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Creating personal meaning through technology-supported science inquiry learning across formal and informal settings

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Abstract

In this paper, a novel approach to engaging students in personal inquiry learning is described, whereby they carry out scientific investigations that are personally meaningful and relevant to their everyday lives. The learners are supported by software that guides the inquiry process, extending from the classroom into the school grounds, home, or outdoors. We report on a case study of personal inquiry learning with 28 high school students on the topic of healthy eating. An analysis of how the personal inquiry was enacted in the classroom and at home, based on issues identified from a study of interviews with the students and their teacher is provided. The outcomes showed that learners were alerted to challenges associated with fieldwork and how they responded to the uncertainty and challenge of an open investigation. The study, moreover, raised an unexpected difficulty for researchers of finding the 'sweet spot' between scientifically objective but unengaging inquiry topics, and ones that are personally meaningful but potentially embarrassing. Implications for further research are shaped around ways of overcoming this difficulty.

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 to revise their understanding of the content and pedagogy of inquiry. As collaboration between teacher and students enhances inquiry, greater levels of involvement are required by teachers than in traditional settings (Crawford, 2000).

Learning science by inquiry can help students to learn how to think like scientists (Edelson, Gordin & Pea, 1999), do real science (de Jong, 2006; Hodson, 1998), and engage in scientific discourse (Grandy & Duschl, 2007). By carrying out authentic science investigations students can also come to understand the natural world as an arena of investigation, where they have agency in deciding what, where and how to study. They learn the benefits and limitations of scientific practice, such as the need for rigour in collecting data, the importance of systematic analysis and the problems of drawing conclusions from incomplete data. Active participation in science should also enable them to gain a greater understanding of the practice of scientists and to take part in discussions about scientific phenomena that affect, for instance, their health and environment.

However, the ideals of inquiry learning confront the realities of school education. (Lakkala, Lallimo & Hakkarainen, 2005). School science must be framed by the curriculum and constrained by practicalities of timetabling and access to equipment. Only a limited range of science investigations can be conducted in a school classroom. A need for equity means that students cannot be required to carry out experiments in the home that require family resources or outdoor space. The school grounds could be a suitable environment to study natural and physical phenomena, but a restricted school timetable combined with concerns for safety may result in a lesson that is rushed and regimented, far distant from Dewey's advocacy of learning based on authentic science practice (Dewey, 1910).

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

– design appropriate experiments (e.g. what variables to choose, how many variables to change, how to state and test hypotheses),

– implement experiments (e.g. make predictions, avoid being fixated with achieving particular results rather than testing hypotheses),

– interpret and present results (e.g. compare and visualize data, then present these appropriately).

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

Underpinning these ambitions is the more fundamental challenge to assist students in coming to see science as personally meaningful and relevant to their everyday lives. Young students may live as scientists, exploring and challenging their world, yet school science is episodic and largely disconnected from the daily life of the learner (Thier, 1987). Such a challenge is therefore one of making inquiry learning 'personal'.

Personal Inquiry Learning

In the United Kingdom the concept of personalized learning has become politicized following a speech in 2004 by the then Schools Minister David Milliband (DSCF, 2009) in which he called for an education system that 'identifies the true potential of every child and then gives them the means to achieve it'. This would be achieved through personalized learning that ensures every pupil achieves the highest standard possible. Some elements of the UK personalization agenda include developing teaching and learning strategies that build on individual needs, and developing a curriculum that engages and respects students.

While we recognize the need to engage and nurture the talents of every student, we do not take an instrumental and systemic approach to personalization. Instead, following Hodson (1998) we have pursued an approach of 'personal inquiry learning' based on enabling students to gain personal meaning from science activity within a rich and familiar environment. Traditional science teaching is typically characterized by an 'elimination of the personal' (Donnelly, 2002). Yet, we suggest that students will both engage with and take a committed stance towards the scientific process by forming questions for which they genuinely want to know the answer, by carrying out investigations that relate to their own needs and concerns, and by discussing emerging findings with peers and experts.

