IScience: A computer-supported collaborative inquiry learning project for science students in secondary and tertiary science education

Kate Anderson[a] and Shannon Kennedy-Clark[b]

Corresponding author: k.anderson@usyd.edu.au
[a]Faculty of Education and Social Work, University of Sydney, Sydney, NSW, 2006, Australia
[b]Division of Education, Australian Film Television and Radio School, Sydney, NSW, 2021, Australia

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Abstract

Pre-service teachers come to teacher education programs with a range of experiences and understandings about inquiry in Science. The IScience project aims to assist pre-service teachers to develop an understanding of the issues and skills required to guide students through an open-inquiry process. In addition, the project provides opportunities for pre-service teachers at the beginning of their teacher training to develop their skills in mentoring high school science students in an open-ended inquiry process. In this study, wikis were used to support the interactions among the pre-service teachers and school students, who were from geographically diverse locations to collaborate on the open-inquiry project. A mixed-method approach to the data collection was used. Data sources included surveys, reflective journals, and pre-and post-tests. The impact of the project on the pre-service teachers' understanding of how to teach science by inquiry is discussed in this paper. The results of the study indicate the pre-service teachers felt more confident in their understandings of scientific inquiry and their ability to teach inquiry.

Introduction

The purpose of this paper is to provide an outline of the impact of the 2011 IScience project on pre-service science teachers' understandings of inquiry in science and the use of information and communication technologies (ICTs) in education. The IScience program is designed to enable pre-service teachers and high school students to participate in an authentic open-inquiry project. IScience is a project that supports pre-service teachers and high school students in coming to a common understanding of what inquiry in science can look like. In the IScience program, pre-service teachers take on the role of mentor to the high school students. Through a process of collaboration, the groups develop a hypothesis, a research plan, conduct an investigation and reflect upon and assess their process and findings. The IScience project culminates with a Science Fair, wherein all participants come together to communicate their findings. The benefits of this integrated approach are numerous for both the pre-service teachers and the high school students. For the pre-service teachers, benefits include an increased confidence in their teaching, a deepened understanding of inquiry, and the development of both the theory and practice of using a range of ICTs in education. For the high school students benefits included development of their scientific inquiry skills, working with students from diverse backgrounds and organising their ideas to present clearly

to a panel of judges. On the basis of the 2011 results, changes will be made to the 2012 project.

In the 2011 IScience project, pre-service science teachers worked with gifted and talented students in the design, development and undertaking of an open-inquiry project that spanned five months. There were four main aims of the project which involved both pre-service teachers and high school students: 1) to help students and teachers to come to a common understanding of inquiry; 2) to build new and innovative ideas; 3) to gain technological proficiency in collaborative online software and building communication; and 4) to develop collaboration and reflection skills. This paper reports on the findings of the 2011 project. The paper presents a background of inquiry learning and an overview of the IScience project. The results and a discussion of the results are presented. The paper concludes with future directions of the project.

Background

Central to the entire discipline of Science is the concept of inquiry and inquiry-based approaches to teaching and learning feature significantly in the Australian Curriculum-Science (ACARA, 2011). The advantages of using the inquiry process as a pedagogical tool in science teaching in improving student understanding and engagement in science have been widely discussed (Blanchard, Southerland, Osborne, Sampson, Annetta, & Granger, 2010). An inquiry is an exploration of the unknown where students develop their own questions and plan their own experiments, analyse their data and evaluate their findings. As part of the new curriculum, teachers will be expected to implement aspects of inquiry learning from stages 4 to 6 (Years 7 to 12) of the high-school syllabus. Pre-service teachers graduating from university are expected to be familiar with the new curriculum and to be able to teach inquiry. The new science curriculum also states that pre-service teachers need to be able to use ICT to teach inquiry-based learning.

Recent reforms in science education around the world have focused on creating curricula that are heavily biased towards inquiry teaching methodologies (Bhattacharrya, Volk, & Lumpe, (2009). Melville Fazio, Bartley, and Jones (2008) discuss the issues that surround this shift in focus towards more student-centred inquiry based pedagogies on science teacher education programs. The issue here is that inquiry is not often taught appropriately. Inquiry is often taught in schools as a series of steps, or a procedure, that lead to a known answer (Siorenta & Jimoyiannis, 2008; Windschitl, 2001).

Moreover, there is a link between the experience that pre-service teachers have had with inquiry and their ability to confidently use inquiry based methodologies with students (Fazio, Melville, & Barlley, 2010). Experienced teachers find implementing some aspects of inquiry based teaching difficult so it follows that pre-service teachers who have no previous experience of inquiry are unlikely to be confident in effectively integrating this strategy into their teaching repertoires (Lustick, 2009). Lustick (2009) also suggests that talking about inquiry in pre-service teacher training courses is not enough to give them a good understanding of what inquiry actually is. Pre-service teachers need to experience inquiry first hand to develop a sound comprehension of the skills and knowledge needed to teach content through inquiry. In the following section, definitions of inquiry are discussed.

