NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

Supporting authentic science in the classroom using collaborative Web-based software

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Declarations

I confirm this is my own work and the use of all material from other sources has been properly cited and fully acknowledged. Part of the work in this thesis has been presented in publications listed in Section 1.6

Luke Raeside

June, 2009

To my wife Linda for her unlimited patience and endurance and to my children, Seán, Úna, Aisling, Niamh, Luke and Linda.

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Abstract

This thesis presents a Web-based Virtual Learning Environment (VLE) called the Education through Virtual Experience (EVE) Portal which supports e-Science learning for schoolchildren. The VLE guides students and teachers in the production of collaborative research papers to summarize their inquiry-based activities. This thesis details the formative evaluations carried out on the VLE and provides empirical evidence to support the hypothesis that the initial version of the VLE successfully supported inquiry-based science investigations. The VLE evaluations also provided an opportunity to assess the effectiveness of each of the VLE components toward our educational objectives. This thesis describes the shortfalls identified in the original version of the VLE, which has lead to the encapsulation of team management, collaborative writing and image-based data collection into the VLE. This thesis also details the initial trials of the collaborative components of the VLE and provides evidence to support the contention that collaboration has been successfully introduced into the VLE. Finally, this thesis provides a technical description of the underlying architecture of the EVE Portal and describes the implementation details of the EVE imaging component.

This thesis makes contributions to e-Learning by providing empirical evidence that an amalgamation of software tools can support an inquiry-based scientific process with schoolchildren and teachers. The encapsulation of team allocation and team-based writing presents an innovative method for supporting inquiry-based learning within schools. The requirements elicitation and customized development of the EVE imaging component highlights many of the difficulties associated with the creation of Web-based software to support constructivist learning at pre-tertiary level. Finally, the EVE Portal provides an innovative way for teachers to capitalize on time spent carrying out inquiry activities through the codification of structure into a software supported process.

Abbreviations

AJAX	Asynchronous Java and XML
API	Application Programming Interface
CSILE	Computer-Supported Intentional Learning Environments
CW	Collaborative Writing
CWE	Collaborative Writing Environment
D3E	Digital document discussion environment
DEC	Declination
EAP	Education Associates Program
ESO	European Southern Observatory
EVE	Education through Virtual Experience
FCL	Fostering Communities of Learning
FITS	Flexible Image Transport System
HCI	Human-Computer Interaction
HDU	Header and Data Unit
HTML	Hypertext Mark-up Language
ICT	Information and Communications Technology
JDOM	Java DOM API
JVM	Java Virtual Machine
OECD	Organisation for Economic Co-operation and Development
PDF	Portable Data Format
RA	Right Ascension
SENSE	School E-Science Network for Study of Environmental Science
SISTER	Science Investigation System for TIE Research
TC3	Text Composer, Computer Supported and Collaborative
TIE	Telescopes in Education
VLE	Virtual Learning Environment
VTIE	Virtual Telescopes in Education
WISE	Web-based Inquiry Science Environment
XML	Extensible Mark-up Language
ZPD	Zone of proximal development

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Chapter 1

Introduction

Virtual Learning Environments (VLEs) in the last numbers of years have begun to make a substantial impact within the educational community. This impact, however, has been most evident at the tertiary level of education. At the pre-tertiary level of education the use of Information and Communications Technology (ICT) is relatively weak despite much literature to suggest that it can play a positive role in school and can benefit student learning. The available evidence would suggest that there is no clear understanding of the form software should take at pre-tertiary level although there is a great deal of consensus on the pedagogical approaches that should underpin such software. Many researchers interested in the use of ICT in pre-tertiary education cite the importance of encapsulating a constructivist pedagogy within educational software to affect the optimal learning at this educational level. Constructivism is an educational philosophy that puts the learner at the center of their own learning, the learner builds layers of knowledge on top of what they already know; this contrasts with the instructivist-type approach which views a student as an empty vessel to be filled with knowledge and subsequently quizzed on that knowledge. Currently there are a number of researchers attempting to build constructivist learning environments, however, there is a gap in knowledge about how to build these software systems to support in-class learning and what form these systems should take. This thesis details a VLE called the Educational through Virtual Experience (EVE)

Portal, which has been designed to support collaborative inquiry-based science projects within a constructivist paradigm, for use by schoolteachers and their students. The EVE research project to-date has involved a formative evaluation phase involving over 161 schoolchildren as testers. The project also involved regular direct input from local schoolteachers in the formative stages. The EVE Portal has evolved incrementally through observation and testing of end-users during trials, through post-trial analyzes of student output and through direct feedback from teachers and students. The formative evaluations of the EVE Portal have provided contributions to this research area by providing empirical evidence that it is possible to successfully construct a Web-based learning environment that supports the inquiry-based processes supported by constructivist-type models. This project also provides a formative methodology for driving innovation that will be of importance to researchers interested in educational technology development, particularly for use in schools. Following this research the EVE Portal now encapsulates collaboration, teamwork and data analysis into the inquiry-based process and provides scaffolds for structuring the writing of research papers produced by the schoolchildren. The sections that follow discuss VLEs in more detail, discuss the current use of software in education and introduce the EVE Portal and the user-centered approach used to drive its development.

