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Introduction

We live in an era when many important aspects of scientific knowledge are challenged. Not only are there well publicised arguments against grand theories, such as species evolution, but the scientific basis of everyday life is constantly being undermined. For example, recent articles in UK national newspapers have cited scientific evidence to assert that taking exercise makes you fat (Daily Telegraph, August 25th, 2009) and that using Facebook can raise your risk of cancer (Daily Mail, February 19th, 2009). When the Internet can provide easy access to entertaining conspiracy theories and pseudo-scientific articles there is more need than ever to enable young people to engage in rational scientific discourse and practices.

Yet it is clear that young learners are not easily attracted to science as a school subject (Lyons, 2006a,b). Learners can be challenged by the modes of thinking that science investigation requires but it is now widely acknowledged that the barrier to engagement goes further than a struggle with cognitive demands such as 'control of variables' (Kuhn, Iordanou, Pease & Wirkala, 2008). The teaching of science must also create an experience of inquiry and interpretation that is inspirationally authentic. As Hodson has expressed it: 'Becoming scientifically capable involves considerably more than acquisition of scientific skills, knowledge and understanding. It also involves the development of personal qualities and attitudes, the formulation of one's own views on a wide range of issues that have a scientific and/or technological dimension and the establishment of an underlying value position' (Hodson, 1998, p. 3). One route to approach this challenge is for science education to embrace more firmly the traditions of inquiry learning, where inquiry is extended beyond a classroom, and teachers may need

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2
3 to revise their understanding of the content and pedagogy of inquiry. As collaboration
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5 between teacher and students enhances inquiry, greater levels of involvement are required
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7 by teachers than in traditional settings (Crawford, 2000).
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10 Learning science by inquiry can help students to learn how to think like scientists
11 (Edelson, Gordin & Pea, 1999), do real science (de Jong, 2006; Hodson, 1998), and
12 engage in scientific discourse (Grandy & Duschl, 2007). By carrying out authentic
13 science investigations students can also come to understand the natural world as an arena
14 of investigation, where they have agency in deciding what, where and how to study. They
15 learn the benefits and limitations of scientific practice, such as the need for rigour in
16 collecting data, the importance of systematic analysis and the problems of drawing
17 conclusions from incomplete data. Active participation in science should also enable
18 them to gain a greater understanding of the practice of scientists and to take part in
19 discussions about scientific phenomena that affect, for instance, their health and
20 environment.
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36 However, the ideals of inquiry learning confront the realities of school education.
37 (Lakkala, Lallimo & Hakkarainen, 2005). School science must be framed by the
38 curriculum and constrained by practicalities of timetabling and access to equipment. Only
39 a limited range of science investigations can be conducted in a school classroom. A need
40 for equity means that students cannot be required to carry out experiments in the home
41 that require family resources or outdoor space. The school grounds could be a suitable
42 environment to study natural and physical phenomena, but a restricted school timetable
43 combined with concerns for safety may result in a lesson that is rushed and regimented,
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3 far distant from Dewey's advocacy of learning based on authentic science practice
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6 (Dewey, 1910).

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8 In addition to the generic problems of managing inquiry learning in school, de
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10 Jong (2006) indicates some specific difficulties faced by students when engaging with
11
12 inquiry learning. Students need support to:

- 13
14 – design appropriate experiments (e.g. what variables to choose, how many
15
16 variables to change, how to state and test hypotheses),
- 17
18 – implement experiments (e.g. make predictions, avoid being fixated with achieving
19
20 particular results rather than testing hypotheses),
- 21
22 – interpret and present results (e.g. compare and visualize data, then present these
23
24 appropriately).
- 25
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- 28

29 This should also be combined with support for participating in the argumentation
30
31 and debate that must surround real inquiry (McAlister, Ravenscroft, & Scanlon, 2004;
32
33 Osborne, Erduran & Simon, 2004).

34
35 Underpinning these ambitions is the more fundamental challenge to assist
36
37 students in coming to see science as personally meaningful and relevant to their everyday
38
39 lives. Young children may live as scientists, exploring and challenging their world, yet
40
41 school science is episodic and largely disconnected from the daily life of the learner
42
43 (Thier, 1987). Such a challenge is therefore one of making inquiry learning 'personal'.
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50 51 *Personal Inquiry Learning*

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53 In the United Kingdom the concept of personalized learning has become
54
55 politicized following a speech in 2004 by the then Schools Minister David Milliband
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3 (DSCF, 2009) in which he called for an education system that ‘identifies the true
4
5 potential of every child and then gives them the means to achieve it’. This would be
6
7 achieved through personalized learning that ensures every pupil achieves the highest
8
9 standard possible. Some elements of the UK personalization agenda include developing
10
11 teaching and learning strategies that build on individual needs, and developing a
12
13 curriculum that engages and respects students.
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17 While we recognize the need to engage and nurture the talents of every child, we
18
19 do not take an instrumental and systemic approach to personalization. Instead, following
20
21 Hodson (1998) we have pursued an approach of ‘personal inquiry learning’ based on
22
23 enabling students to gain personal meaning from science activity within a rich and
24
25 familiar environment. Traditional science teaching is typically characterized by an
26
27 ‘elimination of the personal’ (Donnelly, 2002). Yet, we suggest that students will both
28
29 engage with and take a committed stance towards the scientific process by forming
30
31 questions for which they genuinely want to know the answer, by carrying out
32
33 investigations that relate to their own needs and concerns, and by discussing emerging
34
35 findings with peers and experts.
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41 A central aspect of personal inquiry learning is taking *ownership* of the inquiry
42
43 process. A prerequisite is that students should gain a clear *understanding of such a*
44
45 *process* and of their *agency* in gaining scientific knowledge. They should come to know
46
47 what kind of questions are scientifically appropriate, how these can be framed as valid
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49 inquiries, who they can find and trust as scientific informants, what kind of studies are
50
51 appropriate, why it is important to collect reliable data, how this can be analyzed and
52
53 presented as valid evidence, and how the results of an inquiry can be shared and
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3 discussed. An important issue for research concerns how the domain of such inquiry is
4
5 effectively defined as 'personal' and, thereby, how a sense of problem ownership is
6
7 created. Existing approaches of this sort have tended to identify macro-social topics, such
8
9 as ecology and environment (e.g., Walker & Zeidler, 2007). The approach taken here is
10
11 more micro-social – drawing upon topics that are prominent in the learner's own 'local'
12
13 world.
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16
17 In this paper we address the twin issues of how to support inquiry-based science
18
19 learning within the school system and how to enable students to gain personal meaning
20
21 from engaging in science investigations. We describe a case study where an investigation
22
23 of healthy eating was undertaken by Year 9 students (aged 14) as part of the English
24
25 National Science Curriculum. During the intervention, the students began a science
26
27 investigation in the classroom supported by a teacher, they continued it at home, and then
28
29 discussed and presented the results of the inquiry back in the classroom.
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37 *Representing the inquiry process*