Definitions and characteristics of inquiry learning in science education

There has been much discussion about what inquiry learning is and how to teach inquiry. A number of definitions that encompass characteristics of inquiry have been put forward and these definitions are complementary in that they explain or develop existing definitions. Working from a top down perspective, in this section a broad definition of inquiry is provided, this is then broken down into the way in which inquiry is represented in the classroom. The actual types of inquiry activities are further discussed.

The term 'inquiry', as it relates to science education, has been subject to much scrutiny in the extant literature. The definitions for inquiry include a generic subset of activities that can be conducted in a classroom. For example, Linn, Clark, and Slotta (2003, p. 518) define inquiry as:

> engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, revising views, researching conjectures, searching for information, constructing models, debating with peers, communicating to diverse audiences, and forming coherent arguments.

Inquiry learning can be represented by ill-defined and open-ended problems and is driven by a learner's questions and investigation skills (Edelson, Gordin, & Pea, 1999), and as Veermans, Lallimo, & Hakkarainen (2005) explain, inquiry learning requires more self-regulation than normal classroom learning. At this level of characterisation, the features of an inquiry encompass activities such as developing a hypothesis, developing a plan, conducting an investigation, and analysing and reflecting upon the results.

Within the science classroom, inquiry takes on further complexity as it is linked with the scientific method and the Nature of Science (NoS). Anderson (2002) has categorised inquiry in science education into three specific groups: Scientific Inquiry, Inquiry Learning and Inquiry Teaching. The practice of 'Scientific Inquiry' refers to, primarily the way in which scientists carry out the scientific method. This includes posing a question, developing an investigation around the question, analysing data to provide help explain the results of the investigation and using the results to answer the original question or pose new questions. It embraces the diverse ways in which scientists attempt to pose questions and find answers about various phenomena (NSTA, 2011). This type of inquiry is linked to teachers understanding of the NoS and the way in which scientists study and work.

The second way in which the term 'inquiry' can be categorised is in regards to 'Inquiry Learning'. This terminology can be linked to a constructivist view of learners building on their previous knowledge and constructing new knowledge by being actively engaged in the learning process (Anderson, 2002). Students are able to pose questions themselves and seek the answers to these questions without being given solutions by a third party. Much of the research done into how students learn and how the brain functions supports this type of learning as the way in which deep understanding is obtained (Bransford, Brown, Cocking, & Donovan, 2000).

'Inquiry teaching' refers to the way in which teachers assist students to engage in the inquiry learning process. It involves the skills and methods that teachers choose to use when teaching students about areas of scientific content in an inquiry based learning approach. It requires the teacher to provide experiences that engage and inspire students to pose questions about

particular events and then facilitate the process of students finding the answers to their questions based on collected evidence.

Inquiry teaching can be further classified in terms of the activity types. Windschitl (2000) defines these inquiry activities by the degree of independence students have in asking and answering questions. A low level inquiry would be defined as confirmation or verification activities. These experiences are often referred to as the 'recipe' or cookbook experiments where the teacher is responsible for the question, method and answers. Students verify known scientific principles by following a given procedure (Windschitl, 2000). The next level of inquiry, guided inquiry, is referred to as structured inquiry where the teacher presents a question and the students are given a procedure to find the answer. Guided inquiry requires the students to formulate a procedure to find answers to a question the teacher has posed. At the far end of the inquiry continuum are open-inquiry activities where the students develop their own research question and method of investigation. Guided and open-inquiry investigations are far more intellectually challenging for students than confirmation activities. They are also more challenging for teachers in terms of pedagogy and management (Windschitl, 2000). Facilitating the formulation of sound and verifiable student research questions is a highly skilled and meta-cognitively challenging process that is not simple for teachers.

Pre-service teacher training on inquiry and the nature of science

Explanations of the details about how to actually teach inquiry to students in the classroom are often diffuse and abstract. Moreover, explicit instruction on how to teach teachers and pre-service teachers how to teach inquiry, has not been dealt with in great detail within the field. The IScience project and associated inquiry activities within the pre-service teacher program aim to help pre-service teachers develop their understanding and confidence in teaching open-inquiry.

Many pre-service teachers have not experienced open-ended and investigative approaches to science teaching and learning at school or during their university studies (Cady & Rearden, 2007). This lack of experience with scientific inquiry impacts directly upon the development of pre-service teachers' beliefs about the NoS and their beliefs about teaching and learning science as a discipline (Lederman, Wade, & Bell, 1998; Ross, Skinner, & Fillippino, 2005). Teachers who hold beliefs about scientific inquiry as learning that encourages curiosity and independent thought and investigation are far more likely to adopt inquiry-based practices in their classrooms (Slack, 2007).

At the centre of scientific education is the understanding of the NoS is connected to an understanding of scientific inquiry (Lederman, 1998; Ross, Skinner & Fillippino, 2005). Scientific inquiry and NoS are integrally intertwined. Hence, pre-service teachers must have a good understanding of NoS and its relationship to scientific inquiry to be able to effectively translate this into classroom practices that include inquiry-based approaches (Slack, 2007).

