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Public understanding of plant biology: Voices from the bottom of the garden

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Introduction

In 1963 Bassey published the results of a modest study under the title of ’Science for Tomorrow’s Citizens’, a claim reminiscent of Hogben’s (1938) classic book, *Science for the Citizen – A Self Educator Based on the Social Background of Science Discoveries*. In his study, Bassey addressed the question: What effect does learning science in school have on persons not engaged in science after they leave school? He surveyed undergraduate students in a London Faculty of Arts, a group who had studied some science at school, but not as their central interest or future intention. The ’test’ questions he used were all concerned with knowledge that should or could have been taught in science in secondary schooling, e.g. (i) Are there atoms in air, water, clay and wood? (ii) Which of the following are properties of chlorine? (iii) Which of the following are basic aspects of the modern theory of evolution? He also asked respondents about the ’scientific method’. In broad terms he found that the residual memory of this knowledge was far from substantial, and that the experience these respondents had of school science was that it all seemed to be a long list of irrelevant facts.

This article describes ways in which a group of non-scientists learn what is essentially scientific information, within a part of their lives they consider non-scientific: gardening. The term 'vital relevance' is proposed as describing their informal drive for learning. Their motivation and achievements seem to belie some of the rhetorical claims that science educators make about the value of formal science education. In this sense, it is also, tangentially, a critique of formal schooling in science. On the whole, school science is a rather hidebound, constrained and inertial provision of a somewhat odd selection of titbits of (largely historical) science (DeWitt *et al*., 2013; Hodson, 2014; Toplis, 2014; Zeyer & Dillon, 2014). The discussion presented here is squarely in the Bassey camp, updated by Feinstein (2011), in maintaining that there is little evidence that prevailing strategies of science education have an impact on the use and interpretation of science in daily life. While most science educators and science education researchers nonetheless believe that science education somehow is intrinsically useful for those who do not go on to scientific or technical careers, Feinstein contends that this sense of ‘usefulness’ has largely been reduced to a rhetorical claim.

As Bassey’s respondents pointed out, a longstanding and sustained critique is that school science lacks relevance. The Relevance of Science Education (ROSE) Project (Schreiner & Sjøberg, 2004) and its mirror projects in other countries (e.g. Jenkins & Pell, 2006, in the UK) make the key claim that science in schools – particularly in physics and chemistry – remains unpopular among students not least because it is perceived as irrelevant both for young

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people and for the society in which they live. Moreover, this is a critique that has been unchanged over many decades (Stukey *et al.,* 2013). In most countries, and certainly in the UK, the pressures on school science are wholly unrealistic and its ability to respond beyond these specific and directed pressures is very limited. This is no more than a statement of affairs, and is entirely understandable given that school science is faced with an array of political agendas, inspection regimes, assessment stipulations, curricular impositions, health and safety regulations, student requirements, career education needs and so on (Toplis, 2014; Lloyd-Staples, 2014). Science teachers and curriculum leaders have their hands very full without invoking additional demands through articles such as this. The view taken here, then, is that dramatic *curricular* change in schools is highly unlikely in the next few decades, regardless of incoming or outgoing political or educational agendas, not least because of the conservatism induced by international competition through comparator testing systems such as the OECD's Trends in International Mathematics and Science Study (TIMSS, 2011) and Programme for International Student Assessment (PISA, 2012) surveys. From this perspective, school science should be left to do what it does well in meeting the competing demands made of it within formal educational structures.

So, rather than expect schools to make radical curricular shifts, the intention here is to turn instead to the world of informal learning in order to furnish the extended provision needed for both individual and social relevance – to consider 'vital relevance'. The key argument is that, in general, people find relevance for themselves and what both formal and informal science teachers and communicators actually need to do is enable and facilitate access to developmentally appropriate resources, not least through advances in learning technologies. The discussion below takes four forms:

(i) An 'unpicking' of one aspect of science – plant biology – and an argument for its place within formal and informal science learning systems

(ii) A discussion of auto-didactic, interest-driven, inquiry-based learning in science as a proposed antidote to 'lack of relevance'

(iii) Interviews exploring the *vox populi*, where real citizens talk about their real science in real time

(iv) A consideration of what might constitute serendipitous and vital relevance, of outcomes and possible directions forward.

Plant biology

Plant biology, as the name suggests, is the scientific study of plants: how plants function, their appearance, how they have evolved, their relation to each other, habitats and human use. It

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often includes an understanding of algae, fungi and bacteria, and can entail the lives of plants from tiny floating duckweeds to gigantic redwood trees. Plants are essential to the lives of humans, providing all food, either directly or indirectly, as well as being major constituents of the Earth's atmosphere, the global cycles of nutrients and water, as well as the lives of animals every day. In addition, plants are the source of many important medical remedies, some produce beautiful flowers for which people pay large sums of money, plants and plant materials are worn by people, some produce toxins that kill.

