing [6].

Constructivist learning theory was partly a reaction to the didactic methods of behaviourists: constructivists emphasise the active, constructive process of learning – the learner becomes an 'information constructor' who interweaves new information into a system of pre-existing knowledge and personal subjectivity [6]. The constructivist scheme of things emphasises the importance of the learner's personal history, and the hypotheses that the individual will have formed in her experience of the world [6]. In her social milieu, the learner is continually considering, and revising, her hypotheses [6]. So constructivist knowledge, then, is not absorbed from external reality, but rather the 'information constructor' actively creates knowledge in response to a given context; it is clear that the constructivist scheme of things regards the individual's subjectivity as integral to the learning process, and it stresses that the learner brings pre-existing 'theories' (a sort of personal synthesis of factual information and subjective history) about the way the world might be to the new learning experience.

Cognitivism, like constructivism, was also a response to behaviourist learning theory: unlike the constructivists who emphasised context, cognitivists stress the importance of the learner as a 'thinking agent', and the learner, much like a computer, is an 'information processor' [6]. Cognitivism concerns itself with opening the 'black box' of the mind. Cognitivists state that in order to understand the learning process we must acquaint ourselves with mental processes located in the mind i.e thinking, remembering and problem solving [6]. Knowledge is regarded as a schema of symbols constructed by the mind in order to understand the world [6].

Humanistic learning theory puts particular strands of humanism into practise. Today, humanism can have different meanings: but one distinctive feature of humanism across the spectrum is its emphasis on the autonomy, freedom, and power of human individuals over their own lives. In the history of ideas, the first recorded appearance of a distinctly humanistic outlook dates back to the 5th century BC and is encapsulated in a famous maxim by the pioneering Greek sophist Protagoras "Man is the measure of all things" [7]. The sophists were famous for their agnosticism with respect to the Greek Gods: interestingly, they were also among the first 'learning theorists' and professors of higher education, they argued that one who is a wise-sage (from sophizesthai, a cognate of *sophos*) or expert will be distinguished in their practise of rhetoric and learning – hence, a learned argument is noted for its *sophist*ication [7]. The sophists were in some respects more concerned with the temporary victory of rhetoric over reality than with their arguments corresponding to truth; hence a specious, irrelevant, or obfuscatory piece of reasoning is dismissed as sophistry [7]. But the most distinctive thing about the sophists was their emphasis on man (meaning the human species) as the source of *power*, man as the arbiter of his own destiny, as opposed to man's power being derived from something external, such as the gods [7-8]. This credo is still one of the most explicit things about modern humanism, even though opinion differs widely about what else humanism might mean. Today, scientific-humanism is a mainstream ideology: proponents of this body of thought usually offer Darwinian and enlightenment explanations of morality, and a naturalistic account of human nature – again, the emphasis falls on human reason, not God. There are also other strands of liberal humanism that do not recourse to science or reason for an account of human nature, these strands tend to have a sentimental abstraction of some human attribute, such as 'love', 'morality', 'language', 'freedom', or 'emotion' as their focal point. It is not surprising, then, that humanistic learning theory (which emerged in the 1960's) stresses the autonomy, dignity and potential, of the human individual [6]. The humanistic learner is treated 'holistically' (valued as a whole) as the source of his own particular 'values' and 'intentions'; the learning process is one in which the individual's goals are central, and through learning the individual is empowered so that his goals can precipitate, or become realized [6]. The humanistic educator is a facilitator: the educator positively guides, enables, empowers the learner to move autonomously toward his goal of 'self-actualisation' [6].

In planning my science activity, I considered David A. Kolb's 'experiential' learning theory, which combines different elements of constructivism and humanistic learning theories, but is arguably an independent learning theory in its own right. Kolb's theory of experiential learning involves a cyclical four stage process of experience, perception, cognition and behaviour summarised in figure 1 [9].

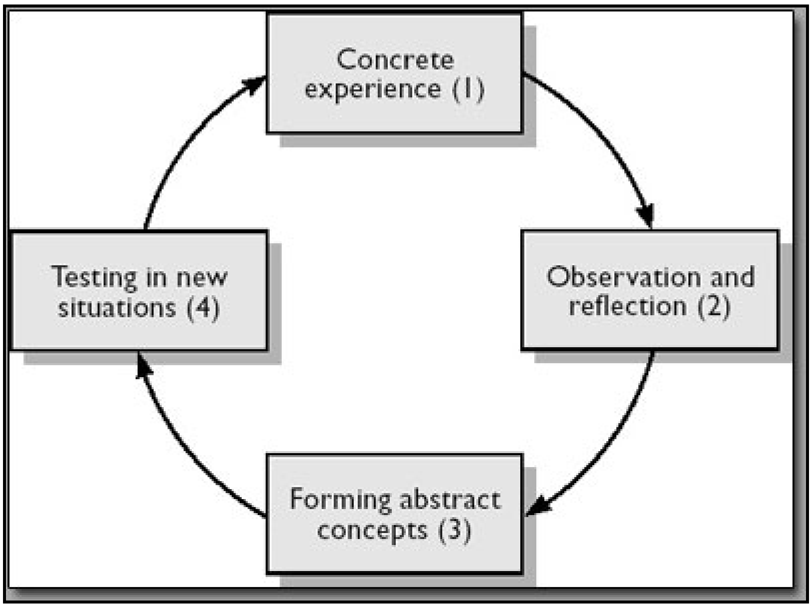

Figure 1. The four stage process of David A. Kolb's experiential learning theory [10].

Kolb's learning cycle can begin at any stage, but it is undertaken in sequence [9]. The learner usually starts out with a concrete experience by actively experiencing something, such as a field trip [11]. The next stage involves observation and reflection, in which the learner will reflect and think about the concrete experience [11]. This is followed by the formation of abstract concepts: the learner will categorize and incorporate new knowledge into their prior knowledge, and place it in relation to other models/ theories [11]. The last stage involves testing those theories, assessing the validity and limitations of a certain model by subjecting it to experiment [11].

Kolb went on to identify four learning styles which correspond to each stage of the learning cycle; each learning style denotes a certain preference by which the learner will approach a new learning-situation [11]. Activists, or accommodators, learn best from 'hands-on' experience, or concrete experience in a learning-situation; activists welcome new experience, and prefer active-learning to contemplation [11]. Activists have difficulty learning in any situation where they are required to be passive [11]. Reflectors, or divergers, prefer to take a step back to think about, reflect upon, their learning experience, they like to gather information before reaching a conclusion, and they like to observe how other people go about the learning process [11]. Reflectors have difficulty learning in situations that require immediate action, since this overrides their cautious, watchful predisposition [11]. Theorists, or assimilators, learn best when they are provided with a sound, logical and consistent theory, and are happy incorporating their thoughts into pre-existing models or schemes, which they use as explanatory tools [11]. Theorists are less comfortable in a “messy” subjective or creative learning experience [11]. Finally, pragmatists, or convergers, learn best in a practical learning situation: pragmatists like to know how knowledge can be put into practice; they treat the experimental approach as the acid-test for any learning experience [11]. So for pragmatists, a situation without any practical/ experimental component will not be a fulfilling situation in which to learn [11]. Individuals are not expected to be clear cut in their learning preferences, but, according to the theory, they tend to exhibit one particular style, and this multifarious approach to learning needs to be considered.

It is clear that learning theory is an old and contentious discipline dating back to antiquity. For my purposes, I felt that Kolb’s experiential learning theory would enable me to appeal to the widest audience possible. Each of Kolb’s learning styles were carefully considered in preparation for my learning event. Precisely how the event was tailored to suit each learning style is discussed in section 4 below.

3. The Castle Museum Event

The learning event took place at Norwich Castle museum. Built by the Normans in 1067, Norwich Castle has been a museum since 1894 (until then, it had been a prison since 14th century), and remains one of Norwich’s main visitor attractions [12]. Its many attractions include the finest collection of paintings by the Norwich School of Artists, including many works by John Sell Cotman, the castle keep, a collection of Anglo-Saxon and Viking treasure, a Queen Boudica gallery, an Egyptian gallery, the world’s largest ceramic teapot collection, and extensive nature galleries including models of local landscapes around East Anglia exhibiting its wild inhabitants (e.g Bitterns on the north Norfolk coast) [12]. The cost of an Adult ticket is £6 (£5.10 concession), or £3.10 for a special exhibitions ticket, a young persons ticket is £4.40 [12].

My project involved looking at the water mould *Saprolegnia* beneath a microscope. *Saprolegnia* was first identified as a pathogen of fish by the local 18th century philosopher and scientist William Arderon, and we decided to work with *Saprolegnia* partly to commemorate him, but also because *Saprolegnia* has many appealing qualities in its own right (discussed below) [13]. The event was planned to take place during National Science and Engineering Week (NSEW), which is a national celebration of science, engineering and technology, organised by the British Science Association, and involves hundreds of event organisers across the country [14]. In 2009, NSEW ran from 6th-15th March, and our event at the castle was held 7-8th and 14-15th March [14].

4. My Learning Objectives Prior to the Event

4.1 Rudimentary Ideas about the Project

To begin with, I had planned to make my event about symbiosis and endosymbiont theory, since I think this prvides a fascinating perspective on evolution. But when I thought about putting the ideas into practice for the event, I felt they were lacking sufficient learner participation. I imagined myself bending over backwards trying to explain this novel idea about evolution (novel to anyone who thinks evolution is *only* a process of random mutation and selection of genes). I knew that I needed something that was, in a sense, 'self-evident', something that any child, whatever learning style, could (imaginatively) pick up and run with. So something immediate, dazzling and self-evident (i.e appealing to the intelligence of the learner, without any prerequisite knowledge) was my primary objective, and the facts/ science underlying the activity would easily unfurl from the primary process (if scientific information was what the learner desired). Hence it also became apparent to me that my project would be centred on the learner, and I would adopt, in the humanistic sense, the role of 'facilitator' – someone who makes the learning experience possible with respect to the learner's individual needs/ abilities.