A number of studies refer to the need for secondary education programs to provide experiences that allow students to reflect on the meaning of science, scientific knowledge and the philosophy of science, however, there are many challenges to this in practice. Da Silva et al. (2006) state that explicit teaching about the NoS is lacking in science teacher education programs. The lack of experience instructing about the NoS in teacher education programs and science degrees leads to vague understandings and lack of application of the NoS in classrooms. As scientific inquiry and the NoS are integrally intertwined, pre-service teachers

need to have a good understanding of NoS and inquiry to be able to effectively translate this into classroom practice (Slack, 2007).

Research conducted into the effect on pre-service teachers' understanding of the NoS and inquiry by providing authentic inquiry experiences for pre-service teachers in teacher education programs indicated that allowing pre-service teachers to participate in open inquiries does enable them to develop a richer understanding of the NoS (Akerson, Hansen & Cullen, 2007). A limitation of this study is that the link between the theory behind inquiry pedagogies and teachers' practice in the classroom is not made explicit. Pre-service teachers are left with a better understanding of the NoS and inquiry but not how to translate this into inquiry-based practices in the classroom.

Computer Supported Collaborative Learning and WEB 2.0 technologies and wikis

As part of the Australian Federal Government's Digital Education Revolution (DER) all pre-service teachers need to develop both understanding and competency in embedding ICT into the content areas by developing their Technological, Pedagogical and Content Knowledge (TPACK) (Department of Education, 2008). A government scoping study indicates that the most common forms of ICT currently used in classrooms are PowerPoint and basic Internet searches, such as WebQuests. These forms of ICT do not make best use of the learning potential of ICT (Education Services Australia, 2010). This study is underpinned by the development of education policies within Australia that stipulate that all pre-service science teachers, upon graduation, need to be able to use ICT to teach inquiry in the classroom. The 2011 IScience program aimed to develop appropriate technological, pedagogical and content knowledge to enable pre-service teachers to select, evaluate and use technologies to support inquiry learning in the classroom. Revisions were made to the structure and approach of the program, including the introduction of wikis, which was done in consideration of the enactment of Australian government policies pertaining to the embedding of ICT in science education.

As the groups involved in the IScience project were dispersed around the Sydney metropolitan region, investigations were undertaken by the research team into how best to support students and pre-service teachers working collaboratively in their inquiries. It was decided that using wikis supported on Wiki*spaces* (www.wikispaces.com), an open-source wiki platform, would provide the most stable and secure platform for the collaborations. A wiki (*what I know is*) is an expandable collection of interlinked web pages that are capable of having content added and edited (Ajjan & Hartshorne, 2008; Usluel & Mazman, 2009). The benefit of wikis in educational contexts is that students and staff can visit, read, add and edit content which means that as a cohort a group of students can collaboratively construct, share, recommend, evaluate and manage resources and materials for the group. As Greenhow, Robelia, and Hughes (2009, p. 247) explain that 'validity of knowledge in Web 2.0 environments is established through peer review in an engaged community, and expertise entails offering syntheses widely accepted by the community'. So rather than a teacher being responsible for providing students with information, the students are able to take control of their own learning experience in a participatory manner and that this can impact positively upon the validity of the knowledge shared. So far this paper has focused on the context for the project. The following section will discuss IScience in greater detail.

IScience

The IScience project was established in 2007 as part of the ASISTM (Australian School Innovation in Science, Technology and Mathematics Project) federal government grant

program to, first, provide high school students an opportunity to develop their inquiry skills and, second, to present pre-service teachers with a firsthand experience of leading a small group of students through an open-inquiry project. The project was designed to allow collaboration between high school students, teachers at four independent high schools in Sydney and science educators at the Faculty of Education and Social Work at the University of Sydney. A mixture of independent and co-educational private and public schools applied to be a part of the IScience program. Teachers from the schools chose students with an interest and or an aptitude for Science. In some schools, the program was used as an enrichment program for their gifted and talented science students.

The project commenced at the beginning of the pre-service teacher education programs for two cohorts; 1st year Master of Teaching (an 18 month graduate entry program) and 3rd year of the combined undergraduate Bachelor of Science/Bachelor of Education program. The pre-service teachers underwent three weeks of initial workshops where exemplars of different types of open-ended inquiry were demonstrated and teachers were shown how to facilitate high school students to generate researchable questions. At the start of their teacher education program the pre-service teachers were asked to reflect on the Inquiry Framework seen in Figure 1. This framework was developed by the chief investigators of the IScience project.