The programme of study of the UK's National Curriculum (Department for Education (DfE), 2013) for science at ages 11 – 14 (key stage 3) describe a sequence of knowledge and concepts, and makes the point that it is vitally important learners 'develop secure understanding of each key block of knowledge and concepts in order to progress to the next stage', and are 'equipped with the scientific knowledge required to understand the **uses and implications** of science, today and for the future' (their emphasis). Insecure, superficial understanding it is said, 'will not allow genuine progression: pupils may… build up serious misconceptions, and/or have significant difficulties in understanding higher-order content.' The content of the curriculum includes knowledge of such issues as:

- Plants making carbohydrates in their leaves by photosynthesis and gaining mineral nutrients and water from the soil via their roots
- Reproduction in plants, including flower structure, wind and insect pollination, fertilisation, seed and fruit formation and dispersal, including quantitative investigation of some dispersal mechanisms.
- Reactants in, and products of, photosynthesis, and a word summary for photosynthesis
- Dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere
- Adaptations of leaves for photosynthesis.

Granted this is a selective portion of the overall content - it is intended here as illustrative rather than definitive. Of interest in this rubric is the sense of school science being built as an 'antidote' to learners' misconceptions. That has been the subject of an enormous body of work over time (for example, Authors, 1983; Driver, Guesne & Tiberghien, 1985; Mikulak, 2011). A first question might be, exactly what misconceptions would a school curriculum remedy that might otherwise have surfaced (detrimentally) in later life? Allen's (2014) excellent text gives a

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wide range of research-noted misconceptions as these relate to both primary-age learners and their (adult) teachers. For example, since earthworms are invertebrate, so then (apparently) are snakes. Food like apples goes bad 'all by itself', rather than being acted upon by bacteria and fungi. An oak is different from an ash tree, and this is an example of variation between organisms - rather than the understanding that variation refers to differences between individuals of the same species. Plants get their food from the soil: teaching materials in biology often contain much information on photosynthesis, yet there is actually minimal discussion of mineral nutrient uptake by plants: most essential mineral nutrients play a role in photosynthesis. It is also a common misconception that plants photosynthesise during the day and only conduct cellular respiration at night. Some teaching literature even states this explicitly. Rather, cellular respiration occurs continuously in plants, not just at night. As Baron (2003) points out, any lack of understanding of basic principles of science is not due to a quantitative scarcity of information. It is probably due to a failure to provide, from schooldays to adulthood, simple clear outlines of scientific principles that will enable all citizens, let alone politicians and journalists, to understand their world, their immediate environment and how decisions can be made and tested rationally. The discussion towards the end of this paper returns to the substance of 'simple clear outlines' and 'vital relevance'. First, though, an outline of inquiry-based learning, auto-didact interest-driven self-education in science.

Inquiry-based and auto-didactic learning

The Higher Education Academy (2007) uses Inquiry-Based Learning (IBL) as an umbrella term to cover forms of learning driven by a process of inquiry, including the more widely known approach of Problem-Based Learning (PBL). Chomsky (1995) argued that the processes of inquiry, the forming of – and acting on - questions, is part of the blueprint for human language and is hard-wired into the brain. Dennett (1991) in turn, coined the term 'informavore': a view of humans like mythical sharks in continuous motion working incessantly to sate their 'epistemic hunger'. Overall, inquiry involves developing and implementing a plan to satisfy curiosity, collect data, evaluate evidence, draw conclusions, reflect on strengths and weaknesses of the plan, and engage in a new sequence (Aulls & Shore, 2008). It entails learning based largely on learners' interest and curiosity with the intent that they engage with a complex problem or scenario in which they are able to direct both the lines of enquiry and choice of methods employed. During the course of this they become increasingly 'inquiry literate' and enter into personal and collective knowledge creation (Barell, 2003; Bereiter, 2002; Deignan, 2009). Price (2003) outlines five stages which shape formal (institutional) IBL processes: (i) creating an inquiry focus; (ii) shaping the inquiry; (iii) gathering and evaluating

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information; (iv) refining understanding; (v) reaching closure. Shore, Birlean, Walker, Ritchie, LaBanca and Aulls (2009) proposed a list of 40 such elements.