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39 From a study of frameworks for representing the science inquiry process (Bruce
40
41 & Bishop, 2002; Shimoda, White & Frederiksen, 2002) we have produced a
42
43 representation of personal inquiry that serves both as a visual map for learners and a
44
45 structure to guide the investigation process (Scanlon, Anastopoulou, Kerawalla, &
46
47 Mulholland, under review). It shows a cycle of questioning, investigation, evidence
48
49 collection, analysis, sharing and reflection, but without prescribing a particular scientific
50
51 method (Figure 1). This is not to indicate that all methods are equally appropriate, but
52
53 that the framework can be adapted to suit different methods of inquiry, including
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3 hypothesis-led experimentation, observation of natural phenomena, desk-based
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5 examination of literature, and discussion with expert scientists. The hatched lines are
6
7 intended to show an interconnection, with each phase building upon previous work and
8
9 informing future action.
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15 [Insert Figure 1 about here]
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20 *Technology Mediation for Personal Inquiry*

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22 Through a process of co-design of technology and pedagogy, a computer-based
23
24 toolkit, called nQuire, has been designed that guides the inquiry process inside and
25
26 outside the classroom. The design of nQuire follows an approach of ‘scripted’ support for
27
28 learning (Dillenbourg, 2002; O’Donnell & Dansereau, 1992) where scripts are dynamic
29
30 lesson plans that guide how students should interact and collaborate in following an
31
32 inquiry. The scripts support students through a sequence of activities including planning,
33
34 investigation, debate, data collection and presentation. nQuire is implemented using an
35
36 open source platform to enable wide access to the toolkit and is accessed through a web
37
38 browser running on desktop and portable devices.
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46 [Insert Figure 2 about here]
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51 The role of nQuire differs depending on the context in which it is used. Within the
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53 classroom, it assists the teacher to elicit suggestions for topics and inquiry questions, and
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55 the students to share, analyze and present findings. Outside the classroom, it guides each
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3 student through phases of the inquiry process, showing what activities are available and
4 providing tools for the collection and visualization of data. It does not prescribe a fixed
5 sequence of activities, but shows the resources and dependencies for each phase. For
6 example, to collect evidence requires having an inquiry question and a plan and,
7 depending on the topic, nQuire will offer a set of appropriate tools to collect and visualize
8 data. The available options change in response to the student's actions.
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20 The computer can be attached to probes to collect data and the information from
21 each laptop can be synchronized with a central server when in school. A teacher has
22 additional software tools to design an inquiry investigation or to adapt one from a pre-
23 prepared template, for example to include local environmental settings or provide initial
24 data. Figure 2 shows a screenshot of the current implementation of nQuire. On the left,
25 the screen shows phases of the personal inquiry. Along the top, below the title of the
26 investigation, the sequence of lessons is shown. In the centre is the current activity, in this
27 illustration an example food diary entry.
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41 *Personal inquiry of healthy eating*

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43 We describe an application of this educational-technology system at one stage in
44 its continuing development, to support personal inquiry learning on the topic of 'healthy
45 eating'. The educational context was for the students to explore whether they ate a
46 healthy diet, specifically to address the inquiry questions: 'What nutrients do I eat?' and
47 'Do I eat enough nutrients to be healthy?'. These questions had been developed
48 collaboratively by the research team, the teacher and a food scientist. They collectively
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3 identified healthy eating as a topic of personal interest to Year 9 children, although given
4 the time of year of the intervention and the time needed to implement the software, the
5 students themselves were not involved in defining the topic. To address the questions the
6 students were encouraged and supported to: understand the science of food and nutrition;
7 collect accurate data on their own eating patterns; analyze their diets in terms of key
8 nutrients to understand whether they were eating healthily; then present the results of
9 their findings to their classmates.
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20 The healthy eating inquiry was designed to achieve educational objectives whilst
21 also enabling the research team to explore the value and practice of technology-mediated
22 personal inquiry. First, the study allowed students to participate in multiple phases of an
23 inquiry project, where each phase had a clear goal leading to a sequence of activities.
24 Second, we wished to explore how learning could be maintained between home and
25 school, by developing learning activities that could be initiated in the classroom and then
26 continued at home. These had to be relevant to the students and their families and to
27 demonstrate a clear scientific rationale and practice. Third, the study aimed to give
28 students responsibility for their scientific investigation. They contributed to the methods
29 used to investigate the question, proposed questions to ask an expert food scientist and
30 were responsible for collecting and recording data. The latter activity was expected to be
31 particularly challenging as students would need to keep complete and accurate data for
32 any inferences to be meaningful.
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50 Investigations outside the classroom concerning healthy eating can be supported
51 by a written diary but this research aimed to embed the investigation into an overall
52 inquiry cycle, employing computer technology to structure and to support planning,
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3 collection of data, sharing and presenting results. Children took photos of their food and
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5 the computer toolkit was designed to enable children to label the food content for each
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7 meal and retrieve relevant nutritional information, to link the images of the meals to the
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9 data, to view charts comparing specific meals with recommended nutrient intake, to
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11 merge and share data with peers and to present the digital information in class.
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15 There is good evidence that inquiry approaches to science can be effective for
16
17 learning (Marx, et al., 2004), even if they present organizational challenges for teachers
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19 (Lakkala et al., 2005). Here, we are seeking to describe inquiry learning that is grounded
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21 in the personal and, more specifically, is mediated by tools designed to support effective
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23 organization of the activities involved. Accordingly, this research addressed the following
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25 questions:
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29 1. How does personal inquiry support scientific reasoning, understanding,
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31 attitudes and communication?
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- 34 2. How do students respond to inquiries that are grounded in the personal?
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- 37 3. What issues arise from students taking personal ownership of the technology
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39 and the inquiry?
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43 *Method*

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45 A case study approach was used to study personal inquiry learning. Multiple
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47 methods of data collection were employed, the details of which are presented below.
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Participants

The participants comprised of 28 students from Year 9 (14 years old) in an inner-city school which serves a deprived area of Nottingham and more than half of the school students have special educational needs (Department for Schools, Children and Families, Achievement and attainment tables 2009). A complete class was recruited to the study (14 girls and 14 boys) that followed the Personal Inquiry activities. In addition, a second class of children (16 girls and 13 boys) from the same year group in school took the same tests at equivalent points in the school year. These children studied their normal school curriculum. Ideally, it would have been desirable for the second class to be undertaking an equivalent curriculum, including a healthy eating topic, but without the personal inquiry approach. However, that was not possible within the constraints of our collaborating school. Consequently, test results from the second class were compared to ensure that any claims made about changes in the outcome scores of the intervention class are not simply due to testing the children on multiple occasions or at different points of the school year.