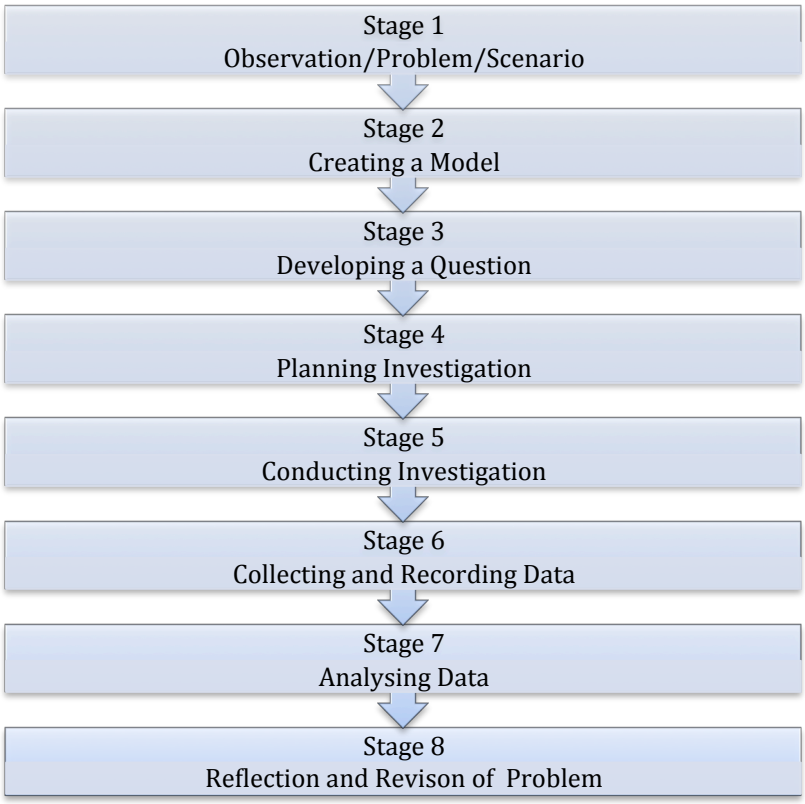

Figure 1: Inquiry Framework

This inquiry framework was used as the basis of the IScience project and the development of the pre-service teachers' understanding of inquiry in science education (Figure 2). The initial stages of the framework attempted to engage students by providing a context for problems that are related to their own experiences (Stage 1). Students made observations of phenomena using hands on demonstrations and other multimedia interactive learning objects that were

designed by the pre-service teachers. The activities revolved around one of the following specific areas; water, global warming, materials, energy, health or transport The students were then asked to choose one area that interested them the most. In Stage 2 of the framework the students were asked to identify their prior knowledge about the topic and develop a model of their understanding. This model may have been in written prose or in the form of a concept or mind map. From this model the pre-service teachers guided the students in the development of a researchable question (Stage 3). Stages 4, 5, 6 and 7 of the inquiry framework include the planning and carrying out of and investigation and the analysis of data collected during the experiment. The final activity within the framework required the students to review their prior knowledge and ideas in light of the results of the experiment and design a new idea or invention based on these new ideas (Stage 8).

At the beginning of the project, students from different high schools were allocated groups on the basis of their interest in particular focus areas of science. Two students from each school were matched up with two students from a different school. Two pre-service teacher mentors were then assigned to each group. As a group, a topic area was decided upon and was decided upon the high school students, in collaboration with the pre-service teacher mentors, devised along with an appropriate research question which was explored during the course of the project. The pre-service teachers also attended workshops on wikis which gave them experience in how to set up, use, and how to teach the school students how to collaborate via a wiki.