The position adopted in this paper, akin to Dabrowska and Lieven (2005) and Aulds and Shore (2008), is that inquiry-based learning, question-asking and explanation-seeking (hard-wired or otherwise) are constructive acts of meaning-making (Authors, 2014). In contrast to Price (2003) and (Armstrong, 2012), engaging in self-directed learning in general life - away from formal institutions - is seldom an organised or structured affair. In such broad contexts, *informal* inquiry-based learning, being auto-didactic, can be seen to include goal-driven inquiry, the generation of problems, use of discussion and dialogue to learn, and feeling relatively comfortable with problems being ill defined. Marsick and Volpe (1999, p5) characterise this kind of learning as:

- Seldom highly conscious
- Triggered by an internal or external jolt
- Integrated with daily routines
- Haphazard and influenced by chance
- An inductive process of reflection and action
- Linked to the learning of others.

It is possible, of course, to engage in non-formal out of school projects and, along these lines, Silvertown (2009) gives a list of more than twenty 'citizen science' projects, from polymorphism in the peppered moth to sampling strategies in research on birds by the British Ornithological Society. OPAL (OPen Air Laboratories) is a large programme of environmental citizen-science activities led by Imperial College London. The overall aim of such projects is to increase public engagement with, and understanding of, science and the environment. For example, community scientists work with local people to develop projects on local environmental issues of importance to them. Together they record local wildlife and the quality of air, soil and water; they analyse and interpret data to understand how local conditions can affect species diversity, distribution and population size. Project Budburst (Havens & Henderson, 2010) in the USA uses a crowd-sourcing approach through which tens of thousands of amateur naturalists contribute observations on hundreds of plant species to amass a very large data set. One focus of this is on the lifecycle, leafing, flowering and fruiting and the project takes its name from the first opening of leaf buds in spring. Since such events are sensitive to environmental conditions, they provide a simple and cost effective way to monitor climate change over the long term.

The comments discussed below do not come from organised projects, but from people's

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everyday lives, their daily routines. There are two broad aspects to these conversations: (i) some illustration and illumination of Marsick and Volpe's (1999) six characteristics, and (ii) some ways in which they have been tackled and contextualised. Pointers for future action within informal inquiry-based learning will be drawn from these latter aspects.

Serendipitous learning and vital relevance

According to Bowles (2004), serendipitous learning recognises that the human search for knowledge often occurs by chance, or as a by-product of a main task. For example, a search for information may launch the user on a tangent that ends up being more productive than the original search query. In such instances, Bowles argues, serendipitous learning has taken place. The term 'chance' here is unfortunate, except in the sense of Pasteur's famous maxim that 'chance favours only the prepared mind'. More reasonably, Zhang, Liu and Si (2011) describe serendipitous learning as a kind of 'never ending rolling knowledge collection', where the learner draws in new knowledge from a variety of sources and fairly constantly updates his or her thinking with this new content. However, since the array of knowledge available is vast and multifaceted, is an 'open domain' and comes in many different formats, and because 'one doesn't know what one doesn't know', then the direction and accumulation of knowledge cannot easily be determined in advance. In these terms, serendipitous learning is neither chance nor random, simply unplanned and open-ended in a complex learning environment. It is sometimes called 'learning through browsing' and browsing has a long and honourable tradition (Xia, 2010). So, serendipitous learning about plant biology and gardening is not merely waiting for a fortuitous event to happen. Serendipity requires action on the part of the recipient - action to create favourable circumstances, action to recognise opportunities when they arise, and action to capitalise on unplanned learning events in a timely manner.

While in 500BC Heraclites highlighted that 'the unexpected connection is more powerful than one that is obvious' (Hurson, 2007), 'powerful' here is interpreted as of high personal (vital) relevance. The manner of informal learning is commonly 'navigation through interest' (Griton, 2011), and such self-determined intentional learning implies that the learner acts consciously and with intent: it is the person who makes or causes things to happen in his or her life. In this respect, 'to find' is an intentional act and the people discussed in this research fit well within a description of personally-driven lively interest, engaged learning that draws from multiple sources. Fischer and Naumer (2006, p. 2) argue that 'people will first and foremost find information from people with whom they have a strong relationship, which are usually found in their circle of family, close friends and their local communities in places such as doctors' surgeries and libraries'. This kind of informal learning, though, is far from a 'situated

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community of inquiry' (Lave and Wenger, 1991), because it lacks any organisational situation, tight-knit or even recognisable 'bounded' community. The people discussed in this research may share concerns, common problems or passions about a topic, but they tend to deepen their knowledge and expertise in this area in an ongoing individualistic, episodic basis.