I had worked previously with the water mould *Saprolegnia*, taking pictures/ videos of the long filamentous zoosporangia (the asexual reproductive structure containing motile flagellate zoospores). *Saprolegnia* was easy to grow on hemp seed. The process of the zoosporangia hatching (see fig 2.), releasing its swimming spores into the outside world, was quite dramatic I thought, and would appeal to most people. But that was not all: obviously searching/ waiting for hatching *Saprolegnia* would not be sufficient alone to keep an audience captivated: a beautiful corollary of using *Saprolegnia* is that it does not exist in isolation, the sugars and exudates released by *Saprolegnia* into its external medium make it a brilliant 'home' with which other marvellous microbes, such as *Vorticella*, rotifers and *Paramecia* associate. Beneath the microscope, *Saprolegnia* filaments appear as a branching reticulum, with which a lively microcosmos of creatures can be seen dancing in and out, sharing their life lines (see fig 3.). This, I realized, was sufficiently exciting for a public engagement event: beneath the microscope, encounters with microbes can transform one's view of "pond-life" from something dull, banal, and inanimate to an emotional captivation, a vivid appreciation of the interconnectedness of all life that, I think, appeals to the microbiologist in all of us – and that seemed worth sharing.

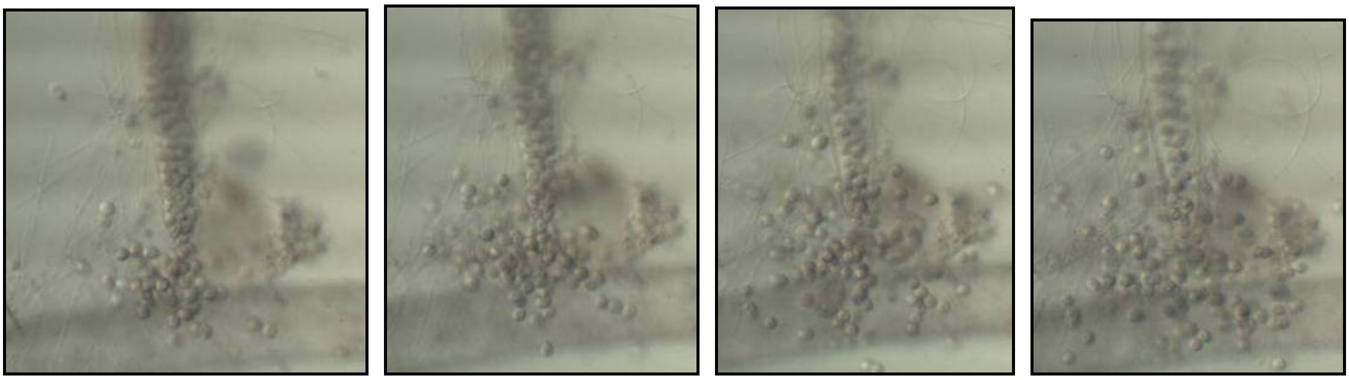

Figure 2. Stills taken from a video (x10 magnification) of *Saprolegnia* hatching zoospores. Each still (left to right) is taken at ~10 second intervals.

Paramecia | *Vorticella* [15] | Rotifer [16]

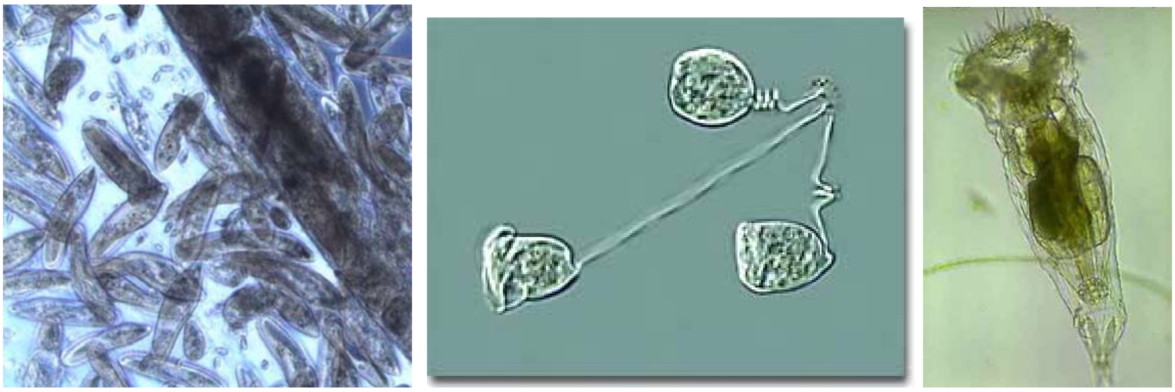

Figure 3. The microbial community that associate with *Saprolegnia* includes (left to right): *Paramecia*, *Vorticella* and rotifers. These make exciting viewing beneath the microscope.

4.2 Preparation for the event

I started planning my event by drawing out what I thought it might look like, and I imagined what the actual event might entail: large groups of people, busy, active, noisy, perhaps I would not get a chance to talk to individuals and would have to focus my attention on groups, in which case everyone needed to have something to do, they needed to be able to have a mix of my attention intermingled with their own action and discovery. My first rough drawing of what I thought the display would look like is shown in Fig 4.

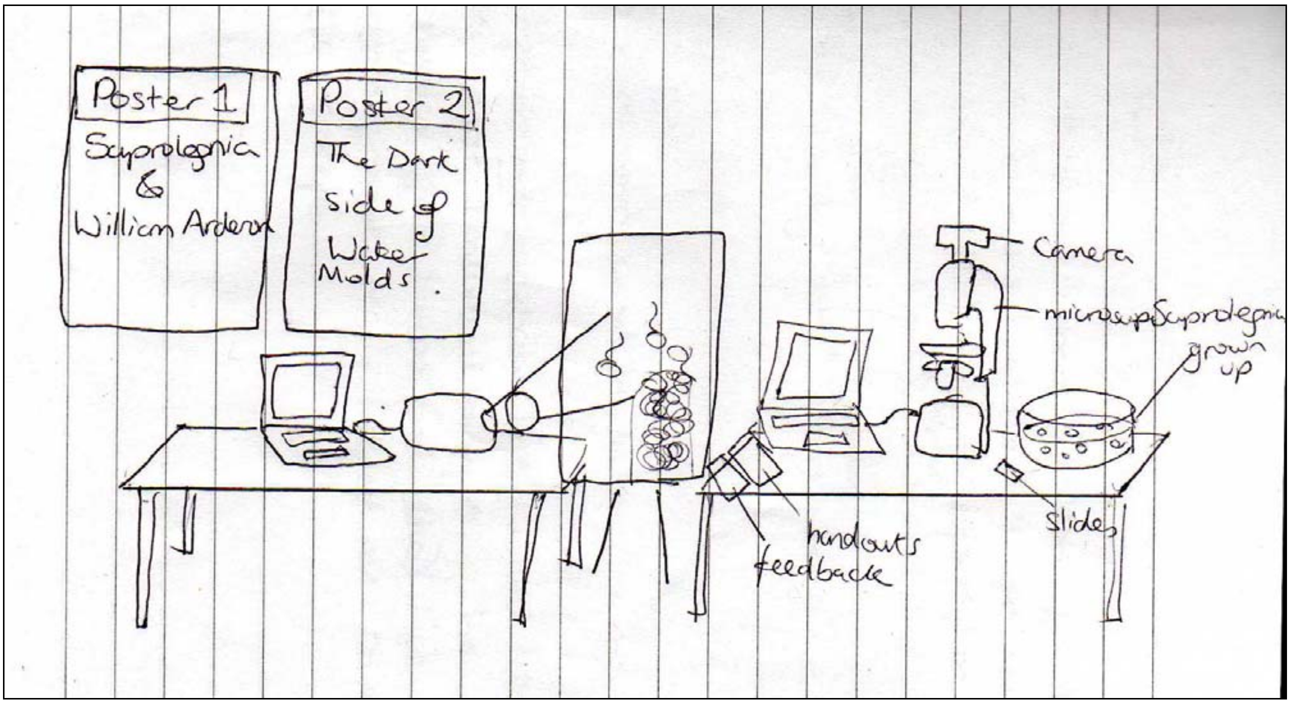

Figure 4. Initial rough sketch of what the learning event might have looked like.

The sketch in figure 4 shows the activity layed out across two tables. One laptop (on the left table) is showing a video of *Saprolegnia* spores hatching, and this is being projected onto a screen. The other laptop is displaying the *Saprolegnia* (grown on hemp seed in the bowl to the right) on a slide beneath the microscope (displayed using a video camera): the learners would have the opportunity to search the slides looking for whatever they found to be stimulating (I would get them started with using the microscope). The right hand table also shows handouts and feedback for the learners to fill out if they wished. Behind the tables, in Fig 4., are two posters, and these would contain the relevant scientific information that might appeal to different learners, I planned to refer to the posters to illustrate particular points that would be relevant to the science activity (see below).

The drawing shown in Fig 4. illustrates the overall layout for my learning event. This enabled me to draw out an equipment list:

Table 1. Equipment list for castle museum event

2x Tables	1x poster display
2x laptop computers	2x extension plugs
2x trinocular microscopes	1x micrscope motic camera
2x boxes of glass slides	2x plastic tweezers
1x glass bowl + cling film	1x scalpel/ knife

Note: the projector shown in Fig 4. is not on the list since it was not practically workable at the event. One week prior to the event, the *Saprolegnia* was grown by adding autoclaved hemp seed to a large glass bowl filled with water from the UEA broad and aerated by a bubbler.