A central aspect of personal inquiry learning is taking *ownership* of the inquiry process. A prerequisite is that students should gain a clear *understanding of such a process* and of their *agency* in gaining scientific knowledge. They should come to know what kind of questions are scientifically appropriate, how these can be framed as valid inquiries, who they can find and trust as scientific informants, what kind of studies are appropriate, why it is important to collect reliable data, how this can be analyzed and presented as valid evidence, and how the results of an inquiry can be shared and discussed. An important issue for research concerns how the domain of such inquiry is effectively defined as 'personal' and, thereby, how a sense of problem ownership is created. Existing approaches of this sort have tended to identify macro-social topics, such as ecology and environment (e.g., Walker & Zeidler, 2007). The approach taken here is more micro-social – drawing upon topics that are prominent in the learner's own 'local' world.

In this paper we address the twin issues of how to support inquiry-based science learning within the school system and how to enable students to gain personal meaning from engaging in science investigations. We describe a case study where an investigation of healthy eating was undertaken by Year 9 students (aged 14) as part of the English National Science Curriculum. During the intervention, the students began a science investigation in the classroom supported by a teacher, they continued it at home, and then discussed and presented the results of the inquiry back in the classroom.

Representing the inquiry process

From a study of frameworks for representing the science inquiry process (Bruce & Bishop, 2002; Shimoda, White & Frederiksen, 2002) we have produced a representation of personal inquiry that serves both as a visual map for learners and a structure to guide the investigation process (Scanlon, Anastopoulou, Kerawalla, & Mulholland, under review). It shows a cycle of questioning, investigation, evidence collection, analysis, sharing and reflection, but without prescribing a particular scientific method (Figure 1). This is not to indicate that all methods are equally appropriate, but that the framework can be adapted to suit different methods of inquiry, including hypothesis-led experimentation, observation of natural phenomena, desk-based examination of literature, and discussion with expert scientists. The hatched lines are intended to show an interconnection, with each phase building upon previous work and informing future action.

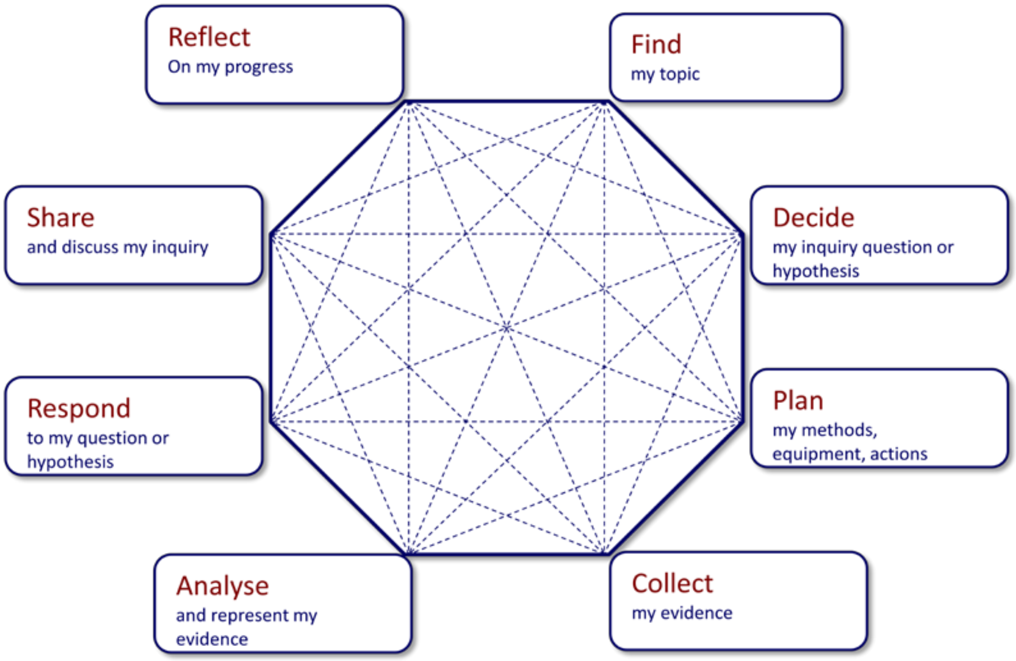

Figure 1: A visual framework to illustrate and guide personal inquiry learning.

Technology Mediation for Personal Inquiry

Through a process of co-design of technology and pedagogy, a computer-based toolkit, called nQuire, has been designed that guides the inquiry process inside and outside the classroom. The design of nQuire follows an approach of 'scripted' support for learning (Dillenbourg, 2002; O'Donnell & Dansereau, 1992) where scripts are dynamic lesson plans that guide how students should interact and collaborate in following an inquiry. The scripts support students through a sequence of activities including planning, investigation, debate, data collection and presentation. nQuire is implemented using an open source platform to enable wide access to the toolkit and is accessed through a web browser running on desktop and portable devices.