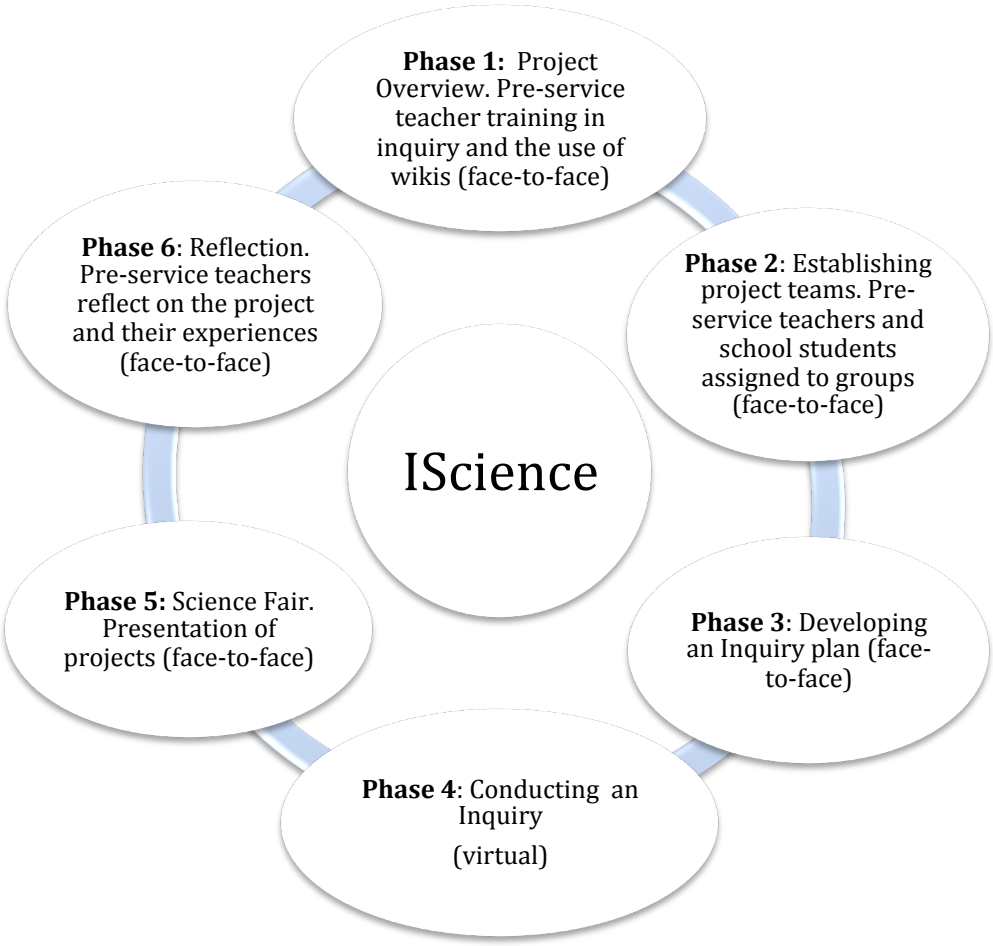

Figure 2: IScience project overview

The groups then met to plan and design an investigation that addressed their research question. The students and pre-service teachers communicated online through a wiki. The group members updated each other on what they had been investigating, questions they had and any research they had conducted. On two separate occasions the groups meet face-to-face to conduct experiments. The wikis were used for the groups' ongoing online correspondence to discuss the project. The project culminated in a Science Fair held at one of the schools where the students presented their projects and findings, that were judged and prizes awarded in different categories.

Research Design

This study was conducted as part of the 2011 IScience project. The study was conducted in both higher and high school education contexts. To avoid confusion, the terms pre-service teachers (university students) and students (high school students) will be used to identify members of the different participant groups. This paper reports upon the pre-service teachers' responses to the study.

Participants

Thirty-six pre-service teachers from the first year of the Master of Teaching and from the third year of the Bachelor of Education programs participated in the project. The pre-service teachers undertaking the Master of Teaching came from a range of educational and work backgrounds. Some had enrolled straight out of undergraduate science degrees others had come from working for many years in Science fields such as genetics or chemical engineering. The average age of the pre-service teachers was 24 with a standard deviation of 4.41. Fifty-six students from Year 8 from Science classes from three independent high schools (two single sex girls and one co-educational) participated in the project. Students that were selected to participate in the project were from the top-streamed science class of each school.

Data Collection and Analysis

The research used a mixed-method approach and, consequently, the data collected were both qualitative and quantitative. This combination of data collection strategies allows for a more robust understanding of impact of the IScience project on pre-service teachers competencies and understandings of inquiry and computer supported learning (Bannan-Ritland, 2003; Brown, 1992; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005). The data collection occurred over a period of five months. Table 1 outlines the data sources. The data were collected over the course of the project and were analysed upon collection. The pre-service teacher reflections on the project were collected after the project had been completed to provide the pre-service teachers with time to reflect upon and respond to the project.

Table 1: IScience data sources

Data Source	Collection Period	Description
Pre-service teacher Reflections	Post project	Pre-service teacher reflective assessment tasks
Wiki Survey (Appendix 1)	Pre-, mid- and post-project.	Modified version of Kennedy-Clark's Theory of Planned Behaviour Survey Instrument (Kennedy-Clark, 2011)
TPACK Survey	Pre- and post-project	Modified version of Schmidt et al's TPACK survey instrument (Schmidt et al., 2009a; Schmidt et al., 2009b)

Results

The results of the analysis of the pre-service teacher reflections, the wiki survey data and the pre-and post-test TPACK survey data are presented in this paper.

Pre-service Teacher Reflections
Analysis of the pre-service teacher reflections show that the IScience project assisted the pre-service teachers in three key areas; knowledge of science content, understanding of the inquiry process and finally highlighting the difficulties of formulating appropriate language and questioning techniques to engage students in the teaching material.

The results indicated that the pre-service teachers developed an understanding of the importance of strong science curriculum content knowledge to their teaching practice. This supports the research findings raised in the literature that pre-service teachers should have a good understanding of the NoS and its relationship to scientific inquiry to be able to effectively translate this into classroom practices that include inquiry-based approaches (Slack, 2007). The majority of pre-service teachers spent a large proportion of their preparation time researching the science content, which was generally at a Stage 4 level of the Syllabus. This emphasis on establishing background knowledge on their topic is reflected in this quote from Anne:

> *I felt that my understanding of the science concepts involved was greatly enhanced by this project. My general science knowledge was improved in the process of researching the topic and exploring all possible facets of it in preparation for the mentoring experience. Anne (M.Teach)*

The pre-service teachers felt they needed to do this in the event that the students asked them questions they were unable to answer. Hence, the pre-service teachers felt that it was necessary to develop topic area expertise prior to working with the students.

The pre-service teachers also found the project helpful in developing a better understanding of the difficulties in teaching using inquiry but also the advantages in using it to help students develop a deeper understanding of science content as one pre-service teacher reflects:

> *Initially, I was skeptical of the practicality of the Inquiry process in the classroom and how it would be beneficial to me as a teacher, however, by the end of the IScience project, I could see the importance of students 'discovering' science for themselves in order to generate meaningful learning experiences. Peter (M.Teach)*

A major concern for many of the pre-service teachers was trying to match the language that they use to describe science concepts with the students' cognitive level of understanding as shown by Sabrina's comment:

> *Prior to my involvement in this project, I tended to use terminology that students would never have encountered before, simply out of habit. I needed to consciously restrict myself when talking to the students and when I did need to mention a term they may not have been familiar with, I would elaborate on the definition to ensure students had a basic understanding of the concept. Sabrina (B.Ed/Science)*

In addition to simplifying their language they commented on the difficulties they had trying to help the students develop researchable questions. The issue of dialogue between teachers and students during the inquiry process is emerging as one that needs further consideration in contemporary research.