So far this section, the initial ideas for the project and how they were brought about have been described. The rest of this section describes how the learning event was tailored to each of the four learning styles i.e theorist, activist, pragmatist or reflector, and then goes on to consider the value of two-way dialogue in a science communication activity.

4.3 Consideration of Learning Styles and what the Learning Event Involved

This section will consider what the learning event may involve for different learners. Since no two learners are expected to come away with the same experience of the event, this section will attempt to provide an account of the same event from different perspectives. There is no 'correct-approach' to the learning event, no strict procedure to follow – my objective was to 'facilitate' the individual's learning experience, whatever they may discover that to be.

For the learning event to suit an activist, it was important that the event involved some form of concrete experience; something would have to be *done*. An activist learner would have felt left out if the learning event required them to be passive. So to accommodate activist learners, the learning event offered plenty of 'hands-on' experience: the learner would be invited to take a slide with *Saprolegnia* on it and to place it on the microscope. I would then explain how to use the microscope, how to explore the slide, with an image of what's beneath the microscope being displayed on the laptop screen. This would provide an activist learner with the opportunity to share their experience with their family, friends, or myself. I would stay with them while they got started using the microscope in order to get a feel for what they want from their learning experience. Some activist learners may have wanted some theoretical/ factual information; they might have wanted to discuss their subjective experience of seeing new microorganisms beneath the microscope. It was important that all learners felt relaxed and that, from me at least, they were assured that time was not an issue; this way, the activist learner will have felt that they had time in which to *explore*, time to think and sense and gather what they needed.

Reflective learners will have needed space to think, watch and ponder the learning event, and would not have benefitted from getting 'caught-up' in the activity without space to observe. For reflective learners, then, it was ensured that plenty of material was on display for them to consider. I prepared two posters (see section 8.1-8.2 appendix): one describing oomycetes (*Saprolegnia* is an oomycete) and their phylogenetic relation to other major kingdoms (animals, plants, fungi), and also some descriptions of *Saprolegnia* and some of the organisms that associate with it (such as *Paramecia*). Furthermore, the reflective learner will have had plenty of activity to watch going on around him: whatever was under the microscope would be displayed on the laptop screens so the reflective learner would benefit from seeing what we were learning about without, necessarily, becoming embroiled in the action. It was important that the learning experience was very visual, and appealed to someone of a visual or watchful predisposition, not just beneath the microscope, but in the learning environment as a whole. The reflective learner might watch me explaining an idea to someone else, they might then refer to one of the posters to deepen their understanding, after which they might want to use the spare laptop to search through some of the videos before, finally, participating in the activity, or preferring just to keep to themselves.

Theorists like to incorporate their experiences into logically sound theories; those theories are then used as explanatory tools. A theorist will have felt left out if the activity involved too much subjective speculation, or non-factual creative thinking. The learning activity catered for theoretical learners by providing plenty of information. The two main sources of information would be gathered from the posters and from the demonstrator/ facilitator. As facilitator, I would enable the theoretical learner to assimilate the new knowledge and put it into context with other scientific knowledge. With the help of the two posters and by engaging in conversation with the demonstrator, the theorist could learn much about *Saprolegnia*: that it was discovered by a local polymath William Arderon in the 18th century (I may guide them toward William Arderon's books on display), that *Saprolegnia* is an oomycete and is closely related to brown algae, that it is typically found in ponds and ditches, and that oomycetes include some significant plant pathogens that have had some important effects on human lives e.g *Phytophthora infestans*, which caused the Irish potato famine. Such information would enable the theorist to understand *Saprolegnia's* phylogenetic relation to everything else, and to understand why oomycetes are important phyla. Once the theorist will have gathered enough information, and put it into context, they may then decide they have had enough of this event, or they may get involved in some of the more active learning experiences on offer.

Pragmatists learn best from situations that have a clear practical, experimental application to 'real-life'. A pragmatist learner, like a theorist, will have felt left out by an open ended, subjective activity. In order to gear the activity toward a pragmatic learner, I dedicated a whole poster (see section 8.2 appendix) to explaining that we were studying an oomycete, and that oomycetes have great consequences for agriculture, and for that reason it is important to understand oomycetes, such as *Phytophthora infestans*, so that we can apply that knowledge to help alleviate such negative effects in the future. This way, the pragmatist learner will be able to appreciate that studying such organisms as *Saprolegnia* can have real and important implications for the way we live. The pragmatist learner would also benefit from the hands-on experience of viewing *Saprolegnia* beneath the microscope to improve their understanding: this way they can synthesise their knowledge about how we can *apply* our knowledge, with learning concrete experience – this process may help to stimulate a memory of the event for future consideration by the learner.

So far I have discussed how I ensured that my learning activity was suited to each learning style, and what the activity might involve for different individuals. The next section will discuss the importance of two-way dialogue and my approach to communicating with learners.

4.4 Consideration of Two-way Dialogue and Science Communication Theory

"…informal dialogue starts to become a place where individuals from within science and its publics can engage in conversations that will lead to learning on all sides. Exactly what this will look like remains up for grabs. Informal dialogue needs to provide scope for sustained engagement and allow all present to voice their views, knowledges and experiences. Dialogue might not just mean discourse, but also include theatre, art, music or storytelling. It will almost certainly involve engaging with the technical experts involved in a different way: treating them not as the only experts present, but as those with a particular kind of knowledge. Indeed, understanding informal dialogue in this way may lead to a new emphasis in the scientific community on dialogue; one which seeks to enable their learning as much as non-scientists. In short, there is plenty of scope for imaginative practitioners of these kinds of events to stabilize the move from deficit to dialogue."
Sarah Davies [17]

Section 2.1 mentioned the shift in science communication theory from a deficit model of communication (in which an expert informs an ignorant layperson about science) to a two-way dialogue model of communication (a reciprocal process in which both scientist and layperson learn from each other). This section aims to discuss some of the problems that have emerged with this shift in outlook, how a residue of deficit language is still apparent at informal science events, and how this problem may be resolved with regard to my learning event.

In her essay 'Learning to engage; engaging to learn: the purposes of informal science – public dialogue', Sarah Davies examines the problem of 'mixed messages' in informal science learning events with regard to the use of deficit and dialogic communication [17]. Today, many organisations, that until recently, espoused a deficit model of public engagement have now embraced a two-way form of communication, such organisations include the House of Lords, and science museums (such as the Dana Centre) [17]. Indeed this shift is aptly reflected in a report on 'Science and Society' by the House of Lords (2000) [18] which stresses the value of dialogue and public consultation; this marked the start of a considerable shift in attitude since the initial PUS agenda set forth by the Royal Society (1985) [19] in which members of the public where thought not to like science enough because they lacked sufficient knowledge, hence if people knew more they would love it more (notice the role of the scientist in the deficit model is far from a 'facilitator', and more akin to a knowledge distributer). The problem that Sarah Davies' essay addresses, however, is that whilst many informal science organizations (that do not have any policyinfluencing agenda) have the best 'two-way' intentions, the language that many such organisations employ reveals a 'deficit' inheritance [17]. Davies bases her study on the Dana Centre, which is part of London's science museum, purpose built for public-science dialogue and on the 'cutting-edge' of UK public engagement [17]. The Dana Centre presents itself as a place for lively open discourse, where members of the public are welcome to challenge/ discuss important issues with leading scientists, usually in the form of panel debates [17]. Unfortunately, such panel debates usually consist of individual panellists speaking for ~15 minutes at the start of an event (each panellist has a head microphone) after which the audience is invited to *comment* or *ask questions* (involving raising their hand and waiting for a microphone to be brought over) [17]. At the start of an event, the introductory speaker was shown to give very mixed messages about the nature of the event: the audience is assured that 'this is not the kind of event where our eminent experts sit here and expound and you receive' and that the event is about 'openness', and 'engagement'; this address, however, is interwoven with language that evokes a theatre-environment in which the panellists are active, and the audience are passive: it is 'almost a full house' and late comers are asked to take seats at the front, the audience is asked whether they have attended 'one of these talks before?', the problem with this language is that people attend a 'talk' to listen to someone else, furthermore the invited scientists are referred to as 'speakers' in contrast to the 'audience members' whose role, it is inferred, is to listen [17]. This type of ambiguous presentation of public engagement events, Davies argues, encourages the pessimistic 'deficit model in disguise' attitude to public engagement [17]. The purpose of public engagement events is fragmented by organisers who simultaneously frame such events in 'deficit' and 'dialogue' rhetoric: in the same breath, the agenda can shift from being a 'talk' with 'speakers' and an 'audience', to being 'not the kind of event where the audience is expected to sit and listen to experts' [17]. Davies suggests that such a 'micro-example' provided by the Dana Centre correlates with what other researchers are finding at the 'macro-level' with large-scale public-engagement events: a mixed message of 'deficit' and dialogue' approaches in which the public/ audience are simultaneously encouraged to 'get involved' and yet permit the terms of the event to be set by practitioners, experts, speakers, or scientists [17].