Listening to self-educated voices

The participants in this small study are as follows:

Table 1: a list of interview respondents

Comments to be made about this small sample are that, (i) they form an 'opportunity sample' of colleagues, friends and neighbours. All are known to the interviewer, some but not all are known to each other; (ii) there is (by design) an equal number of males and females; (iii) they are largely, but not exclusively, middle-aged, middle-class home-owners, engaged in home improvement with the time and financial means to accomplish this; (iv) they are all broadly educated, though only Cindy (latterly) has developed specialist, formal, knowledge of plants; the others are all active and self-taught gardeners; (v) they are confident and articulate, leaning towards supporting and helping others wherever possible.

Individual informal interviews, around forty minutes each, were conducted over a period of one month in a 'natural' mode, attempting to emulate ordinary conversation without the structural and quality demands placed upon more mediated forms of communication. Questions prompted all participants to reflect on gardening, plants, school science, out-of-school science and their own approaches to science and to learning. The conversations all took place within their own homes, were audio-recorded, the discussions of botanical issues were driven by five specific questions:

(1) To what extent are you interested in science?
(2) How do you know what to do in the garden/ allotment?
(3) From where do you derive your knowledge and understanding of plants?
(4) How much help has school science been in arriving at your current knowledge base?
(5) What would make your learning easier?

There are two basic approaches to assessing learning, direct and indirect. The direct is based on observable outcomes, a demonstration by learners of their knowledge or skills. Indirect assessment asks for learners' opinions, of the meaning and utility of the learning having

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occurred (Price & Randall, 2008). In this instance, no attempt was made to assess knowledge directly, no grades were given for 'good garden knowledge' or prizes awarded for healthiest plants or 'best blooms'. Participants were afforded anonymity, assigned a pseudonym and the data analysed qualitatively, using an individualised form of Krueger and Casey's (2009) long-table method to derive answers and opinions related to these five research questions. People shape and reshape their thinking about issues throughout the conversations (Bates, 2005) so that, for example, there might be relatively short answers at the start but they commonly 'warmed to a theme' during the conversations.

(1) Interest in science

None of the participants at the start indicated they were very or even 'somewhat' interested in science in itself. They had no professional or pastime affiliation with science, had not previously seen their 'plant-' or 'garden-based' activities as much to do with science, classing these simply as 'gardening'. Overwhelmingly, opinions followed traditional fault-lines between science and the rest of the world: cold, factual, pedantic science in contrast to the colourful, creative, emotional and tender care of the plants in the garden. Fran's magnolia tree, Karen's Canadian-red *Acer rubrum* (a delight in autumn), Brian's sycamore and the horse-chestnut *Aesculus hippocastanum* hanging over Robert's allotment (both a 'dratted nuisance' in autumn), had distinct and familiar personalities in the interview responses. Certain plants had 'needs' and 'likes' ('hydrangeas need water and like acid soil' (Wendy) rather than *Hydrangea macrophylla* being sensitive to soil pH): the garden was a labour of love not an intellectual scientific exercise. These are examples of the common process of anthropomorphism (Authors, 1996) in everyday life.

By the end of the conversations, however, they all felt that it had drawn their attention to science and the nature of scientific knowledge, and were prepared to admit that plant biology probably fitted somewhere within there. As David said:

> I have a background in design and technology so I kind of, I appreciate something of science though I don't really lay claim to knowing any of it [... And] science crosses over so many aspects of life that you just don't really realise. I suppose if there's such a thing as agricultural science, then my gardening could be a mini amateur version.

In most interview conversations this led to a discussion of 'passion'. Initially, science and passion were seen as inimitable, antithetical. Gardening was 'a fascination', a 'keen interest', a 'joy'. Ruth's zeal was for a section of her garden to be 'wild and natural':

> Ruth: Wildflower meadow planting is enjoying a huge vogue at the moment; they look beautiful and attract wildlife, particularly threatened pollinators. And, you know, real wildflower meadows are vanishing – and native flowers such as green-winged orchid,

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> oxlip, dyer's greenweed and meadow saffron are all going with them.

For Alison, it was a 'release of emotion', a route to calming and well-being, a communing with nature,

> Alison: I lose myself in the garden. Don't be daft, I don't mean literally lose myself, it's not that big. But it's my escapism. Fierce worries in my head, I put on the gardening gloves and grab a trowel, knock seven bells out of the borders, cut back the perennials, dead-head the roses until I'm calm again.