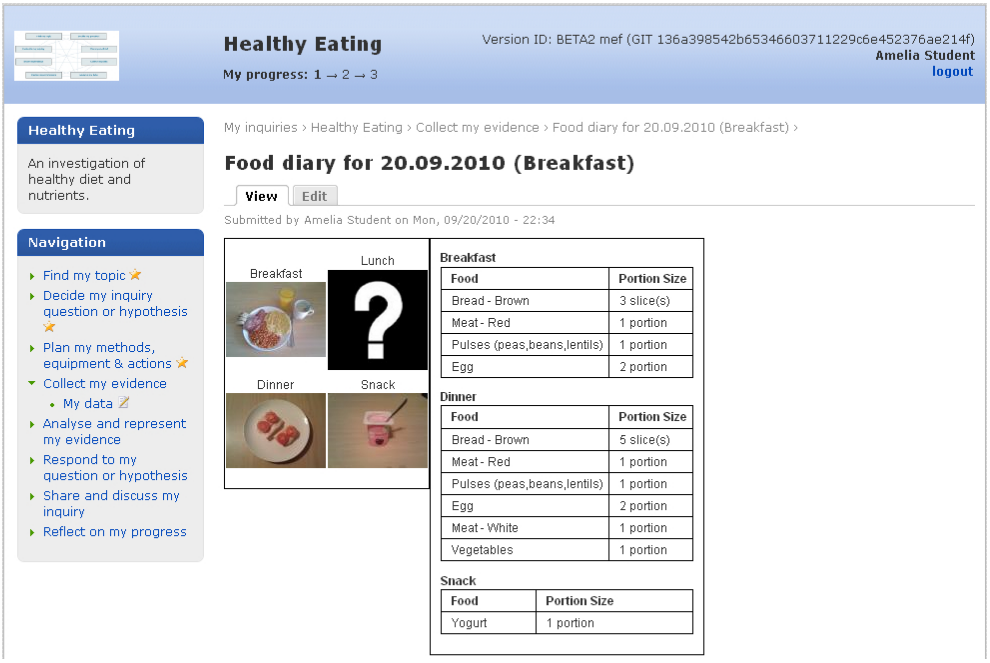

Figure 2: Screenshot of the Personal Inquiry Toolkit

The role of nQuire differs depending on the context in which it is used. Within the classroom, it assists the teacher to elicit suggestions for topics and inquiry questions, and the students to share, analyze and present findings. Outside the classroom, it guides each student through phases of the inquiry process, showing what activities are available and providing tools for the collection and visualization of data. It does not prescribe a fixed sequence of activities, but shows the resources and dependencies for each phase. For example, to collect evidence requires having an inquiry question and a plan and, depending on the topic, nQuire will offer a set of appropriate tools to collect and visualize data. The available options change in response to the student's actions.

The computer can be attached to probes to collect data and the information from each laptop can be synchronized with a central server when in school. A teacher has additional software tools to design an inquiry investigation or to adapt one from a pre-prepared template, for example to include local environmental settings or provide initial data. Figure 2 shows a screenshot of the current implementation of nQuire. On the left, the screen shows phases of the personal inquiry. Along the top, below the title of the investigation, the sequence of lessons is shown. In the centre is the current activity, in this illustration an example food diary entry.

Personal inquiry of healthy eating

We describe an application of this educational-technology system at one stage in its continuing development, to support personal inquiry learning on the topic of ‘healthy eating’. The educational context was for the students to explore whether they ate a healthy diet, specifically to address the inquiry questions: ‘What nutrients do I eat?’ and ‘Do I eat enough nutrients to be healthy?’. These questions had been developed collaboratively by the research team, the teacher and a food scientist. They collectively identified healthy eating as a topic of personal interest to Year 9 students, although given the time of year of the intervention and the time needed to implement the software, the students themselves were not involved in defining the topic. To address the questions the students were encouraged and supported to: understand the science of food and nutrition; collect accurate data on their own eating patterns; analyze their diets in terms of key nutrients to understand whether they were eating healthily; then present the results of their findings to their classmates.