Davies convincingly argues that "informal dialogue seems to be mired within a mass of divergent meanings, purposes and framings" and that a possible solution to this problem would begin by completely rethinking the process of dialogue within public engagement [17]. She suggests that informal dialogue should be thought of as completely divorced from formal processes (e.g the GM Nation? debate): according to Davies, the trouble with informal public engagement, until now, is that it has mimicked the "language and practices of formal dialogue" and hence needs to rebuild itself from scratch [17]. The proposed solution lies in a shift from public engagement orchestrated by large-scale organisations (a paradigm inherited from formal events) to small scale communication focused on individuals and small groups [17]. This shift in perspective is thought to be a lot easier within individuals, as opposed to making changes in organisations [17]. This way, public-engagement participants (including scientists) will not necessarily have to "do-anything" with the opinions expressed at an event except open themselves as individuals to the possibility of change – any change in the lives of individuals as a result of the engagement process is of value in itself [17]. This way, informal dialogue will not suffer the consequences of worrying about large-scale impacts on science-policy (this should be the subject of 'formal dialogue'), since it is concerned with precipitating a change in the lives of individuals [17]. Indeed, this approach values learning, and learning "not merely of 'facts'" but a mutual learning in which the scientist avoids the notion of a 'deficient lay audience' completely by trying to imaginatively regard the learning needs, in all their complexity, of others [17]. This stresses the importance, beyond two-way communication, of mutual 'multi-way' communication, 'multi-way' learning [17].

As Davies states in the quote provided at the beginning of this section, what this new small-scale, individual-focused, multi-way dialogue will involve remains "up for grabs" – but I think my event plan was inherently open to different learning requirements, and embraces this new shift in focus [17]. My event had no set 'learning-agenda', since a learning agenda would prevent the facilitator from allowing himself to change or learn from what others might bring to the table. Instead, the learning-event was planned to be a loose constellation of multi-way dialogue, microscopes, videos, posters, information, looking, seeing, smelling, thinking – and from this medley of potential, the facilitator (as learner), together with other learners, would attempt to learn something new, and as a result of this 'experimental openness', allow ourselves to be changed for the better.

So far, I have attempted to write, in hindsight, on what my learning intentions were *prior* to the learning event. The next section is concerned with reflecting on, and evaluating, these learning objectives in light of experience. It will attempt to understand what was learnt, and what was of value, from the learning event.

5. Self Reflection & Evaluation after the Event

5.1 The Multi-Way Learning Experience

The event itself was busy, but not unmanageable, and I think I managed to provide everyone (almost) with the attention that was needed. Overall, the communication fell into a similar pattern, even if the groups were large (~6-8 people). On average, the group size was ~3 people at a time (not including myself): often one/two children with one/two adults, there was usually 1-3 groups present at any given time. Figure 5 below provides a schematic representation of what the communication process was like.

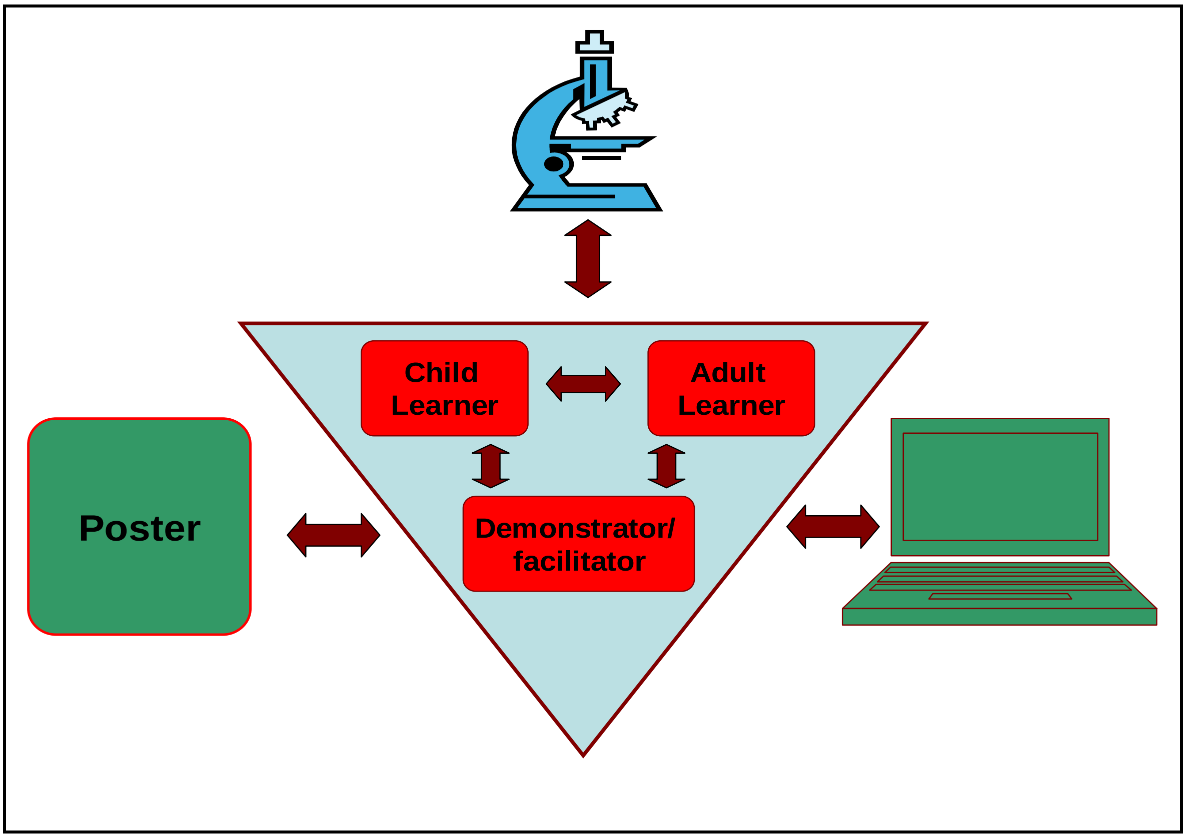

Figure 5. The 'communication process' between the facilitator (myself), the adult learner, the child learner (which could be more than one person in either case), and the learning equipment (poster, microscope, laptops).

Figure 5 shows the 'learners' (including the facilitator) in a 'learning-triangle': the triangle symbolizes the verbal communication that went on between the three participants in the triangle, and the references that were made to posters, microscopes, and laptops as learning aids. There were no children that did not communicate verbally, nearly all of the children asked questions about what they were viewing – most of the children tended to have an 'activist' approach to learning, although some showed 'reflective' preference in watching a friend/ sibling do the technical bits. None of the children showed a strong 'theorist' tendency: none of them seemed to explicitly refer to prior knowledge in relation to their new knowledge (not surprising, considering how 'abstract' science can be), although some were more enthusiastic about 'information' than others (but these children were just as hands-on as the others). The adult learners tended to ask more practical 'pragmatic' questions about "why is this important to society, how does this help?", and for such questions I would refer to the posters (see section 8.2) explaining the important effects that oomycetes have had on human society. In turn, the adult learners would reflect information from me back to the child learner e.g "that's a water mould you're seeing, we can find it in our pond at home!" None of the children asked any obviously 'pragmatic' questions showing concern for how the new knowledge could be applied (again, this was not surprising), but many of them were practically minded and wanted to 'get on' with playing/ using the equipment. Generally, this 'triangle of communication' would continue for quite long periods of time (~15-60 minutes) and some groups would return for further play with the microscopes. I would start talking to the child learner, if they responded (i.e wanted to talk) I would continue talking/ assessing what sort of conversation would work for us (for some children, 'theorists', I provided them with information, for 'activists' I encouraged their enthusiasm for finding microbes). Note: I was not explicitly categorising children as 'activist', 'reflector' etc. but Kolb's learning styles was at the back of my mind, helping me to respond to the child's needs in the best way possible. All of the children tended to show an 'activist' ability, all showed a strong interest in using the microscopes to search for swimming organisms, especially rotifers and *Paramecia*. At the beginning, I drew each child's attention to the tick-sheets: whenever the children saw something of interest they could tick the box beside the picture of the organism to show that they had seen it – this was a good way of reflecting back what they perceived (Fig 6.)

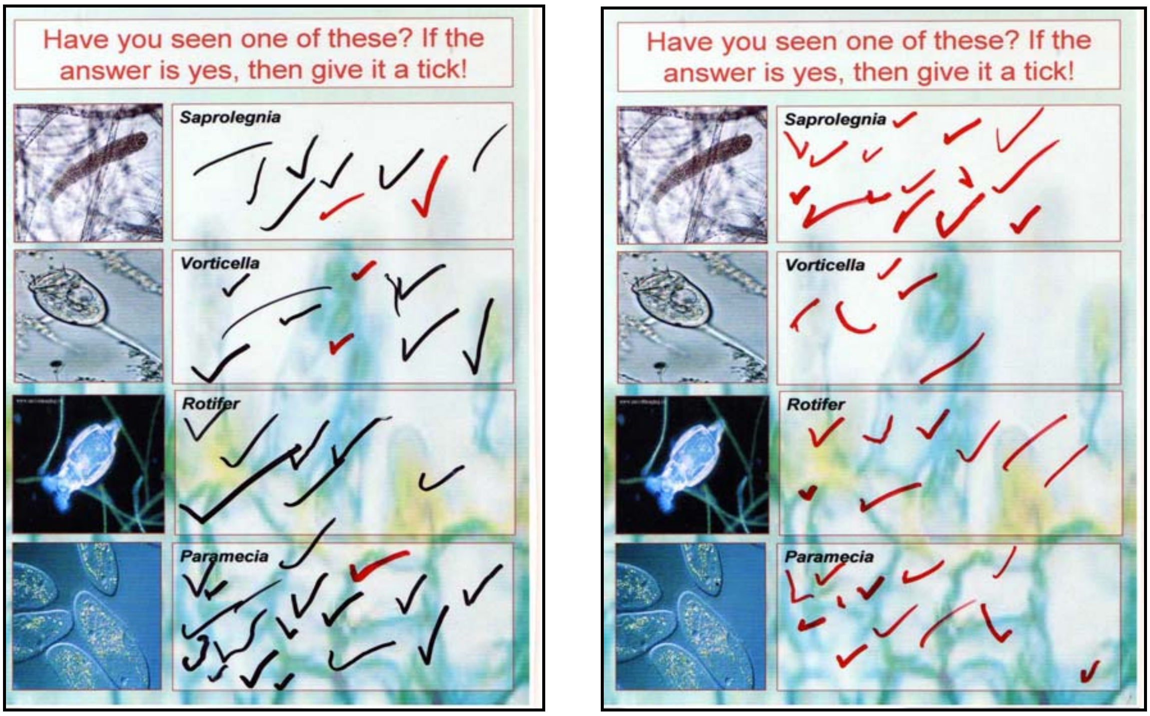

Figure 6. Tick sheets: the children were encouraged to "give it a tick" if they saw any of the microbes in the photographs beneath the microscope.