1.1 VLEs: Definitions and Positions

The definition of the term Virtual Learning Environment is wide and varied. A VLE can provide an environment through which students can post questions relating to material being covered during a semesterized course on campus at tertiary level, whereas other VLE's attempt to replace contact hours between educators and students by provision of materials and discussion forums, effectively replacing the need for contact hours with an educator. Wilson [Wil96] provides a very broad definition of learning environments as "computer-based environments that are relatively open systems, allowing interactions and encounters with other participants", whereas Linn et al. [LDB04] provide a definition that is more closely associated with constructivist viewpoints: "We define a learning environment as the combination of curriculum, technology support, and classroom activity structures orchestrated jointly by a teacher and a computer-delivered program" [LDB04, p.11]. The term Virtual Learning Environment also encompasses many different kinds of educational software, for example, the term VLE has been applied to Powerful Learning Environment, Course Management Systems, Learning Management Systems, Collaborative Learning Environments, Computer Supported Collaborative Learning and Information portals. The nature of interaction with the VLE is significant within the context of education, and therefore it is possible to classify a VLE on the basis of its pedagogical underpinnings, for example, this type of classification is cited in an article by Parkinson and Hudson [PH02]. In this article they refer to two basic types of learning environments as proposed by Lockard and Abrams [LAM94], namely, Type 1 and Type 2:

> "Type 1 applications do not generally change the teaching strategy but do assist in making learning independent as well as helping to reduce the need for direct teacher involvement. Whilst these approaches may assist in alleviating problems associated with direct contact hours, they may not contribute much to the quality of the learning experience"…"Type 2 applications involved using computers to enable teaching and learning in ways that had not been possible employing conventional teaching approaches."

Papert [Pap81], creator of Mindstorms and a pioneer in the area of educational technology also describes a similar dichotomy of educational software, defining the different types of educational tools as those that are "programming the child" or those that involve the child "programming the computer". Some of the literature would suggest that not every educational technologist supports this simplified view of educational software, for instance, Wegerif [Weg04] refers to this simplified classification of the types of educational software as "tutor-tool" or "open-closed". Wegerif goes on to argue that it may be the students approach to the computer that is at issue and that this view of computer software “involves a misunderstanding that stems from a transfer of judgments about teacher-student interactions”. However, even if Wegerif does not necessarily conform to the distinction between VLE’s, he does support the contention that computers, when used in a group setting, provide an added opportunity for students to have discussion amongst themselves and that the “educational value of this exchange structure is strengthened if, in the Discussion moment of the interaction, the computer switches from being a simulation of a teacher to becoming a more passive discovery learning resource or environment” [Weg04]. It is important to point out, from the outset, that the VLE described in this work makes no attempt to replace the educator or reduce student-teacher contact hours and is most closely associated with the “Type 2” applications described above. The EVE Portal has been developed to maximize the use of technology within the existing school environment and curricula and is not intended to be an instructional tool. The EVE Portal provides an opportunity for the students and the teacher to engage in discussion and provide interactive feedback, thus ensuring that the teacher remains at the center of the educational process. It may be that the role of the teacher is to act as facilitator rather than instructor while using the software [Rog04, p.141], however, this role is very much in line with constructivist thinking. Much of the available literature from experts in the field emphasizes the importance of the inclusion of teachers in the design and adoption of educational software. While not all teachers are enthused by the inclusion of ICT in education, many would like to include it in their lessons: Underwood and Underwood [UU90] state that teachers are often enthusiastic about inclusion of new software but they often cite “lack of good software” as the reason for not including ICT in their lessons [UU90, p.10]. Crosier et al. [CCW02], following a three year study of an environment to teach radioactivity, state that there is a lack of focus in educational software development on the teacher and the use of the software in the school environment: “One way of ensuring that software will be useful and usable in the classroom is to ask teachers what they want and to involve them in the process”. Frost [Fro97] conducted a survey on teachers regarding the quality of software for schools in which he reported that many teachers believed that software creators were not developing software with a focus on the classroom use. The EVE Portal has been designed with the inclusion of teachers from the outset with the hypothesis that their inclusion in the development of inquiry-based learning environments would yield appropriate software for use at pre-tertiary level. It will become evident during the course of the descriptions in this thesis that the EVE Portal has been designed to be inclusive of teachers in each of the stages of the inquiry-based process.