Wiki Surveys

Pre-, mid- and post-test surveys were administered to pre-service teachers over the course of the project. The pre surveys were administered during the wiki workshop held in April. The mid were administered in July and the post survey was administered at the conclusion of the study. The survey instrument had both opened-ended and Likert style questions. The analysis of the survey data indicates that pre-service teachers prior to the inital workshop saw wikis as a receptive tool that they could access to find information for their assignments. For example, they could access Wikipedia to obtain background information for an assessment as seen by Peta's comment:

> *Wikipedia to gain a general understanding of a complex topic. Peta (M.Teach)*

However, the pre-service teachers did not understand or have the skills to use wikis in educational contexts for collaboration. In the mid and post-test surveys the educational benefits of using wikis for collaboration were evident as seen by Jason's response about wikis:

> *allows one or more members of a group to remain in contact, uploading useful documents which any member can edit and resubmit . Jason (B.Ed)*

The pre-service teachers had a better understanding of the benefits and limitations of using Web 2.0 technologies in a classroom. For example, the pre-service teachers raised issues such as cyber-safety and the need to scaffold collaboration for the use of a wiki to be effective. The main finding from the survey data was that students found the wikis difficult to manage the workflow effectively with a geographically dispersed cohort of students.

Information and Communication Technologies in Science Education

The pre-service teachers participating in the study completed pre- and post-tests that were designed to measure their TPACK. The tests were administered at the commencement nad conclusion of the project. The survey used a five-point Likert scale (e.g. 1 = 'Strongly Disagree', 5 = 'Strongly Agree'). Schmidt, Baran, Thompson, Koehler, Mishra, & Shin's (2009) TPACK survey instrument used in this study was modified for Australian higher education institutions. According to Schmidt et al. (2009), the survey instrument has an internal reliability (Chronbach's alpha) of Technology Knowledge (TK) 0.82, Science Content Knowledge (CK) 0.82, Pedagogy Knowledge (PK) 0.84, Pedagogical Content Knowledge (PCK) 0.85, Technological Pedagogical Knowledge (TPK) 0.86, Technological Content Knowledge (TCK) 0.80, and Technological Pedagogical Content Knowledge (TPACK) 0.92. This range is considered to be acceptable to excellent (George & Mallery, 2001).

Table 2: Pre-and post-test test scores

	Pre-test Mean	Pre-test Std Dev	Post Test Mean	Post test Std Dev
TK	3.88	0.64	3.84	0.37
CK	4.17	0.65	4.17	0.54
PK	3.37	0.58	3.64	0.44
PCK	3.41	0.87	3.67	0.62
TPK	3.86	0.75	3.96	0.52
TCK	3.79	0.64	3.92	0.33
TPACK	3.59	0.63	3.85	0.43

It is evident from Table 2 that participation in the IScience project had minimal impact on the pre-service teacher's TK (d = 0.1), TPK (d = 0.2), PCK (d = 0.4) and TCK (d = 0.4) and no impact on the pre-service teachers' content knowledge. There was a medium effect size on the PK (d = 0.6) and TPACK (d = 0.6). What this seems to suggest is that the pre-service teachers did not perceive that the project helped to develop their content knowledge or technological knowledge, but that it did help to develop their pedagogical knowledge. However, factors, such as other courses being studied and professional experience may also have an impact on the test scores.

Discussion

The main finding of the IScience project was that pre-service teachers had a deepened understanding of inquiry-based approaches to teaching science. It was found that by linking the theory of inquiry taught in lectures and tutorials to the experience of teaching high school students that the pre-service teachers were able to experience and reflect upon the real practicalities of working with students using, sometimes quite complex, inquiry approaches. Not only did the pre-service teachers comment on the value of asking students to use their own ideas to create and design investigations, but they also reflected on the problems associated with supporting students in an open-ended inquiry. Issues that arose included how the age of the high school students and their limited experience in using wiki*s* impacted on their ability to communicate effectively and work in groups.

The main benefit according to the pre-service teachers was the interaction between themselves and the students. They reflected on the advantages of working closely with a small group of students and were able to relate this experience with working on similar projects but with larger numbers of students in a classroom. They also commented on the challenges they faced working with students, such as the difficulty in simplifying complex scientific concepts and which language to use to help student understanding. The pre-service teachers also found that it was difficult for students to narrow down their ideas and questions to one researchable question. The difficulty for students to develop usable hypothesis has been raised in a number of studies (see for example, Kim and Pederson (2011)). Consequently, in future years there will be more preparation for the pre-service teachers on questioning techniques and how to focus student ideas to allow them to develop well-structured practical research questions.