Without exception, the children found using the microscopes and watching the organisms on the laptop screens the most exciting part of the learning experience. Most of the children liked to communicate verbally with the facilitator and another adult (usually a parent) about what they were seeing beneath the microscope, and they enjoyed using the tick sheets whenever they “saw one”. None of the children explicitly asked about the posters (section 8.1-8.2), occasionally their attention would be directed to something that was mentioned in the posters, and some children (usually the older ones ≥12 years old) would discuss that information, but most of the children lost interest and returned to the excitement going on beneath the microscopes. It was mostly the adult learners who seemed to benefit from the posters, in general it was the adults who adopted a more ‘theoretical-reflective’ style of learning: they read the posters while their children *did* the activity, they would talk to the facilitator about the information given, and would then talk to and watch the child learner *doing* the activity without getting involved directly. So their was a clear disparity between the generations (apparent to the facilitator at least): the adult learners tended to show theoretical, reflective learning tendencies, as well as a pragmatic concern for how the knowledge was applicable, and the child learners tended to be very much the ‘activists’, learning by doing.

It is important to emphasise that there was no psychological test to determine whether anyone was a ‘reflector’ ‘pragmatist’ etc. These are all reflective evaluations from the facilitator’s perspective. Indeed, what was apparent to the facilitator on the outside does not give an adequate account of what the learner’s preference may have been on the inside. This section is intended to describe the communication experience as it appeared from hindsight. The next section focuses on the feedback evaluation left by the adult / child learners.

5.2 Feedback Evaluation

In response to the question ‘Did you enjoy the event?’ on a scale of 1 for poor, to 5 for excellent, the adult learners gave an average of 4.56 (from 62 adults in total). Of the sixty two adults who completed the feedback forms (which assessed the event as a whole, not individual activities), all of them stated that their children had fun and that they would take their children to a similar event in the future. This gives a very positive indication that the event was well received by the adult learners.

The children’s feedback is provided in Figures 7-9 below:

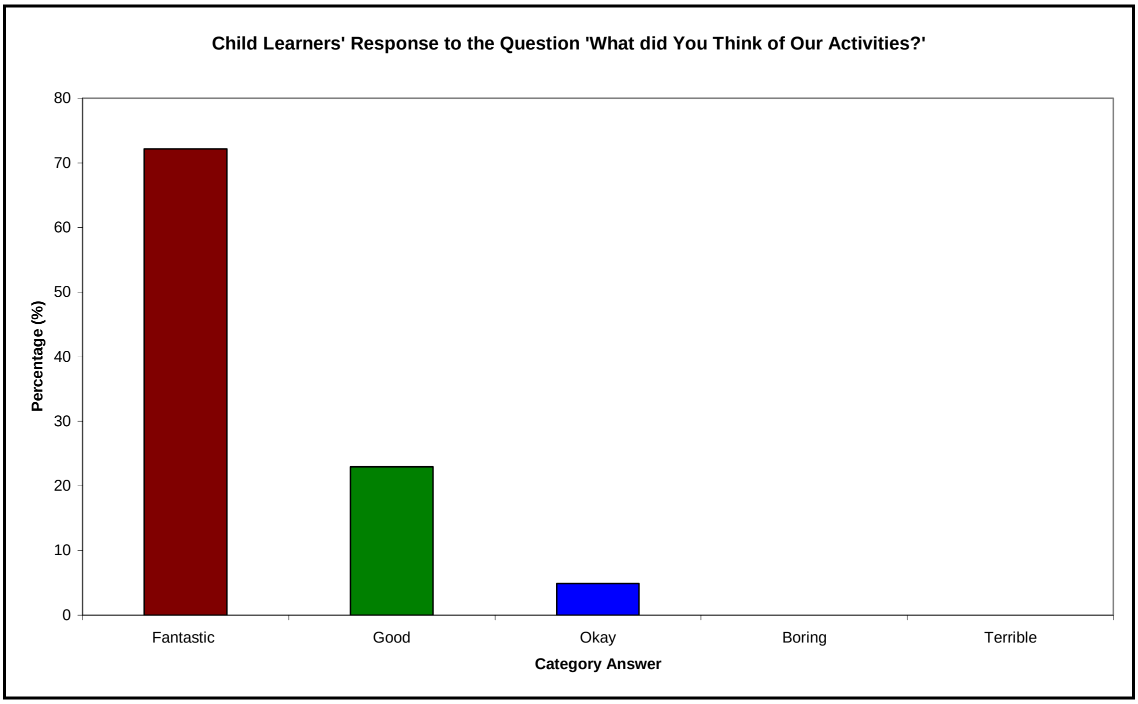

Figure 7. Feedback from children showing what they thought of the activities at the Castle Museum Science Event.

The Children's feedback in figure 7 shows that ~71% of the children thought that the event was 'fantastic', ~23% thought it was 'good', and ~5% thought the event was 'okay'. None thought the event was boring or terrible. Since 94% of the child learners thought that the event was good or fantastic, this feedback suggests that the children felt that it was an exciting, valuable experience.

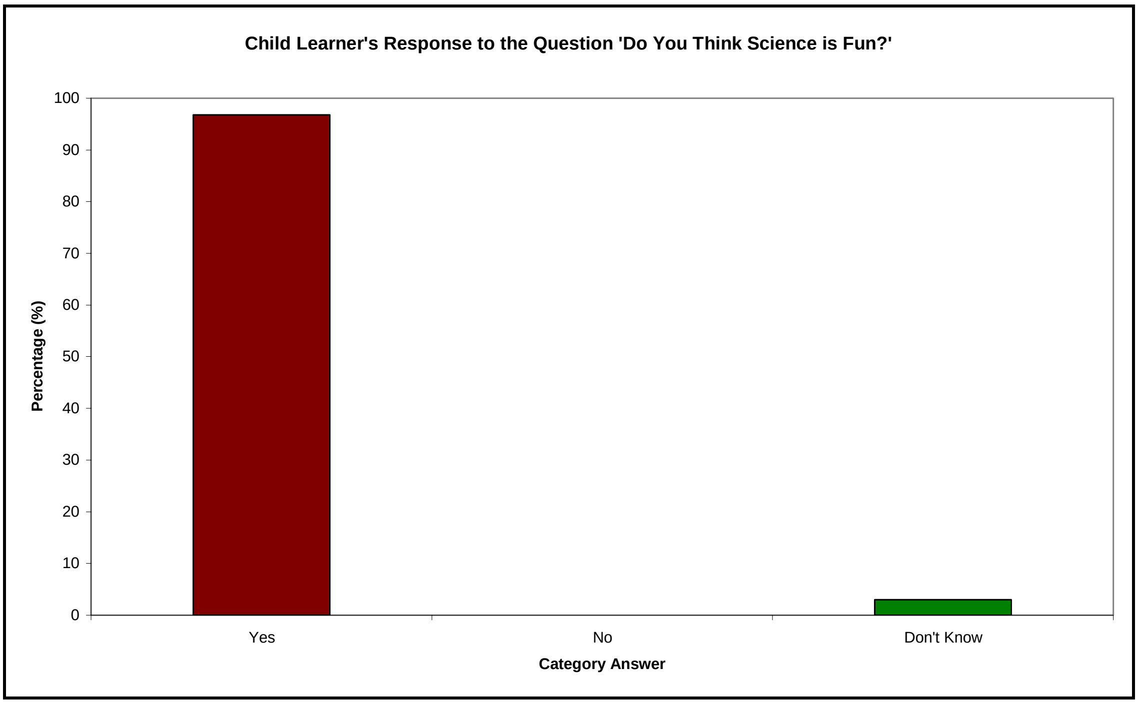

Figure 8. Feedback from children showing whether they thought science is fun.

The feedback from children presented in Figure 8 shows that 96.7 % of the children thought that ‘science is fun’ as a result of the Castle Museum science event. A very positive result.