Equipment

Each student was provided with the toolkit running in a web browser on an Asus EEE netbook computer. A web server installed on each netbook enabled nQuire to operate in stand-alone mode, without access to the Internet, so students without an Internet connection at home were able to carry out the activities. In addition, each student was loaned a digital camera to take pictures of their food.

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Procedure

During the planning for the intervention, many informal sessions were held where the teacher together with a researcher discussed in detail the inquiry learning perspective in the context of lesson planning. These sessions had a dual benefit. The research team came to understand the school, the profile of the students to be involved in the study and the teacher's pedagogical goals, values and approaches. In return, the teacher gained a fuller understanding of the nature of inquiry learning.

Prior to starting the inquiry, the students took written pre-tests to assess their attitudes to science and their knowledge of the domain. Children in the intervention class then participated in the inquiry process as part of nine science lessons over a three week period. The Appendix shows the title and objectives of each lesson as well as homework activities that followed. Two objectives that applied to all lessons were: 1) understanding the inquiry process and 2) monitoring progression through the phases of inquiry. To summarize, the sequence of lessons combined two methods of inquiry: a study of personal eating habits based on an individual photographic diary and a group interview with a dietician. Each child was expected to take photos of all meals and snacks over a week, to import the data on to nQuire, to generate graphs that compared the nutrient intake for each day to the Recommended Nutritional Intake (RNI), and to prepare a group presentation of the inquiry. After the inquiry, children took the same tests of science attitudes and domain knowledge again.

nQuire supported these activities in a number of ways. In class, the teacher introduced the inquiry activities for each lesson; at home students could carry out the one activity as current homework or catch up with previous phases of the inquiry.

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6 [Insert Figure 3 about here]
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10 To support data collection, nQuire provided software tools to upload the photos,
11 add descriptions of the food to each image and select the names of food items from a
12 prescribed list. For example, a child who took a photograph of a sandwich might label it
13 'cheese sandwich' and then select 'bread, white, 2 slices' and 'cheese, 1 portion' from
14 pull-down menu items. The toolkit then presented a table showing the nutritional content
15 for that meal (carbohydrates, proteins etc.). To support students' understanding of the
16 data they collected, the toolkit automatically produced a bar chart that compared their
17 daily food intake to the RNI (Figure 3). To support reflection on their activities, nQuire
18 provided comment boxes for students to record what they did in each phase and what
19 problems they had, if any. The toolkit was also used to compose questions to the food
20 expert and it provided links to an Impress file (the OpenOffice version of PowerPoint) to
21 prepare the presentations of their inquiry.
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41 *Methods of analysis*

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43 The outcomes and processes of the sequence of nine lessons were assessed by
44 multiple methods.
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50 *Outcome Analysis*

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52 A domain knowledge questionnaire was based on the Key Stage 3, Year 9 (Age
53 14) UK curriculum and assessed what nutrients are needed for healthy eating and in
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3 which foods they can be found. It consisted of twelve multiple choice items with one
4
5 correct answer and three distractors (e.g. 'Jane has a healthy diet except she is not having
6
7 enough calcium. Which of these foods does she need? Pasta; Cheese; Fish; Oranges').
8
9

10 The purpose of this was to establish whether students are still able to gain domain
11
12 specific knowledge while undertaking in inquiry-based activity. Attitudes towards
13
14 science were assessed with the Test of Science Related Attitudes (TOSRA) (Fraser,
15
16 1981), where students respond on a five point Likert scale. Four of the most relevant
17
18 scales were selected in advance of the study: Attitude to Scientific Inquiry, Adoption of
19
20 Scientific Attitudes, Enjoyment of Science Lessons, and Leisure Interest in Science.
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27 *Process Analysis*

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29 Each of nine lessons was recorded by three video cameras, with two focused on
30
31 specific small groups and one, sited at the rear of the classroom, on the overall class.
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33 These recordings were supplemented by notes made in class by a researcher. Time-
34
35 stamped log files from each computer provided information about students' use of the
36
37 nQuire toolkit, including text responses to questions and photos uploaded.
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39
40

41 The processes of personal inquiry learning and the subjective experiences of the
42
43 participants were investigated through interviews with the students and their class teacher
44
45 and by videotaped observations of classroom interactions. Informal interviews with the
46
47 teacher were conducted after lessons 1, 3, 4, 5, 6, 7, 8, and 9 to elicit her reflection on the
48
49 lesson, its successes and problems, and the extent to which it had met her expectations.
50
51 Additional interviews were held after lessons 5 and 6 to reflect on how the inquiry
52
53 process met her expectations and her willingness to take this approach for the remainder
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of the lessons. An interview after the final lesson focused on her experience overall, her views on the students' learning, and possible future actions.

Seven group interviews with students aimed to capture their views on the inquiry activities. Three interviews were conducted with a group of three boys after lesson 3, lesson 5, and at the end. Two interviews were held with a group of three girls after lesson 7 and at the end. Two further interviews were conducted towards the end of the intervention: with a group of four boys during lesson 8 and a group of four girls during lesson 9.

Results

We begin by briefly considering the outcomes of the personal inquiry lessons before focussing in more detail on the process of personal inquiry learning.

Outcome Analysis

Due to absences from class, some students missed either the pre or post test and so data is included only from students who took both tests leaving 14 of the 28 students from the Personal Inquiry and 13 of the 29 students from the control class. As the data failed tests of normality, non parametric analysis is used and median scores and inter-quartile range are shown in Table 1. A Mann-Whitney test found no difference between the intervention and control conditions at pre-test ($U = 69$) but a difference at post-test ($U=40.5, p<.02$). A related-sample Wilcoxon test showed a significant increase in the pre to post test scores for the intervention group ($T = 1, p<0.005$), whereas the pre and post test scores for the control group did not differ ($T=6, p = ns$).

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6 [Insert Table 1 about here]
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10 21 students in the intervention and 15 students in the control class took both
11 attitude tests. A mean substitution following missing value analysis was performed for
12 0.01% of the data.
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20 [Insert Table 2 about here]
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23

24 Table 2 shows the pre-test and post-test means and standard deviations for each
25 sub-scale of the Test of Science Related Attitudes (TOSRA). A 2 (Intervention/Control)
26 by 2 (Pre-test/Post-test) mixed MANOVA was carried out on the TOSRA subscales. It
27 showed no main effect of condition ($F(4,31) = .41$) or time ($F(4,31) = 1.7$) but did reveal
28 a condition by time interaction ($F(4,31) = 3.42, p < 0.02$). Univariate analysis found the only
29 subscale that showed this effect was the Enjoyment of Science Lessons Scale ($F(1,34) =$
30 $6.06, MSE = 7.76, p < 0.02, \eta_p^2 = .15$). Post-hoc comparisons (Bonferoni corrected)
31 showed that the control group scores decreased significantly over time ($2.61, p < 0.015$)
32 whereas the Personal Inquiry group stayed the same.
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48 *Process Analysis*