The results from informal post student surveys indicate that there was a positive impact from being involved in the project for both high school students and pre-service teachers in terms of the way in which the program added to their understanding of the NoS, As demonstrated

by Steven's comment, the pre-service teachers did see a link between inquiry and science as a discipline and the importance of this to student learning:

> *I know now that it is essential to encourage students to self-direct their learning so that they gain an understanding of the purpose of science in society and can more easily create the link between science and everyday life. The IScience project is successful in strengthening this link as it provides students with the opportunity to apply their knowledge to common problems encountered by themselves and society. Students are also made aware of how science provides practical skills to all industries, such as commerce, technology and politics. Steven (M.Teach)*

This is consistent with studies, such as Akerson et al.'s (2007), which found that allowing pre-service teachers to participate in open inquiries does enable them to develop a richer understanding of the NoS (Akerson et al., 2007).

Pre-service teachers also reflected on the way in which the IScience project helped to validate to the students that science is relevant to their lives as demonstrated by Kate and Terrie's comments:

> *Students are also encouraged to see how other cultures and perspectives have contributed to and continue to shape science. Kate (M.Teach)*

and

> *Essentially inquiry hopes to bridge the gap between how science is taught to what real world science really involves with real scientists in their fields. Society has this perception perhaps that science involves predominately men (real world stereotype) in lab coats tinkering with gadgets or chemicals. In reality inquiry shows students what the essential skills involved from the ground up in real science. Terrie (M.Teach).*

The pre-service teachers found that using the wiki with students whilst in theory a good idea, in practice was problematic for several groups. The pre-service teachers commented that the students did not add to discussions frequently enough and thought that their age may have limited their ability to use the wiki effectively. In future years the IScience program will focus on providing the pre-service teachers with a better understanding of ways to scaffold and create a wiki that is more user friendly for the students to enable more interaction between the users. More instruction for the high school teachers from the schools is needed about wikis and how to use them so they can assist students' use of the wiki at school.

Whilst there were some practical problems with the wikis, the pre-service teachers could see the benefits of their use for student learning. They commented on the ability of the wiki to help build communities of practice, share results, keep up-to-date with the latest scientific discoveries and as a way of conducting inquiries outside the context of the classroom. Research in the field of computer-supported collaborative learning provided numerous insights both into the design issues and the potential affordances of collaborative tools, such as wikis. Primarily, the research suggests that when designing to support interaction about science, the structure should include a debatable task, cognitive preparation for debate, multiple representations of solutions, compatible partners; and a strong understanding of the topic (Baker, de Vries, Lund, & Quignard, 2001).

Learner perceptions also play an important role in successful collaborative learning situations (Beatty & Nunan, 2004). Learners with awareness of their own ability to actively participate in a task are better able to engage in collaborative tasks. Collaborative learning requires a plan for the work process, critical thinking, and scaffolded learning. Learners need to engage

in these steps to effectively use the collaborative learning environment. Determining priorities, therefore, is also an important part of the collaborative learning process. The learner's perception of the technology is also an important component of the collaborative learning process, as learners must be scaffolded within their learning environments (Beatty & Nunan, 2004). Consequently, when designing the 2012 IScience project, concept maps and better scaffolding of the collaborative use of the wiki will be employed to address the problems that arose during the project.

TPACK is a framework that is used to describe teacher knowledge for the integration of technology into a classroom environment (Mishra & Koehler, 2006), TPACK does not measure an individual's actual technical skills or their performance in the classroom. Rather, TPACK emphasises a teacher's understanding of how technologies can be used effectively as a pedagogical tool in a particular context (Koehler & Mishra, 2010). So it is a measure of the purposeful selection, evaluation and use of a tool relevant to the task and content. The TPACK pre- and post-test results indicate that there was a medium effect size in pedagogical knowledge and their overall TPACK. There was small to no effect size measured in technological or content knowledge. In this instance, students were prescribed a particular tool, a wiki, and the data from the reflective journals indicated that the using the wiki effectively was challenging. What this may reflect is the reality that pre-service teachers need sustained use of ICTs throughout the duration of their degrees in order to develop competencies in the selection, evaluation, and use of a particular tool in the classroom. This is consistent with much of the literature on developing pre-service teachers' knowledge and confidence in using ICT (see, for example, Choy, Wong, & Gao (2008), Kennedy-Clark (2011), la Velle, Wishart, McFarlane, Brawn, & John (2007), and Markauskaite (2007),

Mishra and Koehler (2006) acknowledge that a simple learning-technology-by-design experience, such as used in the project, would not fully prepare teachers for using ICT in the classroom. In this sense, we argue that is perhaps more appropriate to regard the pre-service teachers' experiences with the IScience project as building an ICT foundation that prepares pre-service teachers for later experiences of a deeper and more expansive quality when they enter the classroom (Dewey, 1933). Developing expertise in the use of ICTs to support scientific inquiry goes beyond teacher training programs and relies on constant professional development in which awareness created during pre-service education would serve as an early foundation.

Implications of IScience

There are several implications of the findings of the data analysis on the design of the IScience project. Firstly, in future iterations, pre-service teachers will be provided with a structured introduction prior to commencing project. This will include several lessons before the IScience project begins that will focus on helping pre-service teachers with questioning techniques and how to help the high school students narrow down their ideas to focused, practical researchable questions. There is also the possibility that the pre-service teachers will be asked to carry out their own mini scientific inquiry to help them come to their own understanding of what and how authentic inquiry experiences are carried out in the Science classroom. The rationale for these changes is that the pre-service teachers expressed doubts in several areas of their ability to support students: their questioning techniques, their ability to help students refine their hypothesis set and in articulating their own understanding of an inquiry to the students.