1.2 Software use in education

In recent years VLEs have been adopted as an integral tool in the education sector and this is particularly the case at tertiary level. Moodle [Moo06], for instance, is widely used in tertiary level academic institutes, and its usage is on the increase. Moodle provides a Web portal through which students can register for courses, upload assignments, and interact with other students and their educators via chat and forums. The use of the Moodle environment has grown exponentially since its introduction and now boasts almost 1.5 million registered courses and almost 15 million registered users at the time of writing [Moo07]. The Moodle environment clearly demonstrates the impact that educational software can have and demonstrates that there is a demand for VLEs in education. Some educational technologists argue that Moodle does not necessarily represent a major advancement in terms of the functionality provided to students or educators. For example, in a very recent book on VLEs by Weller [Wel07], he states that Moodle "isn't dramatically different from many other commercial VLEs" [Wel07, p.102]. Weller apportions most of Moodle's success to its open source nature. Moodle has been purported by its implementor, Dougiamas, to be firmly embedded within a social constructivist paradigm of education. Dougiamas provided a full discussion relating to the philosophy and educational underpinnings of Moodle in a podcast recorded by Tim Wilson for Savvy Technologist [Wil07]. Moodle does provide discussion forums and opportunities for discourse between educators and their students online, however, it can be argued that Moodle does not operate solely within a constructivist paradigm. The Moodle website boasts the presence of over 1 million quiz questions and the substantial presence of these quizzes and related instructional course materials would indicate that an instructivist pedagogy is very much in evidence within the environment. Purely constructivist educational software would focus more on the communications and conversations similar to that described by Laurillard [Lau03], Holliman and Scanlon [HS04] and less on the quiz-based approach to learning which has been described by those supporting constructivism as "drill and skill" [O'H04, p.45-46][Coo96]. The EVE Portal discussed in this thesis is not content-based and does not attempt to assess student learning based on instructivist-type quiz questions. The EVE Portal focuses clearly on supporting inquiry-based processes by supporting collaborative writing and other open-ended inquiry-based activities. Although there are no formal questions given to students using the EVE VLE, the formative evaluations have shown that assessment of the output from the students is possible using traditional teacher-based assessment [BRKH05]. It is important to point out that constructivism is "not at all dismissive" of teaching [Pap93a, p.139], moreover, it attempts to minimize the amount of instruction necessary to impart deep learning of a subject by balancing the necessary information acquisition, or "coverage" [BBC00, p.20], with exploratory learning. Chapter 2 explores further the constructivist viewpoint and its application in educational software design. The EVE Portal is firmly embedded within a constructivist paradigm and relies on the teacher and students to guide their own learning through the production of written research papers. The EVE Portal contributes to the efforts to create constructivist software that is both accessible and usable within schools, however, there is a very long way to go before schools reach the level of adoption evident at tertiary level and in industry. This research project has investigated some aspects of the questions relating to ICT use in schools through the development and testing of software solutions which are far removed from the "drill-and-skill" solutions. The evaluations of the various components and versions of the EVE Portal presented in this thesis have generalizable lessons for researchers in e-Learning whether they are educational technologists, computer scientists or interaction design specialists.

Increased investment in ICT for schools has already lead to a vast increase in the availability of broadband and ICT equipment within the school environment. However, the future will see ICT disseminate more and more throughout the educational hierarchy; what form the software will take and how integral it will become in the classroom can only be answered through close co-operative work between computer science researchers and the stakeholders of this software, namely, schoolchildren and their teachers. Educational researchers can provide expertise and input into the learning impacts of such software systems and computer scientists can explore the features that will lead to the adoption of software systems into this population. Through extensive iterative, user-centered development computer scientists can begin to address some of the inhibitors toward the use of ICT in school. Adopting a user-centered, iterative approach to the development of educational software has driven the innovation of the EVE Portal.