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50 The experience of personal inquiry learning was probed with individual and group
51 interviews. The interpretation of these interviews was grounded in an intimate familiarity
52 with the core of the project work, which took place in the classroom. Three researchers
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3 were present in the classroom for all lessons. Their fieldnotes and viewing of recordings
4
5 from three video cameras furnished a context of common knowledge that resourced the
6
7 interviewing and its subsequent interpretation.
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9

10 Three researchers studied transcripts of all the interviews to identify references to
11
12 issues that could provide insight into the three issues addressed below. They also
13
14 analyzed the computer logfiles for patterns of interaction with the computer and for text
15
16 references to the issues (based on problems students recorded with their data collection).
17
18 These sources of evidence were integrated into the commentary below. Interviews are
19
20 indicated by a letter and number, so, for example, T1 indicates the interview with the
21
22 Teacher after Lesson 1, TA5 refers to the additional interview with the Teacher after
23
24 lesson 5, and B3 indicates the interview with boys after Lesson 3. **Analysis of teacher and**
25
26 **student accounts is reported here in terms of the research questions.** Respectively, these
27
28 are concerned with issues of scientific reasoning and communication, inquiries that are
29
30 grounded in the personal, and personal ownership of the teaching of inquiry.
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39 *Issue 1: Scientific reasoning and communication*

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41 Comments related to this issue were organised around four themes: methods of
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43 data capture, socially coordinating around data, systematising data, and task
44
45 orchestration. The activity of data capture by keeping a daily food diary was regarded by
46
47 the students as an appropriate method of investigating personal eating patterns, but some
48
49 recognised the difficulty of keeping accurate records.
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51

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53 [B9] R: *Were they, eventually were they easy or difficult to use, to do? To*
54
55 *actually use them?*
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3 S1: It was easy.
4

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6 R: *The diary?*
7

8 S1: Yes, it was easy.
9

10 S2: It was easy but not that accurate really.
11

12 R: *Why do you think that is?*
13

14 S2: Because you're not going to take a picture of everything you take and
15
16 find out what you eat every day, because you're not going to have your
17
18 camera on you all the time.
19
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21
22 Some also recognized that failure to record all the data would result in under-
23
24 recording of the nutrients, giving a false impression of their daily intake.
25

26
27 [B9] S1: I thought mine would be a lot higher, but they weren't.
28

29 R: *They weren't?*
30

31 S1: No
32

33 S2: And I got mine a little bit wrong as well.
34

35 S3: I got mine wrong as well.
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38 S2: But saying that, if you missed one thing it makes the whole thing
39
40 irrelevant really.
41
42

43 S3: Inaccurate.
44

45
46 In general, there was a useful degree of reflection on the difficulties inherent in
47
48 finding ways to achieve convincing and robust data capture in a fieldwork situation.
49

50 [G9] S1: They might, but there could be different ways of doing it couldn't there?
51

52 R: *Yes.*
53

54 S2: Because you could write down, but if it's easier to take pictures.
55
56
57
58
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60

1
2
3 S3: Yes, but if you had to like do pictures that wouldn't work, because
4
5 people would lie.
6
7

8 S4: Yes, if you went out, you forgot to take your camera, because some of
9
10 them don't let you take your camera in the restaurant. And you write
11
12 them on the piece of paper, so you might not be able to read it.
13

14 S3: But I did. At MacDonald's I did.
15
16

17 A notable feature of the toolkit design concerned the opportunities for
18
19 coordinating with others around data, as would be commonplace in an authentic scientific
20
21 investigation.
22
23

24 During lesson 8, students were asked to create computer presentations to show
25
26 their group's data. The video record indicated that the students tended to work
27
28 independently instead of collaborating as a group. The layout of the classroom, with
29
30 students along one side of each table facing the teacher, combined with difficulties in
31
32 sharing data across devices and lack of a shared large display, meant that this group
33
34 activity was not well supported.
35
36
37

38 [T9] T: I think a lot of them are trying to type, they're all trying to type in the
39
40 same things on the slides into all the machines ... Really you just wanted
41
42 it on, one machine would suffice wouldn't it?
43
44
45

46 Despite the technical and classroom impediments to collaboration, students
47
48 indicated that they benefitted from seeing the presentations from other groups.
49

50 [B9] R: *Did you enjoy the presenting part, where it's actually standing in front of*
51
52 *the class?*
53
54
55
56
57
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60

1
2
3 S: Yes, because it's like it's not just keeping your photos to yourself, it's
4 spreading it round everybody else to see what they think about it and
5
6
7
8 compare it to other people's.
9

10 [B3] S: Being in a group here, it's like, when it's like asking questions if we can
11
12 all work together to figure out a question at least we're not on our own,
13
14 like we normally are in class, having to put our own answers to
15
16 everything while we get accused of copying and everything. So it's nice
17
18 that we can actually have a proper discussion and work it out together.
19
20
21

22 These challenges of data capture and coordination also involve a pressure to
23
24 systematise the data in ways that support interpretation and dissemination. In the context
25
26 of the present study, this was expressed as a challenge of coding and categorising the
27
28 participant reports of their diet. Here there emerged a productively critical consideration
29
30 of the difficulties of coding.
31
32
33

34 [B9] S1: I thought they were inaccurate as well, because you get different stuff.
35
36 You can get different types of potatoes like used potatoes in crisps or
37
38 just plain potatoes, but there's different stuff in, like they use different
39
40 oils.
41
42

43 R: *So they're all going to be different nutritional values.*

44 S1: Not really. There should have been more options.
45
46

47 S2: More detailed options.
48
49

50 S1: You could have chips, you could have crisps, you could have jacket
51
52 potato, so it should have been clearer.
53
54

55 R: *Right, OK. Do you think this affected the results?*
56
57
58
59
60

1
2
3 S2: Yes. I don't think the results were that accurate.
4

5
6 The overall task required a carefully managed sequence of inquiry activities, if it
7
8 was to be successful as a project that allowed reasoning about shared data. The toolkit
9
10 provided a means for orchestrating this activity and it appeared to work effectively. The
11
12 teacher indicated its value in managing the inquiry process:
13

14
15 [T9] T: I think going through the inquiry process as a whole though, it's quite a
16
17 nice tool if you're working through the whole process. Because if you're
18
19 doing that otherwise you'd have an awful lot of bits of paper.
20
21

22 Pupils also gave positive assessments of the toolkit as a means to structure the
23
24 reasoning process:
25

26
27 [B9] R: *Would you use it again <boy>?*
28

29 S1: Yes. It just made, because it was easy to use, because of how it was set
30
31 up, everything was in steps and you knew what you had to do next.
32
33

34 S2: I found it was quite easy because when it's all broken down into steps
35
36 then we know what we're going to like do next and what we're going to
37
38 find out and stuff like that.
39
40

41 It should be emphasized that the products of this empirical effort were recognized
42
43 as useful and provocative. To produce data that represented accurately their daily nutrient
44
45 intake, the students were required to carry out a sequence of actions that comprised
46
47 taking a photograph of each meal, selecting the components of the meal and number of
48
49 portions (e.g. 'white bread, 2 slices') from a pull-down menu, then for each day
50
51 comparing the nutrients calculated by the computer with the RNI. Some students found
52
53 this comparison revealing.
54
55
56
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1
2
3 [G9] S1: ...the RNI thing, that was interesting because it showed you how much
4
5 you eat and then how much you're supposed to eat.
6
7

8 S2: Yes, that was interesting, because then we know like...

9
10 S1: ... what to eat more of ...