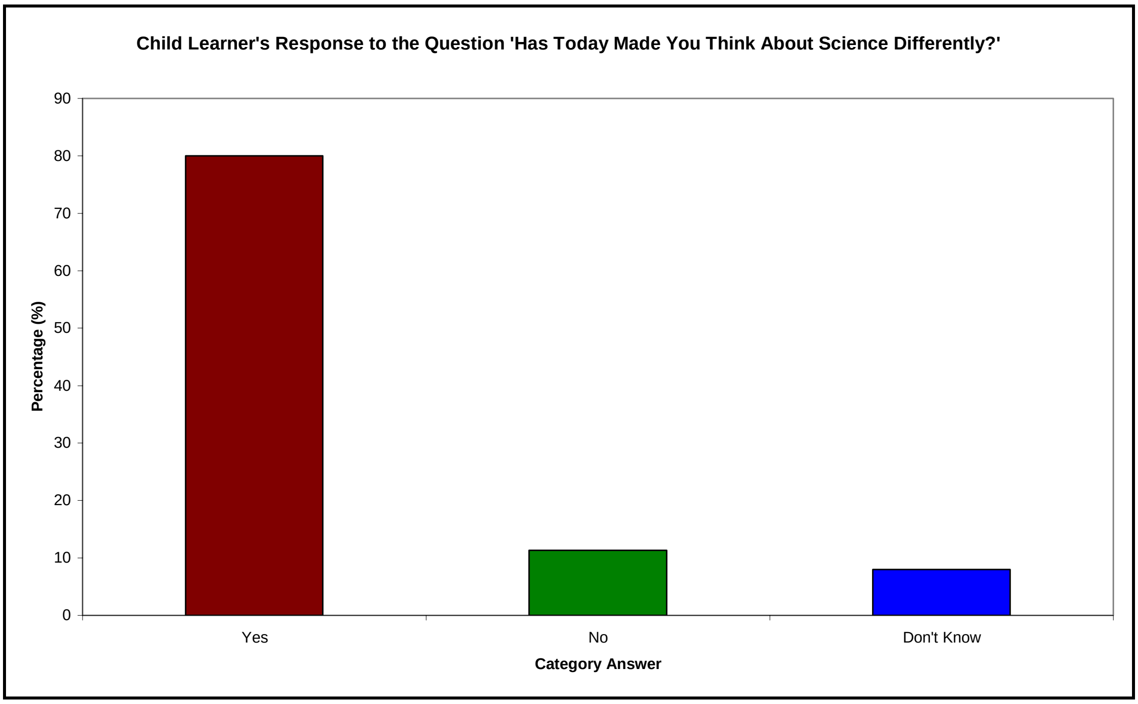

Figure 9. Feedback from children showing whether they see science differently as a result of the learning event.

The children’s feedback presented in figure 9 shows that 79% of the children who submitted feedback felt that their views of science were different from when they arrived. Judging by the previous results showing that most of the children thought the event was ‘fantastic’ and ‘fun’, it is safe to suggest that their ‘different view’ was positive – hence they saw science in a more positive sense as a result of the event. The 11% that did not see science differently as a result of the event may already possess an abiding love for science, so this does not necessarily imply a negative result. The 8% who did not know whether they saw science differently may have felt bewildered by the events, or they may have needed time to think and assimilate the day’s activities.

Forty seven of the adult learners left the first part of their post code to indicate how far they (and their families) had travelled for the event. The areas from which they came are provided in figure 10 below.

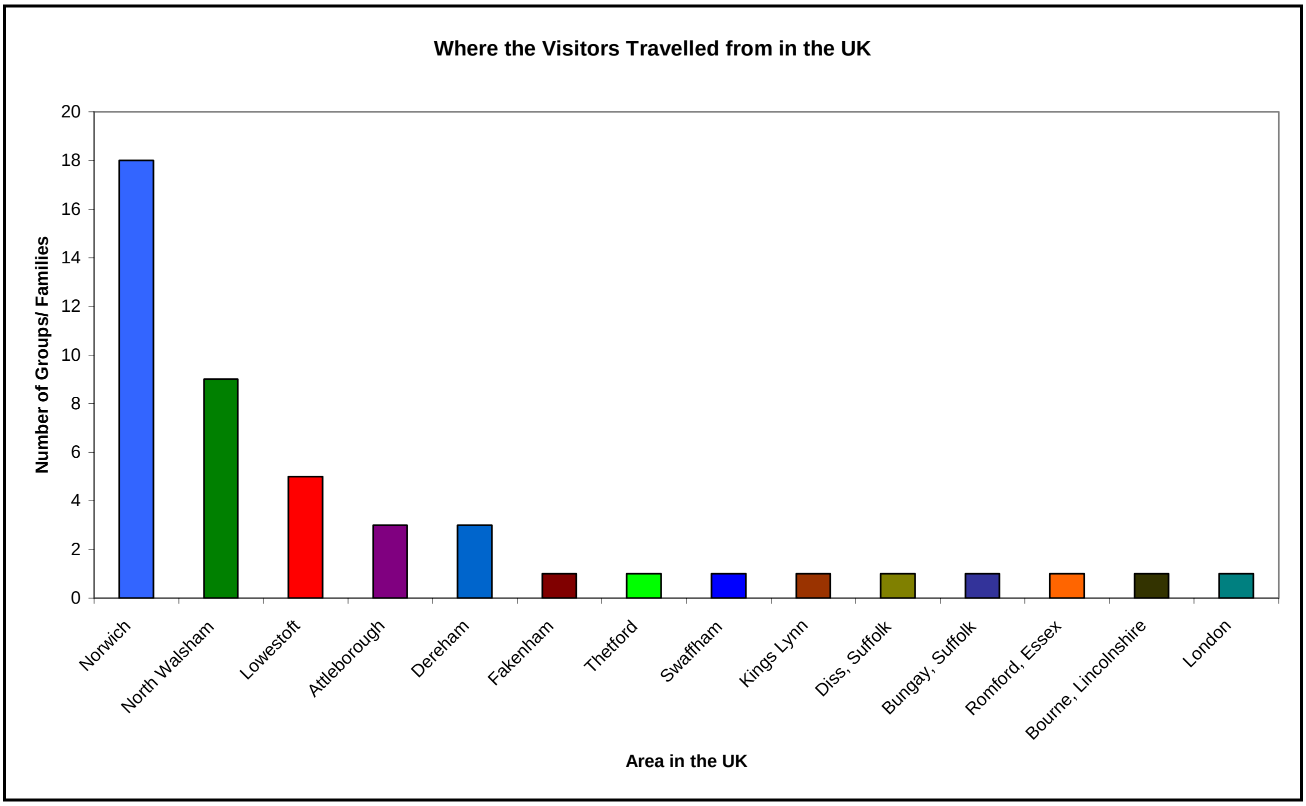

Figure 10. Where the groups/ families that engaged in the learning event had travelled from.

Figure 10 shows that most of families/ groups that engaged in the learning event travelled from Norwich. Of all the groups that left a postcode, 89% of them were from Norfolk.

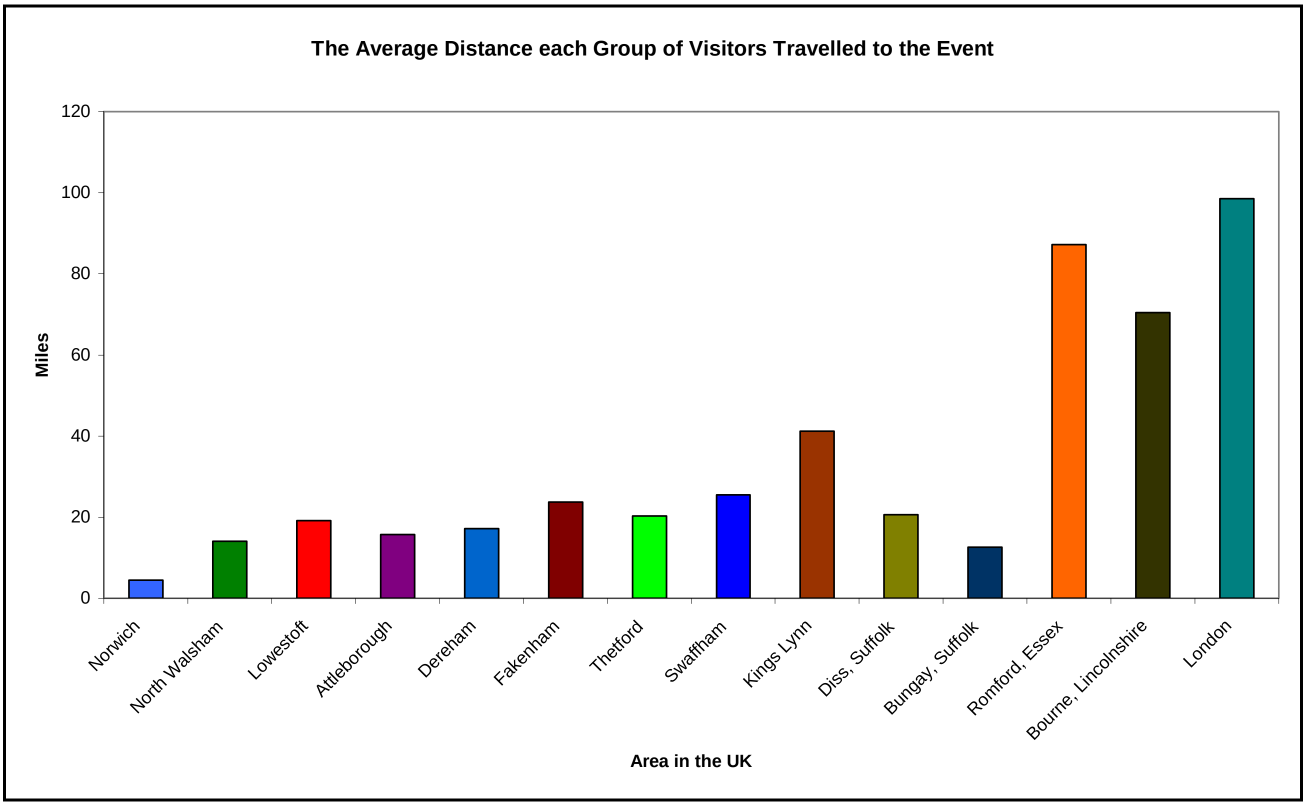

Figure 11. The average distance travelled by each group/ family that attended the learning event.