School science had been anything but passionate. There was some grudging acknowledgement that odd teachers, TV presenters may be enthusiastic about science, but that was written off as eccentricity or 'paid to be like that'. In most cases the accumulation of gardening knowledge was incidental although 'once I got going, it became a fixation' (Robert). He had been moved to build and use a new composting system for his allotment. This took considerable detailed research; he had 'compiled a dossier on it' and had acquired a consistent and well-developed knowledge of the biology involved:

> Rob: When I dig, turn, layer and water my compost, I feel as if I am doing the composting, but I now know the bulk of the work is actually done by organisms, fungi and bacteria. The composting speeds up the natural process of decomposition, provides good conditions for the organic matter to break down more quickly. And its good to have the larger decomposers too, things like mites, centipedes, bugs, snails, millipedes, spiders, slugs, beetles, ants, flies, flatworms and earthworms. They all chew and grind the materials into smaller pieces.

Then he grinned and said:

> Did you know, it is only very recently I found out an earthworm doesn't become two worms when you cut one in half. One half might live and grow again but the other bit doesn't. You don't get two worms for the price of one.

Two other general points can be made about the responses overall. First, these twelve participants all held considerable bodies of scientific knowledge related to plants and plant biology. All could refer to plants by their species names, understood optimal growing conditions, appreciated the differences - for example - between annuals, bi-annuals and perennials, had a good sense of rootstock grafting and cloning, an understanding of wind-bourne and insect pollination, of photosynthesis. Dave even quoted the 'formula', learned by rote some long years past: 'Carbon dioxide plus water plus light equals glucose plus oxygen'. Second, as noted earlier, the interviews could probe this knowledge but, necessarily, could not 'test' this in any formal sense, as Bassey did in 1963. The key ingredient in all of the responses, though, was that knowledge (Richard: 'All that I have learned about gardening') is affect-driven, motivated and sustained by interest and curiosity at the very least, and veered towards

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zeal, zest and obsession at several points.

(2) How do you know what to do?

This question was largely interpreted in two ways: (i) as concerning elements of landscaping and design, and (ii) actually 'what works in the garden'. Most landscaping ideas were derived from gardening books, magazines, television programmes, 'watching what the neighbours did' (Fran), hiring – or being – a landscape gardener (Cindy), visits to ornamental gardens in southern England such as Sisley, Ripley and Kew, and attendance at London's Chelsea Flower Show (Hamish).

Peter:

> When I was growing up, the garden was a place to slip out at night to drink beer and smoke. The lawn was mown, the patio kept neat and tidy, but nothing horticultural ever took place, my parents just weren't interested. Then came the ownership of my first house at the age of about 30. Ponds were built, flower beds created and the lawn cared for. A Readers Digest book was bought from a second-hand bookshop and the information therein consumed with a passion. I tended to my garden and it really looked good.

Richard:

> At 13 my pals and I started growing cannabis. It was absolutely essential no one found out, so a grow-bag was placed on top of the vicarage and the cannabis seeds sown with loving care. It was guarded and nurtured by the other members of the church choir. Books and magazines on the subject of irrigation were read eagerly and the secret maintained. We couldn't consult an adult because this was considered too dangerous. The crop was disguised between tomato plants but not very well.

'What works' came from a variety of sources, principally experience. Trial-and-error and experimentation featured consistently, particularly in terms of watering and feeding, and all of the respondents had gardening books of one sort or another on their shelves, to know 'when to prune the roses', 'how to treat the lawn' or to 'identify bugs and infestation.' Alison said:

> Allison: Gardening has always featured in my life. I was given a small part of the garden as a child, which I called my own. I planted snap-dragons, pansies, lupines, fox gloves and such like. A bit random, really, mostly what was at the end of a seed packet. When my mother worked in the garden, I worked my plot. I did a lot of weeding and that was an exercise in differentiating 'good' flowers from 'bad' weeds. "Is this a weed?" was a constant question with the answer, more often than not, "Yes, darling, you can pull that one." This always took place in the summer and was totally forgotten about at other times. Sweetpeas featured, I remember, for their smell. The source of all information was my parents.

'You learn from doing' (Brian), though that was also conceded to be an expensive way to learn given the cost of nursery-grown plants, and 'you learn from others when they give you

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seedlings or off-cuts'. Brian regularly consulted his father, a keen gardener and considered an expert on such things.

(3) From where do you get your knowledge and understanding of plants?

This generated a profusion of responses, with two main directions: general versus specific knowledge. Responses concerning general knowledge and 'background' were directed towards books, magazines, the back of seed packets, neighbours, the radio (BBC's *Gardener's Question Time* being a favourite), TV gardening programmes, other allotment users, the staff at garden centres, Brian's father (again). In terms of specific knowledge, the overwhelming answer was from the Internet.

> David: If you have the time and energy you look everything up. What's the fastest growing hedgerows? Because the fencing got blown down and I don't want to replace it. What's the best way to encourage butterflies? – grow *Buddleia* by the way – so that the garden looks good. How to de-moss the lawn? What feed to give what plants? What's the best way to get rid of slugs and snails? - coffee grains apparently, saves my lettuces.