The healthy eating inquiry was designed to achieve educational objectives whilst also enabling the research team to explore the value and practice of technology-mediated personal inquiry. First, the study allowed students to participate in multiple phases of an inquiry project, where each phase had a clear goal leading to a sequence of activities. Second, we wished to explore how learning could be maintained between home and school, by developing learning activities that could be initiated in the classroom and then continued at home. These had to be relevant to the students and their families and to demonstrate a clear scientific rationale and practice. Third, the study aimed to give students responsibility for their scientific investigation. They contributed to the methods used to investigate the question, proposed questions to ask an expert food scientist and were responsible for collecting and recording data. The latter activity was expected to be particularly challenging as students would need to keep complete and accurate data for any inferences to be meaningful.

Investigations outside the classroom concerning healthy eating can be supported by a written diary but this research aimed to embed the investigation into an overall inquiry cycle, employing computer technology to structure and to support planning, collection of data, sharing and presenting results. Students took photos of their food and the computer toolkit was designed to enable students to label the food content for each meal and retrieve relevant nutritional information, to link the images of the meals to the data, to view charts comparing specific meals with recommended nutrient intake, to merge and share data with peers and to present the digital information in class.

There is good evidence that inquiry approaches to science can be effective for learning (Marx, et al., 2004), even if they present organizational challenges for teachers (Lakkala et al., 2005). Here, we are seeking to describe inquiry learning that is grounded in the personal and, more specifically, is mediated by tools designed to support effective organization of the activities involved. Accordingly, this research addressed the following questions:

1. How does personal inquiry support scientific reasoning, understanding, attitudes and communication?

2. How do students respond to inquiries that are grounded in the personal?

3. What issues arise from students taking personal ownership of the technology and the inquiry?

Method

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

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, Students 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 students (16 girls and 13 boys) from the same year group in school took the same tests at equivalent points in the school year. These students 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 students 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.

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. Students 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 student 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, students 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.

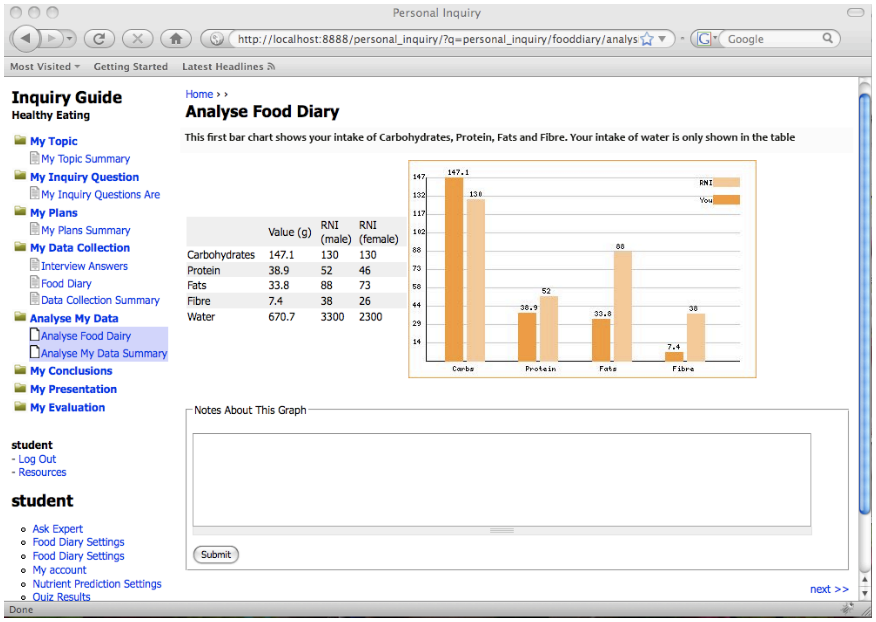

Figure 3. Screenshot with a bar chart comparing the user's daily food intake with the RNI.

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

Methods of analysis

The outcomes and processes of the sequence of nine lessons were assessed by multiple methods.

Outcome Analysis

A domain knowledge questionnaire was based on the Key Stage 3, Year 9 (Age 14) UK curriculum and assessed what nutrients are needed for healthy eating and in which foods they can be found. It consisted of twelve multiple choice items with one correct answer and three distractors (e.g. ‘Jane has a healthy diet except she is not having enough calcium. Which of these foods does she need? Pasta; Cheese; Fish; Oranges’). The purpose of this was to establish whether students are still able to gain domain specific knowledge while undertaking in inquiry-based activity. Attitudes towards science were assessed with the Test of Science Related Attitudes (TOSRA) (Fraser, 1981), where students respond on a five point Likert scale. Four of the most relevant scales were selected in advance of the study: Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, and Leisure Interest in Science.