Figures 10 and 11 taken together show an inverse relationship between the number of families attending, and the distance they had to travel to attend. The number of people attending the learning event was proportionate to the distance the family/ group had to travel. The average distance travelled to attend the event was 17.4 miles, which is roughly the distance from Norwich to Dereham (NR19), which by car takes ~34 minutes each way [20]. So the average visitor/ learner spent over an hour travelling to and from the event (whether they came specifically for the event is unknown), which shows a considerable effort in its self.

Table 2. below will attempt to give a rough breakdown of the socioeconomic categories of the visitors from Norfolk (89% of the total) using their postcode to determine their Acorn Category [21], and some of the general information about each Acorn Category provided by upmystreet.com [22]. Acorn is a market research company which "categorises all 1.9 million UK postcodes using over 125 demographic statistics within England, Scotland, Wales and Northern Ireland, and 287 lifestyle variables, making it the most powerful discriminator, giving a clearer understanding of clients and prospects" [21].

Table 2. Providing general socioeconomic information about each group of visitors/ learners from their Norfolk postcode using 'Acorn Classification' and 'upmystreet.com' [21-22].

Norfolk Postcode & Distance Travelled	**Group % of total visitors from Norfolk**	**Acorn Classification [21]**	**General Information (income, education, family) [22]**
NR28 (14 miles) **NR10** (8.7 miles) **NR12** (11 miles)	29 %	Type 11 (3.7% of UK population). Wealthy Acheivers: well-off managers, detached houses.	High family income. Tend to be slightly older with older children. Affluent traditional lifestyle. Medium level of education (to degree level).
NR2 (0.4 miles)	14.3 %	Type 19 (1.09% of UK population). Urban Prosperity: suburban privately renting professionals	High income, very high interest in current affairs. Very high proportion is educated to degree level. Few have children. Very proficient using the internet.
NR32 (19.2 miles)	12 %	Type 44 (3.04% UK Population). Hard pressed: struggling low income larger families.	People living in this postcode are mostly people on low incomes (nearly 1/3 of families earn less than £10,000 per year), with large families living in council properties/ semis. Very low proportion of people educated to degree level. Many families have school age children, >10% single parent families.

NR14 (6.2 miles)	9.5 %	Type 5 (1.85% UK Population). Wealthy Achievers: older affluent proffesionals.	Affluent greys: typically couples >45 yrs old, children have left home. High family income, high interest in current affairs. Highly qualified.
NR17 (15.7 miles)	7.1 %	Type 10 (2.26% of UK Population) Wealthy Achievers: well-off working families	Well-off working/ commuter families. High family income. Highly qualified professional / managerial jobs. Very high proportion of couples with children.
NR19 (17.2 miles)	7.1 %	Type 28 (2.39% of UK Population). Comfortably off: working families.	Medium family income. Low proportion educated to degree level. Mostly larger families with primary school children.
NR9 (10.2 mile) **PE37** (25 miles)	4.8 %	Type 4 (2.5% of UK Population) Wealthy achievers: well-off managers.	Very high family income. Highly educated, high proportion of couples with children.
NR3 (1 mile)	2.5 %	Type 36 (2.13% of UK population). Comfortably off: older people, flats.	Medium income. Slightly higher than average level of education.
NR4 (1.6 miles)	2.5 %	Type 1 (1.7% of UK Population). Wealthy acheivers: affluent mature professionals.	Very high income, the most affluent in the UK. Very high level of education, business professionals etc. Mainly couples with children.
NR5 (2.2 miles)	2.5 %	Type 45 (3.03% of UK Population). Hard Pressed: older people.	Usually older people with a low income, living in semis. Very low level of education.
NR15 (9.3 miles)	2.5 %	Type 33 (3.13% of UK Population). Comfortably off.	Mostly older couples. Medium family income, low level of education.
NR21 (23.7 miles)	2.5 %	Type 29 (3.28%). Comfortably off: mature families.	Mainly mature families in suburban semis. Medium level of income, medium level of education. High proportion of couples with children.
PE34 (41.2 miles)	2.5 %	Type 8 (2.17%) Wealthy Acheivers: mature couples	Likely to have medium income, low level of education.

The information generated by using the first part of each group/ family/ visitor's Norfolk postcode shown in Table 2 generally displays a high level of income, education and family-based households. The information provided by ‘upmystreet.com’ [22] categorised each postcode into ‘high, medium, or low’ levels of income or education – these have been arranged into graphs shown in figures 12 and 13.

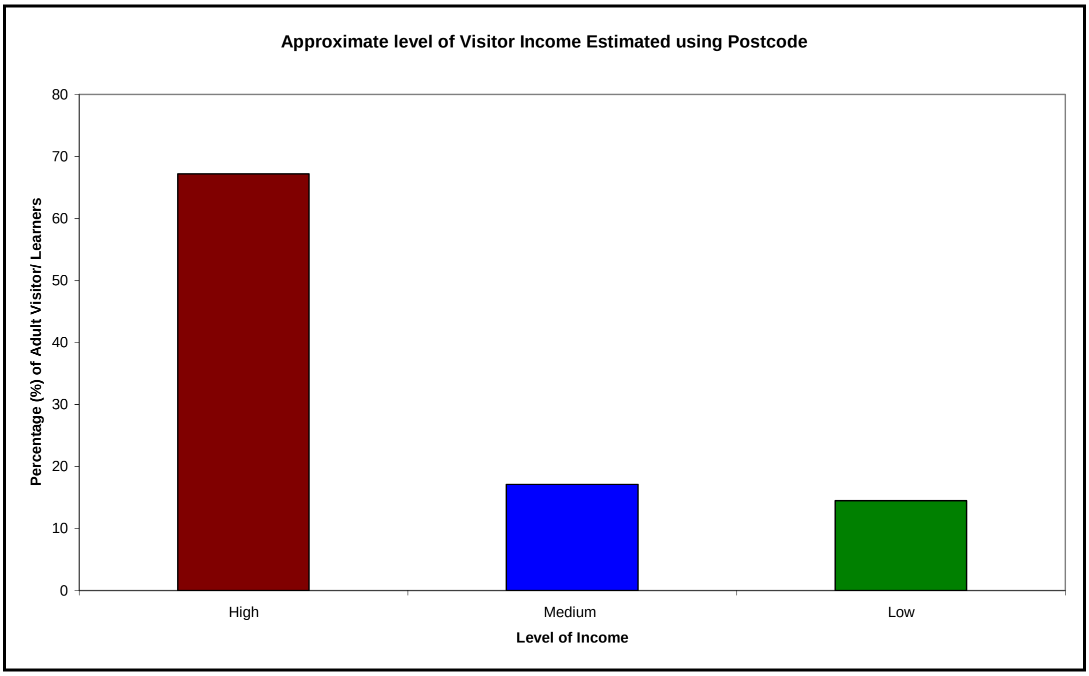

Figure 12. Approximate level of visitor/ learner income.

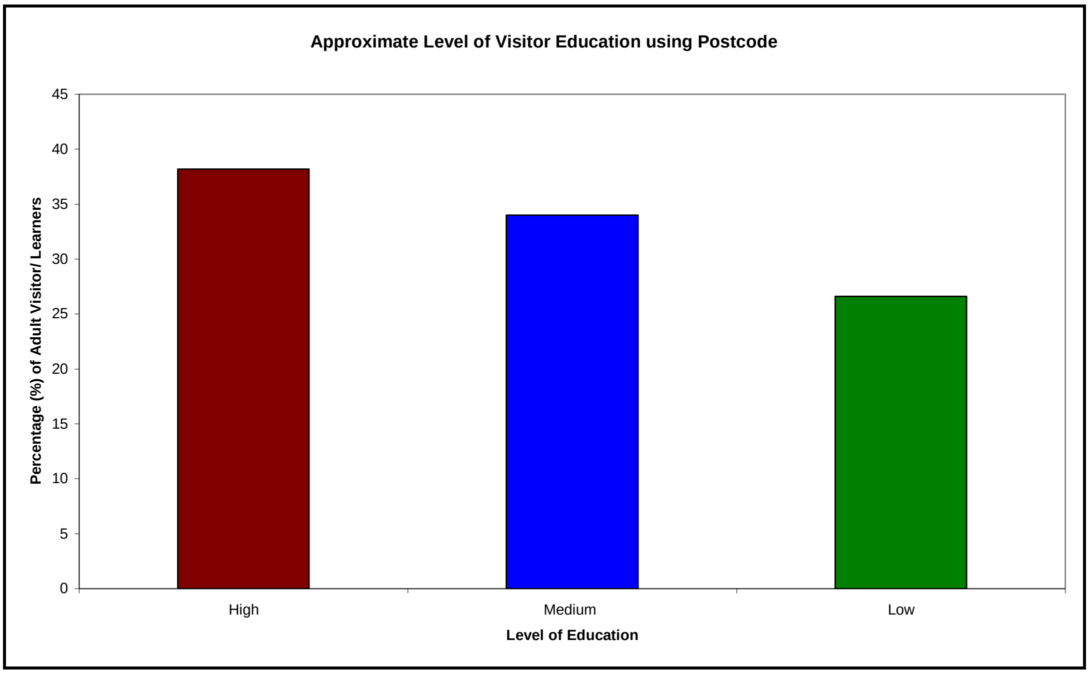

Figure 13. Approximate level of visitor/ learner education.

Of the 89% of visitor/ learners from Norfolk, ~67% were high income families, whereas only 14.5% were low income families (Fig 12.) The levels of education, however, were more evenly dispersed: 38% came from a postcode where a high proportion of people are educated to degree level, 34% medium frequency, and 27% of visitors were from postcodes where occupants are estimated to have a low number of degree level qualifications (Fig 13.). Whilst it was good to have a fairly even distribution of educated to less educated people attending the event, it is a shame that most of the people were from high income families (Fig 12.) Perhaps more could be done in the future to improve access to the NSEW Castle Museum event for families on low incomes. After all, the normal price for two adults and two children to visit the Castle museum is £20.80: this means that, unless a discount is advertised, families on low incomes will be likely to ignore an event at the Castle Museum [12].