11
12 S1: I need more vitamins.

13
14 S2: Basically I wasn't eating enough.
15
16

17
18 In one interview extract, the students indicated that they had made connections
19
20 between personal diet and body functions.
21

22 [B9] S: We kind of realized that like all the food groups, we all realized what
23
24 they do for us. It's like carbohydrates for energy and fibre's for the
25
26 toilet.
27
28

29 The teacher also described the sequence of activities as productive, though she
30
31 suggested the need for more discussion and for the children to produce
32
33 written summaries:
34
35

36 [T9]: T: I think in the data collection, the analysis and the presentation I think
37
38 [met] my expectations, yes, they over-ran from what I expected, but I
39
40 think that was a really good way of doing that and I think that worked.
41
42 So I think it's more, [...] about what is the point of some of the tasks
43
44 and do we actually need a written answer for that? [...] more of a
45
46 discussion and more of maybe them writing a summary of the topic or
47
48 what they're looking to research or what we've decided on.
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Issue 2: Responses to inquiry grounded in the personal

A central aim of this study was to support students in carrying out science investigations that had personal relevance. If acting as scientists can show them something of immediate importance, then they might come to understand the relevance of the scientific method to their daily lives. A scan of teenage magazines shows a fixation with diet, and our early discussions with the teacher suggested that healthy eating would be a meaningful and appropriate inquiry topic. What we had not anticipated was that some students would find the process of taking and sharing photographs of their food embarrassing.

[T3] T: I'm quite surprised, I was surprised still they're not, some of them are just not taking any data, got any data. <Girl 1> because she was embarrassed. She was embarrassed about letting anyone else know. I don't think <girl 2> wanted anyone else to know either, what she was eating.

[G9] S1: ...when you had to take pictures, everybody didn't take pictures because they was too embarrassed to take pictures. ...

S2: Because if people eat chips and chips and chips or something like that, then they don't want to take pictures because they eat chips.

S1: No, they don't want to take pictures every day of chips.

S2: Because they'll think that people'll bully them because they eat the same.

Once the students realized that others were taking photos, that the data was necessary to complete the investigation, and after the teacher and researcher had

1
2
3 reiterated that they would not be identified in class by their photos, then all the students
4
5 contributed some photographs, as shown by the computer logfiles.
6
7

8 [T5] T: I think they realized that they couldn't do part of the lesson, you know, it
9
10 was themselves that were letting us down or letting themselves down,
11
12 wasn't it? You know, they couldn't get on, because you know, the buck
13
14 stops with them, they've got to take photos.
15
16

17 [B5] S: ... I got worried about what other people would think, so I deleted two of
18
19 the pictures, But then when Miss said that, I was like 'Oh, you could
20
21 have told me that like yesterday.'
22
23

24 R: *When I said what?*

25
26 S: When you said that no-one else will see your data in class. I thought it
27
28 would be shown to everybody else in the class, so I deleted the picture.
29
30

31 R: *So maybe if we do something like this again it should be made quite*
32
33 *obvious right from the start who would see your data.*
34
35

36 S: Yes.
37
38

39 The teacher gave a positive assessment to of the students' learning outcomes,
40
41 particularly with regard to understanding the inquiry process:
42
43

44 [T9] T: Yes. I think they've certainly got a better understanding of how healthy
45
46 their diet was and how important it is that, what crisps and fizzy drink
47
48 are doing to you. And I think [...] they've got a far better
49
50 understanding of the inquiry process because we very rarely would do
51
52 the whole thing in school and they've got no idea really how properly it
53
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works from start to finish. So I think the learning curve of that was probably much steeper than the learning curve of content.

Issue 3: Personal ownership of the technology and the inquiry

Each student was lent a digital still camera and a netbook. Apart from nQuire, the netbook also provided a Linux operating system with an internet browser and a small suite of applications including a word processor and arcade style games that were pre-loaded on the machine. The students were asked to take this equipment home to capture their food diaries and to bring it into school for each science lesson. We found that student and teacher commentary on this issue centred on issues of ease-of-use, engagement, mobility and domestication.

The teacher indicated that the students found the computers easy to work with and did not find the software complicated :

[T1]. T: The good moments were that [...] the children could easily access the computers, they didn't find it difficult to work them, or they didn't seem to find it that complicated.

This was supported by interviews with the students who tended to frame this in terms of familiarity with the medium.

[B9] S: I found it easy to use because I've got one like it at home.

Engagement with the toolkit was positive and this was often expressed in terms of a contrast between old and new learning media.

[B3] S: ...how can I put it? You're still learning though, because it's like you're not just copying things out of a textbook and because ...we're doing

1
2
3 things that we enjoy like on a laptop, which all kids are going to love
4
5 anyway and, to be honest, working out of textbooks is boring. So if
6
7 we're working on laptops, because it's more enjoyable it's easier to
8
9 take it.
10
11

12 Despite this favourable judgement, as the lessons progressed, some students found
13
14 it awkward to carry the laptop between home and school.
15

16
17 [G9] S: Well, to start it was alright.
18

19
20 R: *To start?*
21

22 S: But then it kept on getting annoying because you had to carry something
23
24 everywhere in your bag.
25
26

27 Allowing a novel digital device to blur the separation between home and school
28
29 required that this device undergo a degree of domestication. The appearance of a personal
30
31 inquiry resource stimulated various domestic reactions. Some required the learner to be
32
33 protective. In explaining the scarcity of photo data, one student noted:
34

35
36 [B8] I only took a couple because my brother deleted them.
37

38
39 In general, there was a concern about caring for this new device.
40

41 [B9] S1: My parents didn't really mind about bringing it home, just as long as I
42
43 looked after it.
44

45
46 S2: That was my Mum's main concern, that I'd break it.
47

48 Engagement by adult members of the family covered a range of possibilities.
49
50 These included minor hijacking.
51

52
53 [G9] R: *How did your family react to the technology?*
54

55
56 S1: Went straight on the science.
57
58
59
60

1
2
3 R: *How did your family...?*

4
5
6 S2: Yes, they went straight on it.