Otherwise these respondents were resourceful and resilient in other ways in their pursuit of knowledge,

> Ruth: I mostly go online, you can get most things there. Sometimes I sit in the local library because they have those oversize coffee-table books. I smuggle in bits of leaf and flowers in my handbag – I'm sure they'd object if they knew - so I can identify what they are, match them against the pictures.

> Cindy: It depends if you mean tricks-of-the-trade or real knowledge. Even though I've worked in the business quite a while, I realised that I was relying on kind of pass-me-downs, you know, hearsay and old-wives tales, bits and pieces of knowledge and know-how. That's why I enrolled in this course I'm doing at Kew Gardens. And wow! Now, the people there really do know their science! They're great.

> Peter: The weekend newspapers are good, there's usually a section on what you should be doing in the garden at particular times of year. I have thought about joining a gardening club but, to be honest, I wouldn't make the time. The local nursery is good, I phone them, they're probably sick of me, but they do have a help-line and the girl on the other end does sound like she knows what she's doing.

A general point to be made here concerns the discussion of informal knowledge by Marsick and Volpe (1999) above. The scientific knowledge displayed by these interviewees is largely tacit and seldom highly explicated, commonly integrated with their daily routines, patently serendipitous and shaped by chance, an inductive process of action and reflection, and often linked to the learning of others. As Fensham and Harlen (1999) suggest, their knowledge is highly relevant to everyday situations – memorable and enduring simply because of that.

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(4) How much help has school science been in arriving at your current knowledge base?

Following the last point above, this question was greeted by a degree of head shaking, wry smiles, laughter and mild embarrassment. None of the participants wanted to lay claim to any consistent school-based knowledge, and all but a few had disparaging anecdotes about their school science. Karen said:

> If I go back to year two in junior school, I remember we were asked to go out and collect different kinds of leaves and bring them back to class. I asked "why?" and was told that she would explain once we collected the leaves. "Why can't you tell me now?" and I was told, "Just go and get leaves". I said, "Well which leaves should I get if you won't tell me what we are going to do with them?" "Just get anything then". So I didn't because I didn't see the point.

Fran mentioned:

> It's hard, the link between what is taught and what we know is really difficult to identify. One year the kids and I planted a Christmas tree. It would gradually drop leaves and I remembered – from school quite possibly – that they make the soil below the tree acid. So we then went out and found and planted some acid-loving plants below.

David returned to the notion of background versus specific knowledge:

> I guess there must be some background in there, stuff you know but you don't know you know. It's like anything at school, history, geography, French, it's in there somewhere and you don't realise you call on it because you've never had reason to isolate where exactly it came from. You dredge things up in a pub quiz you never knew you knew. But nowadays, when I go to find out about something, I remember where I got it. You know, where I read it, who told me, where I saw it. School science was pretty useless, but who knows what drips and dregs are still in there?

Hamish was prepared to concede some learning:

> In secondary school - I failed my 11-plus with distinction - we were shown how to extract alcohol from yeast. I remember the teacher explained each phase and the principles of extraction and the exact temperatures. Like the good lads that we were, we could then make our own alcohol. And later, I used the same principles, bottles of wine were carefully frozen and the alcohol was taken before it froze itself. Learning had certainly taken place, just not as originally intended.

(5) What would make your learning easier?

This question gave rise to long pauses for thought. Each of the twelve respondents already drew on a variety of sources for support and practical advice, had a good grasp of information systems and access to guidance. In general they were active in increasing their 'background knowledge' as well as resilient in pursuing particular inquiries to solve specific problems. Wendy said:

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> Wendy: I'm plagued by Japanese knotweed. I go on the Royal Horticultural Society website and the Environmental Agency site to see how to get rid of it, but it seems to be a mammoth job over three or four years, with loads of herbicides. I understand most of the things they say – I had to look up what a rhizome is. I have an app for my iPad for good gardening but I don't really use it. I prefer to learn by chasing things up.

They all agreed there was an abundance of information, that they had easy access and enough 'nous' (Richard) to navigate the available systems to get what they wanted. Ruth describes her drive and motivation as 'oomph',

> Ruth: there's nothing I can't really find if I want it, if I have the oomph to go get it. I suppose I really like someone to show me things, you know, physically be there to guide and for me to copy, like when I was trying to do some grafts recently. Following instructions on screen [on the laptop] is not easy in the garden shed!