Process Analysis

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

The processes of personal inquiry learning and the subjective experiences of the participants were investigated through interviews with the students and their class teacher and by videotaped observations of classroom interactions. Informal interviews with the teacher were conducted after lessons 1, 3, 4, 5, 6, 7, 8, and 9 to elicit her reflection on the lesson, its successes and problems, and the extent to which it had met her expectations. Additional interviews were held after lessons 5 and 6 to reflect on how the inquiry process met her expectations and her willingness to take this approach for the remainder 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).

	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)

21 students in the intervention and 15 students in the control class took both attitude tests. A mean substitution following missing value analysis was performed for 0.01% of the data.

		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

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

Process Analysis

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

Three researchers studied transcripts of all the interviews to identify references to issues that could provide insight into the three issues addressed below. They also analyzed the computer logfiles for patterns of interaction with the computer and for text references to the issues (based on problems students recorded with their data collection). These sources of evidence were integrated into the commentary below. Interviews are indicated by a letter and number, so, for example, T1 indicates the interview with the Teacher after Lesson 1, TA5 refers to the additional interview with the Teacher after lesson 5, and B3 indicates the interview with boys after Lesson 3. Analysis of teacher and student accounts is reported here in terms of the research questions. Respectively, these are concerned with issues of scientific reasoning and communication, inquiries that are grounded in the personal, and personal ownership of the teaching of inquiry.

Issue 1: Scientific reasoning and communication

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

[B9] R: *Were they, eventually were they easy or difficult to use, to do? To actually use them?*

S1: It was easy.

R: *The diary?*

S1: Yes, it was easy.

S2: It was easy but not that accurate really.

R: *Why do you think that is?*

S2: Because you're not going to take a picture of everything you take and find out what you eat every day, because you're not going to have your camera on you all the time.

Some also recognized that failure to record all the data would result in under-recording of the nutrients, giving a false impression of their daily intake.

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

R: *They weren't?*

S1: No

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

S3: I got mine wrong as well.

S2: But saying that, if you missed one thing it makes the whole thing irrelevant really.

S3: Inaccurate.

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

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

R: *Yes*.

S2: Because you could write down, but if it's easier to take pictures.

S3: Yes, but if you had to like do pictures that wouldn't work, because people would lie.

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

S3: But I did. At MacDonald's I did.

A notable feature of the toolkit design concerned the opportunities for coordinating with others around data, as would be commonplace in an authentic scientific investigation.

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

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

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

[B9] R: *Did you enjoy the presenting part, where it's actually standing in front of the class?*

S: Yes, because it's like it's not just keeping your photos to yourself, it's spreading it round everybody else to see what they think about it and compare it to other people's.

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

These challenges of data capture and coordination also involve a pressure to systematise the data in ways that support interpretation and dissemination. In the context of the present study, this was expressed as a challenge of coding and categorising the participant reports of their diet. Here there emerged a productively critical consideration of the difficulties of coding.

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

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

S1: Not really. There should have been more options.

S2: More detailed options.

S1: You could have chips, you could have crisps, you could have jacket potato, so it should have been clearer.

R: *Right, OK. Do you think this affected the results?*

S2: Yes. I don't think the results were that accurate.

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

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

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

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

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

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

It should be emphasized that the products of this empirical effort were recognized as useful and provocative. To produce data that represented accurately their daily nutrient intake, the students were required to carry out a sequence of actions that comprised taking a photograph of each meal, selecting the components of the meal and number of portions (e.g. 'white bread, 2 slices') from a pull-down menu, then for each day comparing the nutrients calculated by the computer with the RNI. Some students found this comparison revealing.

[G9] S1: …the RNI thing, that was interesting because it showed you how much you eat and then how much you're supposed to eat.

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

S1: … what to eat more of ...

S1: I need more vitamins.

S2: Basically I wasn't eating enough.

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

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

The teacher also described the sequence of activities as productive, though she suggested the need for more discussion and for the students to produce written summaries:

[T9]: T: I think in the data collection, the analysis and the presentation I think [met] my expectations, yes, they over-ran from what I expected, but I think that was a really good way of doing that and I think that worked. So I think it's more, […] about what is the point of some of the tasks and do we actually need a written answer for that? [...].more of a discussion and more of maybe them writing a summary of the topic or what they're looking to research or what we've decided on.