7
8 R: *Ah, they used it then as well?*

9
10 S2: Yes, my family used it as well. For games. Only at first, just on games
11
12 and looked at what it does and then my brother wanted one, but he can't put
13
14 a disc in and it hasn't got Microsoft summat.
15
16

17
18 Other family members provided a generalised encouragement to value the
19
20 opportunity.
21

22 [B9] S: My Mum didn't really mind because it's like, she said it's good to do
23
24 because when they were at school it was all just hard work, keep your face
25
26 in a book or something. But we've got modern technology to use.
27
28

29 Not all family input was constructive. One student recounted a comment on the
30
31 group work.
32
33

34 [G9] S1: After a bit, my Mum said 'Are you *still* doing that?'

35
36 S2: Yes, so did my Mum. She said 'Well, it's a bit annoying.' She said
37
38 'There's no point doing it if everyone else is going to do it.'
39
40
41
42

43 Discussion

44
45 The primary aim of the study was to investigate whether students aged 14 can be
46
47 helped to understand and engage with the scientific process by carrying out investigations
48
49 between school and home that relate to their personal needs and concerns. Although the
50
51 students did not choose the inquiry questions ('What nutrients do I eat?' and 'Do I eat
52
53 enough nutrients to be healthy?') they were framed to be relevant to their everyday lives
54
55
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1
2
3 and to relate to a concern of many teenagers with food and health. Evidence from the
4
5 interviews suggests that the students were interested in the topic and genuinely curious to
6
7 find the answers. Moreover, the learning activity was substantially different to normal
8
9 classroom lessons and while this posed problems for the teacher of classroom
10
11 management and coordination across lessons, it did allow the students to experience the
12
13 uncertainty and challenge of an open investigation. The activity extended across nine
14
15 lessons, so at the start the students were uncertain as to their agency in carrying out the
16
17 investigation and how the work would progress and finish.
18
19
20
21

22 Whilst the main point of the intervention was to deepen their understanding of the
23
24 practices of science (such as collecting relevant and accurate data, communicating
25
26 results) we also expected they would increase their knowledge of the role of nutrients and
27
28 of the nutritional content of foods. The results of the domain knowledge questionnaire
29
30 showed that the intervention students on average increased their scores by 20% from pre
31
32 to post-test. This is unlikely simply to be due to the effects of repeated testing as the non-
33
34 intervention group (who had not studied healthy eating) showed no improvement.
35
36
37
38

39 The results for the attitude scores, however, show no change. Students completed
40
41 four subscales of the TOSRA (Attitude to Scientific Inquiry, Adoption of Scientific
42
43 Attitudes, Enjoyment of Science Lessons, and Leisure Interest in Science) before and
44
45 after the study. The mean scores from the intervention students were unchanged on all
46
47 scales. Those for the control group also remained unchanged, except for the 'Enjoyment
48
49 of Science Lessons' subscale, which decreased. Longitudinal studies of attitudes to
50
51 science lessons often report a decrease both over the school year and across the middle
52
53 and high school period (e.g. George, 2006). Given that students in the intervention group
54
55
56
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1
2
3 had participated in a research study, receiving extra attention and loan of computer
4
5 equipment, it is not surprising they expressed more enjoyment of science lessons than the
6
7 non intervention group. Moreover, it is disappointing that the attitudes to science did not
8
9 alter from pre to post test. This acts as a timely reminder that students' attitudes to
10
11 science can be resistant to change and that research teams should not be over optimistic
12
13 in their predictions for the likely impact of short term interventions.
14
15

16
17
18 Meanwhile, it is evident from the process analysis that students became more
19
20 aware of the different methods of data capture, difficulties inherent in data capture
21
22 outside the classroom, as well as challenges surrounding collaboration and sharing of
23
24 data. A further finding is that although owning the technology for a period of time
25
26 allowed students to be engaged in learning between lessons, as time progressed some
27
28 students expressed discomfort with the routine, particularly in finding it awkward to carry
29
30 the laptop between home and school. Some also experienced difficulties at home, such as
31
32 requests to be protective, appropriation of the technology by family members, and in a
33
34 few cases discouragement from taking part in the study. These all point to challenges in
35
36 adopting personal technology to maintain a continuity of learning between school and
37
38 home. It also raises questions of how to exploit affective issues as opportunities, for
39
40 example to discuss ethical issues of the scientific community, such as confidentiality and
41
42 ownership of the research.
43
44
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48
49 The research team and teacher recognized in advance that for the data analysis
50
51 lessons (lessons 3-5) to proceed, the students had to collect valid data in the form of
52
53 photographs of food, correctly labelled with nutritional content. Thus, the students were
54
55 asked to take photographs from lesson one, with each subsequent lesson requiring more
56
57
58
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1
2
3 accurate data collection. The students did come to realize for themselves the scientific
4
5 truism that analysis of data needs data to analyze.
6
7

8 Since the school experienced general difficulty in engaging its students in science
9
10 and it had a no homework policy, the project took a risk in asking students to collect data
11
12 outside the lessons. Accordingly, data collection at homes was limited to taking
13
14 photographs of food to act as reminders of what they ate. The students then added
15
16 information about portions and types of food and needed to compare charts generated by
17
18 the software. This way the experience did not focus on the numerical aspects such as
19
20 counting mass and calories but rather on nutritional components of each meal together
21
22 with comparisons of meals during a day or longer.
23
24
25
26

27 The decision to photograph meals had an unintended consequence as some
28
29 students were reluctant to take or share photographs of their food. In retrospect, this
30
31 might have been obvious. A photograph of a plate of food generally looks less appealing
32
33 than the real dish, and many students eat meals and snacks of low nutritional content yet
34
35 are concerned about their self-image. However, neither the researchers nor the teacher
36
37 identified this as a problem in advance of the study and we are not aware of the
38
39 consequences of 'too personal' investigations being identified in literature on inquiry
40
41 learning.
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45

46 The problem was addressed in this study by the expedient of emphasizing to the
47
48 students that they would not be identified as authors of their photographs when they were
49
50 presented in class, and by the teacher requiring them to take photographs as data for
51
52 analysis in class. Although this had the desired effect of eliciting notated photographs
53
54 from every child, it did not entirely resolve the issue of embarrassing self-disclosure. The
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1
2
3 students worked in groups to share and present their data, so they had to show their
4
5 photos and daily nutritional charts to others in their group. This might have been avoided
6
7 by each child working alone, but the group discussions were an import element in
8
9 modelling the scientific process of sharing and cross-checking data. It might be possible
10
11 for the students to work in groups with anonymised data from their peers, but that would
12
13 require an additional layer of technical complexity and classroom management.
14
15