The last words here lie with David:

> I think if I was researching something else in science, I'd be more worried about what I don't know. But the garden is hardly life or death. Well, to the plants maybe, but not to me. If I get the watering wrong, the feed, the soil, the light etcetera, then I'll lose some plants. But the beauty is that there is always next year, I get to have another go. It's real fun when it all comes right but it's not a disaster if it goes wrong. Hard on the wallet, maybe, but nothing else.

Then he added,

> Mind, I suppose you *can* get it wrong if you introduce, what are they called? Invasive species. I think rhododendron is one, and they go out of control. Putting the wrong fish in the pond that eat all the others. Yup, I think you have to know your science properly for that bit.

Discussion

The public (non) understanding of science is an easy target. Bauer, Allum and Miller (2007) chide against a simple deficit model and make the clear point that if there were not a substantial gap between the knowledge of scientists and that of the general public, then science would be in a serious way indeed. They also note that the public is not homogeneous, that there are many who have specific high-level knowledge and understanding in certain fields without being more generally and broadly scientifically literate. Nor do they see the school educational system to be the remedy for any knowledge 'ills'. While many have been vexed by what exactly counts as science, or studying something scientifically, as debated by Ziman (1991), Wynne (1996) and numerous others, Rahm (2010) and Rahm and Grimes (2005) most certainly see gardening as a science-based activity. Azevedo's (2013) work on science hobbies sheds light on how such long-term, interest-based leisure activities operate to foster and sustain the highly personalised knowledge and understanding.

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It is worth re-stressing that this small-scale research is representative only of a very specific social grouping. The high level of interest in gardening exhibited by these respondents demonstrates that, at a basic level, their 'everyday hobby' is actually an effective science engagement tool. It is well known that the process of interviewing itself can act as an 'active intervention' in people's thinking (Authors, 1987) and it is clear that the informal interviews documented here increased the salience of plant biology for these respondents, many of whom felt, upon seeing the connection with science, that they could – and should - form an more educated opinion.

As noted earlier, there was no sense in which the interviews were a test of knowledge, although respondents' understanding of botanical issues was raised on several occasions. Peter searched his memory at one point in an attempt to recall what was, and was not, a monocotyledon; Hamish recalled that the botanical sense of a 'fruit' includes many structures that are not commonly called 'fruits', such as bean pods and tomatoes. Similarly, Ruth became embroiled in a long discussion on the nature of 'seedless' grapes, failing to understand how they became seedless in the first place and how they could possibly propagate to provide further (seedless) crops if they were, in fact, seedless. Her knowledge within biology, as for all the respondents, had 'not come together' for her. One consequence was that she immediately resolved to explore what was meant by *parthenocarpy*, understand what it was and how it worked. As Baron (2003) points out, there exists ample information to assist people in learning about, in this case, plants: any lack of understanding can be the result of guiding orchestration (Authors, 2005).

Informal learning is difficult to link directly to outcomes but some can be identified and assessed, for example, by the way that beliefs affect choices and their consequences for action taken. Individuals bring themselves to their learning tasks, and so, their strategies and approaches are mediated by their ideals, values, histories, and prior socialisation. Context greatly shapes learning practices and choices, including triggers for learning, and these vary by the interests and preferences of the learners themselves (Poell, Chivers, Van der Krogt & Wildemeersch, 2000). The responses here support the idea that an individual's intentionality, pro-activity, learning intensity and critical reflectivity affect the nature of their learning. In their study of adult 'learning lives', Facer and Manchester (2012, p4) observed that individuals draw on five key types of learning resources: *cultural* (e.g. cultural repositories of knowledge and information such as museums, books, libraries); *people* (e.g. friends, families, educators, counsellors); *commercial* (e.g. advertising, sales advice); *embodied* (working things out through bodily movement); *reflective* (e.g. reviewing, auditing and reflecting upon experiences). These

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resources are clearly evidenced here in this short study, with individuals following particular trails through the science information they gathered - as and when they needed it.

Important work by Layton, Jenkins, Macgill and Davey (1993) at the University of Leeds provided fascinating case studies of adults in situations where they needed to know some science in order to 'survive'. Compared with the passivity of the science knowledge in Bassey's survey here was, in the words of those researchers, 'practical knowledge-in-action'. Science for their adult respondents was not a 'conceptual cathedral' to be remembered, but a 'quarry to be raided' for information to be put to use. Much as Layton *et al*. report, the participants discussed here were rarely inclined to frame their gardening challenges in terms of science. 'Everyday' activities like gardening are seldom included in science unless directed, and the knowledge these respondents gained shows many of the characteristics suggested by Marsick and Volpe (1999) discussed earlier and, being somewhat haphazard, lacking structure and 'orchestration' (Authors, 2005b). While some of these respondents saw the social obligation of 'keeping up appearances', more often than not they sought the pride and emotional comfort to be derived from well-kept and thriving garden plants.