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 reiterated that they would not be identified in class by their photos, then all the students contributed some photographs, as shown by the computer logfiles.

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

[B5] S: ... I got worried about what other people would think, so I deleted two of the pictures, But then when Miss said that, I was like ‘Oh, you could have told me that like yesterday.’

R: *When I said what?*

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

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

S: Yes.

The teacher gave a positive assessment to of the students’ learning outcomes, particularly with regard to understanding the inquiry process:

[T9] T: Yes. I think they’ve certainly got a better understanding of how healthy their diet was and how important it is that, what crisps and fizzy drink are doing to you. And I think […] they’ve got a far better understanding of the inquiry process because we very rarely would do the whole thing in school and they’ve got no idea really how properly it 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 students 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 things that we enjoy like on a laptop, which all kids are going to love anyway and, to be honest, working out of textbooks is boring. So if we're working on laptops, because it's more enjoyable it's easier to take it.

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

> [G9] S: Well, to start it was alright.
>
> R: *To start?*
>
> S: But then it kept on getting annoying because you had to carry something everywhere in your bag.

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

> [B8] I only took a couple because my brother deleted them.

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

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

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

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

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

S1: Went straight on the science.

R: *How did your family…?*

S2: Yes, they went straight on it.

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

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

Other family members provided a generalised encouragement to value the opportunity.

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

Not all family input was constructive. One student recounted a comment on the group work.

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

S2: Yes, so did my Mum. She said 'Well, it's a bit annoying.' She said 'There's no point doing it if everyone else is going to do it.

Discussion

The primary aim of the study was to investigate whether students aged 14 can be helped to understand and engage with the scientific process by carrying out investigations between school and home that relate to their personal needs and concerns. Although the students did not choose the inquiry questions ('What nutrients do I eat?' and 'Do I eat enough nutrients to be healthy?') they were framed to be relevant to their everyday lives and to relate to a concern of many teenagers with food and health. Evidence from the interviews suggests that the students were interested in the topic and genuinely curious to find the answers. Moreover, the learning activity was substantially different to normal classroom lessons and while this posed problems for the teacher of classroom management and coordination across lessons, it did allow the students to experience the uncertainty and challenge of an open investigation. The activity extended across nine lessons, so at the start the students were uncertain as to their agency in carrying out the investigation and how the work would progress and finish.

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

The results for the attitude scores, however, show no change. Students completed four subscales of the TOSRA (Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, and Leisure Interest in Science) before and after the study. The mean scores from the intervention students were unchanged on all scales. Those for the control group also remained unchanged, except for the ‘Enjoyment of Science Lessons’ subscale, which decreased. Longitudinal studies of attitudes to science lessons often report a decrease both over the school year and across the middle and high school period (e.g. George, 2006). Given that students in the intervention group had participated in a research study, receiving extra attention and loan of computer equipment, it is not surprising they expressed more enjoyment of science lessons that the non intervention group. Moreover, it is disappointing that the attitudes to science did not alter from pre to post test. This acts as a timely reminder that students’ attitudes to science can be resistant to change and that research teams should not be over optimistic in their predictions for the likely impact of short term interventions.

Meanwhile, it is evident from the process analysis that students became more aware of the different methods of data capture, difficulties inherent in data capture outside the classroom, as well as challenges surrounding collaboration and sharing of data. A further finding is that although owning the technology for a period of time allowed students to be engaged in learning between lessons, as time progressed some students expressed discomfort with the routine, particularly in finding it awkward to carry the laptop between home and school. Some also experienced difficulties at home, such as requests to be protective, appropriation of the technology by family members, and in a few cases discouragement from taking part in the study. These all point to challenges in adopting personal technology to maintain a continuity of learning between school and home. It also raises questions of how to exploit affective issues as opportunities, for example to discuss ethical issues of the scientific community, such as confidentiality and ownership of the research.

The research team and teacher recognized in advance that for the data analysis lessons (lessons 3-5) to proceed, the students had to collect valid data in the form of photographs of food, correctly labelled with nutritional content. Thus, the students were asked to take photographs from lesson one, with each subsequent lesson requiring more accurate data collection. The students did come to realize for themselves the scientific truism that analysis of data needs data to analyze.