16
17 This raises a more general tension in inquiry science learning. To participate in
18
19 the great scientific debates of contemporary society, students need to gain empathy with
20
21 the scientific process, to think and act like scientists, to gain a direct appreciation of the
22
23 challenges and delights of exploring the material world. The lure is through personalized
24
25 inquiry, where each child devises an inquiry question of personal relevance, or the
26
27 inquiry topic resonates with students' everyday concerns (Hodson, 1998; Edelson, et al.,
28
29 1999). But to be a scientist requires detachment from the scientific process, to collect data
30
31 in a rigorous manner and subject it to objective scrutiny. Is it possible to find the 'sweet
32
33 spot' between objective but unengaging, and meaningful but **potentially** embarrassing,
34
35 personalised inquiry learning?
36
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40
41 One way forward is to devise individual inquiry questions that students want to
42
43 answer, but do not require such a large amount of self-disclosure. Another possibility is
44
45 to collect personal data, then ensure that it is anonymised before being shared and
46
47 analyzed, with the students fully informed that they will not be associated with their data.
48
49 Both approaches require more complex technology and classroom management. The first
50
51 would need the computer and the teacher to accommodate a range of inquiry methods and
52
53 probes. The second would need a process of separating the collectors from their data.
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3 Both are opportunities to be explored in future research. However, our preferred solution
4
5 is for the students, through discussion amongst themselves and with the teacher, to
6
7 propose an inquiry topic over which they have sense of ownership and collective interest.
8
9
10 This is the approach taken for our subsequent study.
11

12 13 14 15 *Conclusion*

16
17 We have reported a case study of personal science inquiry learning with technology
18
19 dwelling on the participants' own accounts of the experience as they reveal a number of
20
21 specific ways in which personal inquiry works to configure a more realistic experience of
22
23 science. Our findings have shown that students can be alerted to a number of challenges
24
25 associated with fieldwork: the management of data, the demands of collaboration, the
26
27 ambiguities of measurement, and the need for management of activities. This did not
28
29 threaten their enjoyment of the lesson nor did it negatively impact on their understanding
30
31 of topic, although it is disappointing that the students' responses to the science attitude
32
33 scales did not reveal any enhanced interest in science. The findings also reveal practical
34
35 challenges that will be important to consider in moving this approach to science learning
36
37 forward. The toolkit was successfully accommodated within a traditional science
38
39 classroom and moved inquiry into the personal space of the home. However, its arrival
40
41 there, at least at first, can provoke a variety of responses in relation to domestication.
42
43
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46
47 These need to be anticipated, although we believe they are easily managed and capable of
48
49 being directed towards constructive forms of support. More deeply rooted challenges lie
50
51 in the management of the 'too personal' dimension of personal inquiry learning. It may
52
53 remain for the teacher (negotiating with students) to find the 'sweet spot' that takes
54
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1
2
3 advantage of the engagement arising from meaningful investigation while not serving as
4
5 an identity threat to the participating learners.
6
7

8 Given that many students of this age are quite happy to reveal personal
9
10 information about themselves in social internet activities, the finding that some do not
11
12 want to share a picture of what they eat is a fascinating contradiction. It indicates the
13
14 difficulty that teachers have in making links to the real world. Through this research we
15
16 provided recommendations by acknowledging the problem, identifying that some topics
17
18 may be too personal to study or data may be too embarrassing to share with peers. Yet,
19
20 this needs to be balanced against topics that students have little motivation to study. What
21
22 exactly works might be limited to a balance between motivation and embarrassment.
23
24
25

26
27 A challenging aspect of this study was that it took place within a school with
28
29 significant attendance issues as well problems in engaging its students in science and in
30
31 out of school work. This was positive in that we were working with a population that
32
33 does not normally participate in trials of new technology and pedagogy. However, it did
34
35 offer significant problems for the research (e.g. decreased sample size, high mortality
36
37 rate) and for the pedagogy (e.g. pupils missing crucial lessons, forgetting equipment at
38
39 home, and complaints about carrying equipment back and forth). Furthermore, it was not
40
41 possible to work with an equivalent class of students who were following the same
42
43 curriculum but without the Personal Inquiry approach. This limited any comparative
44
45 claims we can make from this study. It offered, however, a rich environment to extract
46
47 fruitful evidence of school inquiry-based science with a personal perspective.
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52
53 This study aimed to explore how a personal inquiry can become integrated into
54
55 school science. It highlighted how the ideals of inquiry learning confront the realities of
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1
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3 school education and it articulated challenges emerging from taking new technology and
4
5 new pedagogical activities from a research environment to integrating them into
6
7 classrooms and homes. It does not offer a solution however for scaling up; it is rather the
8
9 first step towards making such innovation routine. Given the rapid development of hand-
10
11 held technology, activities like recording, photographing, interpreting graphs may
12
13 become commonplace, but there still needs to be a way of amalgamating these
14
15 components. The nQuire toolkit offers such functionality through an authoring tool that
16
17 teachers can use to modify or design new inquiries that fit their needs. It is yet to be
18
19 explored how such interventions can be sustainable so that teachers and students are
20
21 empowered to create personal meaning through science inquiry.
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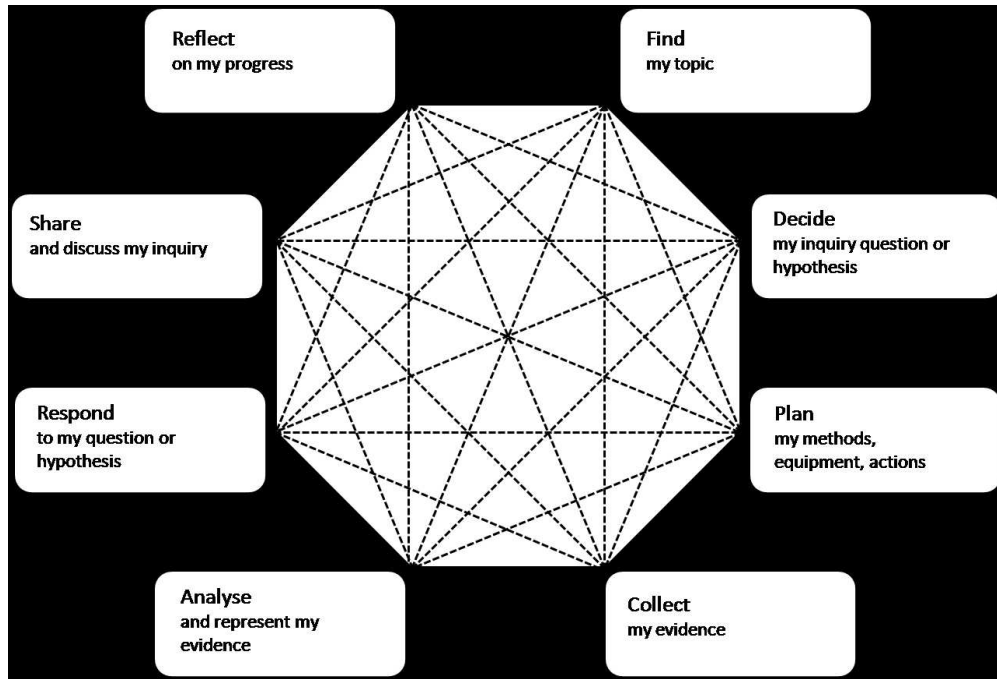
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Appendix: Outline lesson plans for the Healthy Eating inquiry