1.3 Development of educational software using a user-centered approach

There is much evidence that iterative development can produce quality software as there are many opportunities to test and modify the software throughout the development process [Som89, PSR94, BMF02]. The field of Human Computer Interaction (HCI) has recognized for many years the importance of user-centered development toward the successful adoption of software for general use [PSR94, DFAB03, Nie93, JST^{+}99]. In more recent publications this has been shown to apply equally to the Internet [Bad02, SP04, Nie00]. Several recent authors have also acknowledged the increasing number of children using ICT resources including the Internet and how the building of interactive software for this population requires different approaches to design and testing [GMR06, MB03b, DBB+98, Dru02, Nie07a, Nie07b, SR99, ESK+96]. Developing educational software is a specialized area. Educational technologists would purport the maximal inclusion of the stakeholders within the educational software development process. Researchers such as Druin et al., [Dru02, DBB+98] have defined several levels of involvement of stakeholders in the development of educational software. Druin et al., [Dru02, DBB+98] classify the differing roles the user can play in the development from the most involved "design partners" to the more traditional role of "user" and "tester". According to Druin et al., it is essential that the stakeholders are at the center of the development of software, however, it is also important for the software developers themselves to have a clear view of the pedagogy that will be applied to the software solution. Markopoulos and Bekker (from the User Centered Engineering Department at the University of Eindhoven) [MB03a] in a journal editorial state that interaction design for children is an "emerging area for human-computer interaction research" and expect "research that considers interaction of children and technology to grow in volume and depth". Weller [Wel07] believes that the usability design of educational websites is even more challenging than the design of regular commercial websites in that the students and educators will not simply visit the site once for information purposes or to carry out some simple transaction, but that it is more likely that the interactions will span over "weeks, months, years even" [Wel07, p.9]. Many leading educational technologists, for example Underwood and Underwood [UU90], cite "ease of use" as one of the main selection criteria for use of one educational tool over another; therefore considerable focus needs to be placed on the user interface design. Squires and Preece [SP99, SM94, MS86], two authors widely published in HCI have formally linked the development of educational software and usability. It is also possible to cite examples of innovation within the educational technology field that have been published within the HCI literature [PLL+99, SBS98]. The development of educational software requires acceptance by the educators and the students alike; McCrory [McC06] refers to the work of Kay [Kay98], creator of Smalltalk and one of the pioneers in the use of technology in education; Kay describes the difficulty of adopting new technologies but offsets that effort in learning with the potential learning benefits. McCrory, however, makes the point that the Internet has produced a universally simple interaction experience for teachers and students alike and that this ease of use has produced a disincentive to spend much time learning new software; specifically, if they can't use the software properly within "a few minutes, it is too hard". The formative evaluations stage of the EVE project acknowledged the importance of the inclusion of teachers and students [BRKH05]. The EVE Portal has evolved through extensive user-testing and the detailed analysis of the test results. The iterative development of the EVE project has provided a research opportunity to apply, in combination, the principles of HCI studies, educational technology and aspects of educational research to the question of designing effective software to support e-Science in the classroom.

1.4 The Iterative development of the EVE Portal

The Virtual Telescopes in Education (VTIE) project begun in 2001. The aim of the VTIE project was to engage schoolchildren in a scientific process [HdF$^+$02] and allow students to explore the night sky using a remote telescope. The VLE, at the time, consisted of an amalgamation of professional software tools for the retrieval of images from telescopes, analysis of astronomical images and basic word processing. The students using the VTIE VLE carried out astronomy-based investigation under a specific topic, for example, Spectra, Galaxies etc. In 2003, further testing took place on the VTIE VLE, however, a greater emphasis was placed on critical analysis of the VLE as it existed and its fundamental ability to address its educational objectives. Furthermore, greater emphasis was placed on the wider implications of constructing an inquiry-based environment. Detailed formative evaluations were carried out to identify successes and shortfalls of the software and the results of the trials were critically analyzed [BRKH05]. Additionally, a team of primary and secondary school teachers was invited to take part in the development of a new VLE that would aim to better address the needs of the teachers and schoolchildren. These formative evaluations resulted in the creation of a new version of the VLE known as the EVE Portal. The EVE Portal has produced innovative solutions to a number of the shortfalls identified during the VTIE evaluations, particularly the lack of student collaboration and data collection. The EVE Portal has provided an opportunity to address many research questions associated with VLE development for schoolchildren and teachers including:

- Pedagogical concerns of teachers: Teachers participated in regular meetings when forming the portal, and they also participated in online discussions via the VTIE discussion forum. Additionally, a number of the teachers were present when the initial trials were being carried out. This close involvement of teachers at the formative stages of the development ensured that their pedagogical concerns were factored into the software design [BRKH05].

- Practical concerns of teachers: Teachers participating in the VTIE development listed many practical concerns that must be addressed when developing software for use in school. These included the cost of the software and licensing issues and also the need for software support [BRKH05]. The EVE Portal is freely available, completely Web-based and support has been provided to participating schools.