Vital relevance

Beyond the basic level of awareness-raising, the responses reported here strongly suggest a marked qualitative difference in the kind of 'engagement' with the topic. Each of these respondents, in his or her own way, exhibited what might be called 'vital relevance'. Stuckey *et al*. (2013) make the point that there are many meanings for the term relevance, and these vary according to the stakeholders, in this instance, within science-learning enterprises. High levels of relevance for some barely register for others: relevance for distant examinations or future employers may feature far less for the thirteen year-old faced with a worksheet on osmosis. There are several dimensions to the relevance exhibited by the respondents here, in that it:

(i) Is very personal, concerning individuals' private 'learning life', relationships, and passions

(ii) Can generate long immersive periods of animated 'learning intensity' (Rivero, 2010)

(iii) Means knowledge and learning is specific and 'grounded' (sometimes literally) in immediate activities – in this case in the garden

(iv) Has a strong affective dimension: feelings and emotions, pleasure, satisfaction and dissatisfaction are important drivers

(v) Is really quite specific: the interest and drive can be directed at one very particular distinct and definite topic.

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In their work mentioned above, Facer and Manchester (2012) observed four broad prompts or motives for learning, these were: *personal events* (personal experiences and transitions that required emotional adjustment and personal development); *practicalities* (the development of skills and knowledge in pursuit of action in the world); *participation* (learning in pursuit of social engagement) and *pleasures* (learning prompted by curiosity and interest for its own sake). It is certainly possible to see three of these four prompts at play here, the least observable being gardening for social participation. While this may well have been the case, for example, for allotment holders, partners and neighbours, it did not surface distinctively in these interviews.

Gardening is an affective pastime: it engages emotions at a variety of levels – from satisfaction of a job done to the aesthetics of the garden, from colour and variety to touch and smell. Once the 'motivational fuse' was lit, these respondents became forcefully active learners, pursued personal lines of inquiry, undertook typical inquiry-based learning; became auto-didactic. The immediacy of the gardening experience produced strong emotional reactions in many of these respondents, which contributed clearly to the issue under discussion (cf. Authors, 2000). These respondents were surprised at themselves in being able to put science in a social and emotional context. It made the issues seem worthy of serious consideration.

There is clearly a gap between what happens in the majority of school science classrooms, and the ways people can be immersed in the various issues in their personal and social spaces. 'Vital relevance in everyday science' as discussed here clearly arises in unpredictable ways. While it does not provide complete answers, it contributes a significant element to a more complicated process of meaning-making. Having the drive (or 'oomph') to be self-educative, auto-didactic, engage in self-directed inquiry learning, allows learners significant input into the selection of topic or focus of the activity, engages them more deeply with the learning task, generates a greater intensity of learning.

Formal schooling lasts a short time relative to a normal lifespan. Beyond schooling, we must look to release the power of self-directed, interest-driven, inquiry-based, immersive and transformational problem solving that is characteristic of auto-didactic learners. Advances in learning technologies through information gateways, rich audio-visual communication, sophisticated resources, social networking and knowledge communities all allow for a wealth of provision for the motivated. Learners like the ones discussed here are likely to experience greater learning benefit from access to developmentally appropriate resources, increased time to explore topics and multiple opportunities to undertake information searches throughout the learning activity (Armstrong, 2012).

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Alison	Retired art teacher, recently moved to a new house, reshaping garden abandoned by previous owners
Brian	Mid-thirties father-of-two, newly 'up-sized' to a larger family house, busy re-shaping the garden for two young children
Cindy	Mid-forties owner of a florist business, now undertaking a course in landscape gardening
David	Retired secondary head teacher, having built a substantial house extension is now creating a garden from the ensuing building site
Fran	Re-furbisher of furniture and clothing, avid traveller to Australia and the far east, keen DIY gardener
Karen	Owner of a small suburban garden, interested only in so far as the garden remains neat and tidy
Hamish	Aged fifty, manager of a car salesroom, knowledgeable about plants and floral arrangements
Peter	Retired educational administrator, recently constructed a new patio area round the house
Richard	Retired policemen, dog owner, keen to make the most of the garden for his pets
Robert	An allotment owner, keen gardener (and cook) of vegetables principally for the kitchen and the table
Ruth	Keen interior designer, floral arranger, enjoys decorative gardening, herbaceous borders
Wendy	Currently re-furbishing the family home and restoring a house in France, soon to begin work on the garden

Table 1: A list of interview respondents

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