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

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

The problem was addressed in this study by the expedient of emphasizing to the students that they would not be identified as authors of their photographs when they were presented in class, and by the teacher requiring them to take photographs as data for analysis in class. Although this had the desired effect of eliciting notated photographs from every student, it did not entirely resolve the issue of embarrassing self-disclosure. The students worked in groups to share and present their data, so they had to show their photos and daily nutritional charts to others in their group. This might have been avoided by each student working alone, but the group discussions were an import element in modelling the scientific process of sharing and cross-checking data. It might be possible for the students to work in groups with anonymised data from their peers, but that would require an additional layer of technical complexity and classroom management.

This raises a more general tension in inquiry science learning. To participate in the great scientific debates of contemporary society, students need to gain empathy with the scientific process, to think and act like scientists, to gain a direct appreciation of the challenges and delights of exploring the material world. The lure is through personalized inquiry, where each student devises an inquiry question of personal relevance, or the inquiry topic resonates with students' everyday concerns (Hodson, 1998; Edelson, et al., 1999). But to be a scientist requires detachment from the scientific process, to collect data in a rigorous manner and subject it to objective scrutiny. Is it possible to find the 'sweet spot' between objective but unengaging, and meaningful but potentially embarrassing, personalised inquiry learning?

One way forward is to devise individual inquiry questions that students want to answer, but do not require such a large amount of self-disclosure. Another possibility is to collect personal data, then ensure that it is anonymised before being shared and analyzed, with the students fully informed that they will not be associated with their data. Both approaches require more complex technology and classroom management. The first would need the computer and the teacher to accommodate a range of inquiry methods and probes. The second would need a process of separating the collectors from their data. Both are opportunities to be explored in future research. However, our preferred solution is for the students, through discussion amongst themselves and with the teacher, to propose an inquiry topic over which they have sense of ownership and collective interest. This is the approach taken for our subsequent study.

Conclusion

We have reported a case study of personal science inquiry learning with technology dwelling on the participants' own accounts of the experience as they reveal a number of specific ways in which personal inquiry works to configure a more realistic experience of science. Our findings have shown that students can be alerted to a number of challenges associated with fieldwork: the management of data, the demands of collaboration, the ambiguities of measurement, and the need for management of activities. This did not threaten their enjoyment of the lesson nor did it negatively impact on their understanding of topic, although it is disappointing that the students' responses to the science attitude scales did not reveal any enhanced interest in science. The findings also reveal practical challenges that will be important to consider in moving this approach to science learning forward. The toolkit was successfully accommodated within a traditional science classroom and moved inquiry into the personal space of the home. However, its arrival there, at least at first, can provoke a variety of responses in relation to domestication. These need to be anticipated, although we believe they are easily managed and capable of being directed towards constructive forms of support. More deeply rooted challenges lie in the management of the 'too personal' dimension of personal inquiry learning. It may remain for the teacher (negotiating with students) to find the 'sweet spot' that takes advantage of the engagement arising from meaningful investigation while not serving as an identity threat to the participating learners.

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

A challenging aspect of this study was that it took place within a school with significant attendance issues as well problems in engaging its students in science and in out of school work. This was positive in that we were working with a population that does not normally participate in trials of new technology and pedagogy. However, it did offer significant problems for the research (e.g. decreased sample size, high mortality rate) and for the pedagogy (e.g. pupils missing crucial lessons, forgetting equipment at home, and complaints about carrying equipment back and forth). Furthermore, it was not possible to work with an equivalent class of students who were following the same curriculum but without the Personal Inquiry approach. This limited any comparative claims we can make from this study. It offered, however, a rich environment to extract fruitful evidence of school inquiry-based science with a personal perspective.

This study aimed to explore how a personal inquiry can become integrated into school science. It highlighted how the ideals of inquiry learning confront the realities of school education and it articulated challenges emerging from taking new technology and new pedagogical activities from a research environment to integrating them into classrooms and homes. It does not offer a solution however for scaling up; it is rather the first step towards making such innovation routine. Given the rapid development of hand-held technology, activities like recording, photographing, interpreting graphs may become commonplace, but there still needs to be a way of amalgamating these components. The nQuire toolkit offers such functionality through an authoring tool that teachers can use to modify or design new inquiries that fit their needs. It is yet to be explored how such interventions can be sustainable so that teachers and students are empowered to create personal meaning through science inquiry.

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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.
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.