On the basis of the results of the 2011 project, pre-service teachers will be given more time to develop their competence in the use of the wikis. It was shown in this study that pre-service teachers did not develop the technical skills to manage the online collaboration effectively. Pre-service teachers will be led through an introductory lesson about what wiki's are and also more information on how to set up a wiki suitable for the interaction between themselves, students and teachers. Furthermore, as communication on the wiki was shown to be problematic, the use of the wiki will be more structured. For example, the high school students will be asked to nominate a particular time they will be available to log into the wiki so that live chats can be undertaken. The school teachers will also be asked about the possibility of the students having some class time to dedicate to logging on and working on the wiki and their IScience project.

It was also shown that the pre-service teachers felt that they lacked expertise in the actual inquiry topic. Hence, the pre-service teachers will be given a choice as to the topic area they would like to focus on. It is anticipated that they will pick content areas they are familiar and confident in so as to enable them to focus more on the inquiry process and student interaction rather than learning new subject matter content. The pre-service teachers will be asked to devise a number of hands-on stimulus activities around their topic area to provide the pre-service teachers with an overview of how the inquiry may evolve with the high school students. During the preparation phase of the project, the pre-service teachers will be required to anticipate researchable questions students may come up with during the project. They will then be asked to use these in classes to predict what types of activities, questions and equipment they might need to prepare for the students. It is hoped that this will provide the pre-service teachers more of an insight into how the IScience project will work and ameliorate the anxieties of the 2011 participants. The results of this study indicate that the pre-service teachers need to have a strong understanding of inquiry, the topic area and the wiki platform so that they may feel that are in the role of expert in the inquiry.

Conclusions

The present study provides additional evidence to support the validity of the IScience program in that the IScience project enabled the pre-service teachers to develop a better understanding of inquiry learning and collaboration. The pre-service teachers' indicated that they had a better understanding and increased confidence in undertaking open-inquiry in their Science teaching. The pre-service teachers benefited from establishing links to schools and through their roles as student mentors. The findings and feedback from the stakeholders involved in the project indicated that both the pre-service teachers and the students were motivated and engaged, and that the pre-service teachers reported that they had a better understanding of science inquiry, the NoS and the use of wikis as collaborative tools at the conclusion of the project.

Despite the benefits outlined by the participants in the project, there were several issues that the research team will address in the next iteration of IScience. A concept mapping exercise will be introduced in the preliminary meeting with the pre-service teachers to hopefully facilitate the development of a more nuanced understanding of the scope of the project, as it was shown in this study that the pre-service teachers did not grasp the complexity of the project until they were midway through the five month inquiry. Moreover, a better support network and just-in-time feedback for the use of wikis is being developed as a number of the participants underestimated the need for their moderation in maintaining student engagement and motivation. Overall, the pre-service teachers reported that they were able to utilise the

skills gained during the project whilst on professional experience, and that they felt more confident facilitating an open-inquiry with students.

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Appendix 1

Wikis in iScience
Pre/Post Questionnaire

Date:_____ Gender: F / M Age:_____
First name:_____
Degree:_____
Teaching experience: _____

Please answer the following questions. Please answer both sides of the questionnaire.

Teaching, Pedagogy and Content Knowledge

Please circle the most appropriate response to the following seven statements.

1. I can teach lessons that appropriately combine science, ICT tools and teaching approaches	Strongly agree	Agree	N/A	Disagree	Strongly disagree
2. I can select ICT tools to use in my classroom that enhance what I teach, how I teach and what students learn	Strongly agree	Agree	N/A	Disagree	Strongly disagree
3. I can use strategies that combine content, ICT tools and teaching approaches that I learnt about in my coursework	Strongly agree	Agree	N/A	Disagree	Strongly disagree
4. I can provide leadership in helping others to coordinate the use of content, ICT tools and teaching approaches in my school	Strongly agree	Agree	N/A	Disagree	Strongly disagree
5. I can choose ICT tools that enhance the content for a lesson	Strongly agree	Agree	N/A	Disagree	Strongly disagree
6. I can teach lessons that appropriately combine science, wikis and teaching approaches	Strongly agree	Agree	N/A	Disagree	Strongly disagree
7. I feel confident in my ability to design, develop and use a wiki in an educational context	Strongly agree	Agree	N/A	Disagree	Strongly disagree

Current Knowledge of Wikis

8. What does Web 2.0 mean? _____

9. What is a wiki?_____

10. What are some wikis that you know of?_____

11. a. How often do you contribute to or visit wikis?

    Weekly Monthly Never Fortnightly Rarely

    b. Name/type of wiki:_____

12. Have you ever used a wiki in an educational context?(if yes, explain context and frequency)_____

13. In what contexts do you think wikis can be used in education? (i.e. how would you as a teacher use them in a classroom) _____

14. What are some advantages/benefits for students in using wikis in subjects like science?_____

15. What are some of the problems that may arise?_____

16. Would you, as a teacher, use a wiki a classroom? (please explain your answer)_____

Thank you!