5.3 Written feedback regarding my learning event

The feedback I received from learners was overwhelmingly positive. On the feedback evaluation forms, learners were asked to state 'What three amazing things did you learn today?' some of their responses are shown in Table 3.

Table 3. Learner feedback written on feedback forms.

"About smaller life forms"	"Microscopes"
"Microbes can be found in different places"	"How to use a microscope properly"
"Living microbial things"	"That tiny things can move"
"Protozoa can eat bacteria"	"Water creatures"
"Bacteria and fungi under the microscope"	"There are tiny things that move"
"Using the microscopes"	"About *Paramecium*"
"It was fascinating to see *Paramecium* up close"	" *Vorticella*"

The prominent learning themes expressed in Table 3 seem to be 'microscopes', '*Paramecia*', 'movement' and 'microbes'. This suggests that many of the learners valued using a microscope to observe microbial life, particularly *Paramecia*. As a learner myself, I too found the *Paramecia* particularly exciting. The feedback shown in Table 3 shows a keen appreciation of the microbial world, indeed, the feedback was answering the question "What amazing things did you learn today?" – it is very positive to know that many of the learners thought it was an 'amazing' activity.

The photograph (Figure 14) shown below depicts what the event might have looked like to an observer:

Figure 14. The facilitator (left) with fellow learners.

Figure 14 shows the facilitator getting a fellow learner started with one of the microscopes. Other young learners appear to be engaged, using the equipment for their learning needs.

Besides the feedback left on the evaluation forms, learner feedback also came in the form of emails shown in Tables 4 & 5.

Table 4. Written feedback from a learner

We really appreciated the Science weekend thank you. My older son spent the rest of the weekend finding things to look at under his decent microscope and from his conversations with myself and others it was clear that your presentation really sparked something in his thinking and interest. If you can have that kind of influence on even one person, that's great.

Table 5. Written feedback from a learner

Thanks to the people who have done such a great job-and they really deserve to be praised for keeping 3 boys, two aged 8 and one aged 9, (and their parents, and one grandparent !) entertained and interested and being so wonderful to us. We are so pleased to be renewing our yearly pass, and have recommended Norwich Castle to everyone!

We can't wait to come back! Please have science week again, and let us know of your next activities.

Our boys-listening intently, being excited and enthusiastic, looking entranced in microscopes for an hour, asking sensible questions, captivated in the Museum until the end and wanting to come back-it's a miracle !! Not a Games console in sight and they weren't bored for a second !!

The parent feedback shown in Tables 4 & 5 shows a great appreciation of the learning experience. Indeed, one parent states that the presentation had a positive influence on her son, it “sparked something in his thinking and interest” (Table 4.) The parent feedback shown in Table 5 seems positively surprised that her two eight year old, and one nine year old, boys were “listening intently, being excited and enthusiastic, looking entranced in microscopes for an hour”. Indeed, if there was one thing that surprised the facilitator, it was the length of time that the child learners were spending at this particular activity – several groups stayed for approximately an hour, some of them even came back for more. To be able to retain a child’s voluntary attention for longer than 10 minutes is a very positive indication that the child learner must have felt stimulated by the learning experience.

The learners were also invited to leave comments/ feedback in a booklet. Some suggestions were made, such as “what does it make you think of?”, “does it remind you of anything”, “do you think anything could be done better?”. Some of the answers are included in Table 6 and they can also be seen in section 8.3 of the appendix.

Table 6. Learner feedback left in the Facilitator’s booklet.

“I think the Paramecia is amazing. I couldn’t believe they were alive.” Thomas Dollman, aged 11.

“I never thought analysing the processes of decay could be so interesting. The microorganisms were quite beautiful too, which surprised me. I would like a few more contextual examples of how oomycetes affect human (and other) life. The potato famine really helped me to understand the concept.” Jess, aged 23.

“Billy aged 8 enjoyed looking through the microscope. Excellent instructions from the volunteer, made it very accessible and interesting for the children. Both volunteers are extremely knowledgeable.”

“Very interesting! Fascinating to see how the Fungi is the playground for bacteria and stuff.”

“Good idea giving people the chance to use the microscope which I wouldn’t have had the chance to use. Good job!” George Dagenham.

"I think it is very clever but a bit weird. It reminds me of the bubbles in a Jacuzzi."

"They are really fascinating and look really cool under the microscope. They move very fast!" Naomi aged 13.

"It's amazing how many things are going on in a tiny space! It's really cool!" Jasmine aged 9.

"Brilliant – science made fun and interesting for all ages."

"Presentation could be better, a bit messy"

"I enjoyed myself!!! It was great!" Millie Duncan aged 11.

"I think it looks like a germ, it makes me feel sick."

"Thanks, learnt so much." Keki aged 9.

"Tiny things can move" Daniel aged 8.

"Fun having a go spotting different microorganisms."

"It's strange how they move about and we found a big fat one!"

"I want to become a scientist now!"

"It was cool and inspirational." "Fantastic, do this again." "Absolutely amazing!! Awesome!!"

"I enjoyed it." Olivia aged 7 "Cool!!!" Jasmine aged 9 "Amazing!" Lydia aged 9.

"It looks like a swarm of bees!!" "They are really fast and tiny"

The feedback shown in Table 6 shows that many of the learners thought it was a valuable learning activity. The words "amazing", "fantastic" and "cool" are repeated many times. The general sentiment seems to be one of surprise, astonishment even, at using microscopes to see "fast and tiny" microorganisms. Many of the learners state that they thought it was "interesting" and "fascinating". Most of the comments relate to *doing*, *seeing*, or *using* something, this correlates with my previous observation that most of the child learners had a very 'activist' approach to learning; although some preferred to watch their siblings have first go, they all (seemed) to ensure that they satisfied their curiosity by *using* the microscopes. Another theme of the feedback seems to be one of pleasure in having an opportunity to use a microscope, which indicates that it is an unusual activity, although the feedback in Table 5 states that the learning event made one child learner get out his "decent microscope" at home. Indeed, a few of the learners said that they had microscopes at home, but they also said that they were not of the same “quality” as the ones being used. There were also a couple of criticisms: one person would have enjoyed “more contextual examples of how oomycetes affect human (and other) lives”. This is a fair criticism, but I do not think that many of the learners will have benefitted from more examples since most of the children ignored the theoretical aspects (the posters), and I was conscious of not flooding the learners with information/ examples. I think the fact that the person who wrote that criticism worked at the Castle Museum suggests that “more contextual examples” will have appealed to a minority audience. That said, I will certainly consider providing more examples in future public-engagement work, as long as - if it is an informal event - it does not compromise the ‘openness’ of the learning experience. Another learner mentioned that they thought the presentation could have been better i.e less messy: it is true that once the event was underway, the tables became rather messy, unfortunately this was quite difficult to control, since it was important that the child-learners felt free to take their time and explore (which often involved leaving a mess). I did my best to clear the tables during the brief periods when I was alone. But I don’t think many of the learners were bothered by this.

Overall, the feedback suggests that the learners found the event to be a most valuable experience. I think I managed to convey, without any set procedure, the excitement that I experienced when looking at *Saprolegnia* and other microbes beneath the microscope (section 4.1). The feedback suggests that this was an experience the learners will remember, and that they felt changed in a positive way by it. But, as mentioned in section 4.4, this was intended to be a ‘multi-way’ learning experience whereby the facilitator does not assume any didactic position, but allows himself to become an active participant in the learning process. I shall conclude by providing an account of my learning experience.

6. Conclusion

> “I believe that it would be worth trying to learn something about the world even if in trying to do so we should merely learn that we do not know much. This state of learned ignorance might be a help in many of our troubles. It might be well for all of us to remember that, while differing widely in the various little bits we know, in our infinite ignorance we are all equal.”
> Karl Popper [23]

Section 4.4 describes a new type of ‘multi-way’ dialogue for informal science learning events. The new emphasis falls on “learning on all sides”, as opposed to providing a deficient lay audience with ‘scientific facts’ [17]. Indeed, the role of scientist/ experts in public-engagement is reformulated, the public will be “almost certainly engaging with the technical experts involved in a different way: treating them not as the only experts present, but as those with a particular kind of knowledge” [17]. This was the role I tried to follow, and the evidence provided by the learners' feedback suggests that it was successful: I was a facilitator with a particular type of knowledge – there was no special value placed on what I had to offer. Indeed, rather than attempt to improve an other by giving them information, the value of the event was created by a sharing experience in which both parties learnt on the wing. It strikes me that this process does justice to an important part of what learning involves: since it is impossible *know before we know*, we have to cultivate a means for change in ourselves in order to make knowledge possible.

It is a strange notion that the best way forward for informal science learning might be to abandon the deficit principle of conveying facts to others, and instead, consider how we can enable ourselves to learn more with others about our particular type of knowledge. It is paradoxical because it suggests that in order to *teach* others, we should think of how we might *learn* with others. But it seems to work. I'm sure that many of the learners will remember *Paramecia* as a result of this 'multi-way' process; whereas if I had only tried to inform them of what *Paramecia* is I doubt they will have remembered anything. For my part, I have learnt much about how people learn in informal settings, I have learnt how to communicate with people better, and I have a deeper understanding of the science as a result of trying to explain it to others. This project aimed to assess whether a new shift from deficit to dialogue could be put into practise: this work suggests that a good way to approach informal science teaching is to start by considering what we could learn with others.

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