Lesson	Domain objectives	Inquiry objectives	homework
1: My Topic My Inquiry Question	Make predictions about the food that they eat.	Understand the inquiry process as a whole. Reflect on the inquiries of others.	To take photos of what they eat in general.
2: My Plans My Data Collection	Decide what questions to ask a food scientist.	Choose an appropriate scientific method for the personal inquiry. Use technology to gather data through observations	Take photos of what they eat and show portions.
3: My Data Collection	Consider the answers from the expert and ask any further appropriate questions.	Reflect on data collected by their group. Understand that scientists evaluate their data to decide if it is relevant and valid. Understand that scientists keep records of their own work.	Take photos of what they eat and upload photos to the Toolkit.
4: Analyse My Data	Understand how to compare actual nutrients eaten with the RNI for each, in a bar chart.	Make valid inferences from the data collected: personally and for the class	Take photos of what they eat and upload them to the Toolkit.
5: Analyse My Data	Recognise healthy and less healthy diets from nutritional information in the bar chart.	Use a model to form their own conclusions. Understand that scientists use all valid gathered information to inform their answers.	Take more photos, upload them to the Toolkit and generate more graphs.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	6: My Conclusions	Identify healthy and unhealthy diets.	Understand their inquiry and decide on an appropriate style and structure to present to their peers.	
	7: My Presentation	Prepare group presentations to express their findings.	Display their findings through a succinct presentation. Suggest further work on their inquiries.	Prepare presentations.
	8: My Presentation	Present their findings in the classroom.	Critically assess presentations of others. Respond appropriately as an audience.	
	9: My Evaluation	Improve the group presentations by incorporating critical evaluation.	Understand the inquiry process and suggest improvements to written instructions. Reflect on the inquiries of others.	

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A visual framework to illustrate and guide personal inquiry learning.
217x146mm (150 x 150 DPI)

Review Only

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Healthy Eating

My progress: 1 → 2 → 3

Version ID: BETA2 mef (GIT 136a398542b65346603711229c6e452376ae214f)
 Amelia Student
[logout](#)

Healthy Eating

An investigation of healthy diet and nutrients.

Navigation

- ▶ Find my topic ★
- ▶ Decide my inquiry question or hypothesis ★
- ▶ Plan my methods, equipment & actions ★
- ▶ Collect my evidence
 - My data ↗
- ▶ Analyse and represent my evidence
- ▶ Respond to my question or hypothesis
- ▶ Share and discuss my inquiry
- ▶ Reflect on my progress

My inquiries > Healthy Eating > Collect my evidence > Food diary for 20.09.2010 (Breakfast) >

Food diary for 20.09.2010 (Breakfast)

[View](#) [Edit](#)

Submitted by Amelia Student on Mon, 09/20/2010 - 22:34

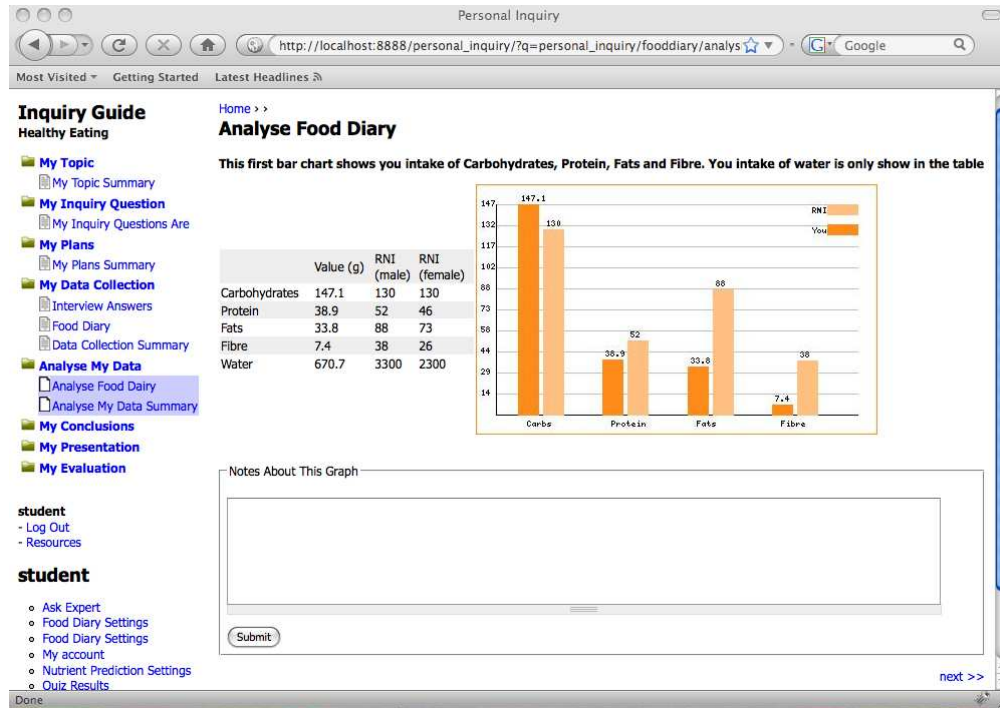
Breakfast	
Food	Portion Size
Bread - Brown	3 slice(s)
Meat - Red	1 portion
Pulses (peas,beans,lentils)	1 portion
Egg	2 portion

Dinner	
Food	Portion Size
Bread - Brown	5 slice(s)
Meat - Red	1 portion
Pulses (peas,beans,lentils)	1 portion
Egg	2 portion
Meat - White	1 portion
Vegetables	1 portion

Snack	
Food	Portion Size
Yogurt	1 portion

Figure 2: A screenshot from the nQuire toolkit

Review Only



Screenshot with a bar chart comparing the user's daily food intake with the RNI.
352x248mm (72 x 72 DPI)

	Intervention (n=14)		Control (n=13)	
	Median	Inter-quartile range	Median	Inter-quartile range
Pre-test	46%	25	50%	38
Post-test	67%	21	50%	13

Table 1: Percentage Scores by Condition and Time (Median and Inter-Quartile Range)

For Peer Review Only

		Intervention(n=21)	Control (n=15)
Attitudes to scientific inquiry/50	Pre	32.23 (3.04)	30.95 (3.87)
	Post	32.28 (2.44)	31.68 (2.39)
Adoption of scientific attitudes/50	Pre	28.98 (2.12)	29.40 (4.37)
	Post	29.88 (2.14)	28.89 (2.99)
Leisure interest in science/50	Pre	29.19 (4.30)	27.47 (5.79)
	Post	29.47 (3.53)	29.52 (5.62)
Enjoyment of science lessons/50	Pre	25.62 (3.65)	27.24 (3.71)
	Post	26.23 (2.70)	24.63 (2.89)

Table 2: Means (and standard deviations) for the Test of Science Related Attitudes by condition and time