- Encapsulation of Team Management: The VTIE VLE did not model team structures within the software. Teachers attempting to engage students in a team project need to create and manage teams of students during the course of a project. The EVE Portal models team structures which are required to manage a collaborative virtual project [BRWK07].

- Encapsulation of Collaboration: The VTIE VLE did not address the need to formalize collaboration within the software, and in particular to produce collaborative research papers. The EVE Portal facilitates collaborative writing using the Collaborative Writing Environment (CWE) [BRWK07, BRWK06].

- Data collection and analysis: The VTIE VLE did not have appropriate integrated software necessary for data collection and analysis in astronomy. The EVE Portal has addressed these concerns through the development of an imaging component for image-based data collection [RBO+05, RBWK08].

The gathering of requirements for the EVE Portal was reliant on observational evidence and subsequent analysis of perceived difficulties during laboratory interactions and through content analysis of the research papers produced by the students. The important role that observation can play in the development of usable software has long been recognized within the field of HCI [PSR94, SP04, DFAB03, Nie93, BMF02], for instance Nielsen [Nie93], an internationally recognized expert in usability engineering states that "new insights are almost always achieved by observing and talking to actual users in their own working environment" [Nie93, p.75]. Importantly, observational methods have also been advocated by leading educational technologists [HS04, O'H04, FP04]: "A number of studies have shown that observing learners working with technology can be a very productive way of exposing ideas and learning processes" [HS04, p.191]. According to Fincher and Petre [FP04]: "Observation can produce very rich, highly-situated data reflecting behaviour in context. It can provide opportunities to identify important factors which were previously un-remarked." [FP04, p.51]. Hoadley [Hoa04] summarizes his experience during the development of inquiry-based software as follows: "Good design is iterative. The process of creating something to create a goal is repeated many times as the designed artifact or process is tested, observed, and refined" [Hoa04, p.146]. The EVE Portal has incrementally shifted into an environment that can fully support classroom based inquiry-based investigations, driven almost entirely by the educational goals and through feedback received (observationally and directly) by the students and their teachers.

The research activities of the EVE team spanned a number of research areas including, pedagogical design in software, software engineering, educational technology and project management. My role within the EVE team involved all of these activities to varying degrees, however, the vast majority of my focus was on the pedagogical design of the VLE, the educational technology research context of the project and project management. My role within the pedagogical design included the establishment of the research contexts for the project and the analysis of the effectiveness of the various iterations of the software toward the educational goals. In terms of the software engineering aspects of the project my role involved the analysis, design and implementation of the imaging tool (Chapter 5) which also had the effect of testing the underlying architecture of the VLE framework and its ability to incorporate new tools. This helped to identify potential obstacles associated with the introduction of future tools within the framework. My involvement with the development of the CWE was not on its implementation but on its educational technology applications, i.e., carrying out analysis on the tool's usage during testing which fed into the implementation of the overall system. The evolution of the CWE from the VTIE Paper Writing tool was largely due to the observational evidence gathered during the evaluations. My role also within the team also involved the analysis of the outcome from the various tests carried out in the evaluations and the presentation and dissemination of that work throughout the appropriate research communities.

The current EVE Portal represents an incremental shift from a VLE that existed in 2001, which was composed of an amalgamation of software components that were specifically tailored for professionals, to a VLE that identifies the teacher and the student as the primary users and presents interfaces that are capable for use within the school environment. The transformation of the VTIE VLE to the EVE Portal has made a contribution to the future development of ICT applications for use within the school environment. The EVE Portal contributes responses to the questions: what should educational software for pre-tertiary education look like?, and what form should it take?. This thesis maps the evolution of the EVE Portal from its conception to its current form and details the hypotheses that drove the development and testing. Specifically the hypothesis that an amalgamation of software components could support scientific inquiry [BRKH05]; the hypothesis that team management and collaboration could be fully supported within that inquiry-based process [RBWK08]; and finally the hypothesis that a fully Web-based environment can support the data collection and analysis processes within the VLE [RBWK08].

1.5 Thesis Overview

This thesis presents a detailed case study of the iterative development of a VLE, the EVE Portal, to support collaborative inquiry-based science investigations by groups of students and details the methodologies applied and analyses carried out during its creation. Chapter 2 provides a literature review which spans many of the current and pertinent research questions concerning educational technology researchers in the field. Chapter 3 details the formative evaluation stages of this project, which concluded that an aggregation of software components can successfully support children carrying out astronomy-based projects using a scientific process. Chapter 4 describes in detail the process of evolving the VLE to support collaboration and teamwork and reports on the results of the initial trials of this collaborative software. Chapter 5 describes an individual contribution which includes the requirements elicitation and construction of an imaging component to broaden the range of inquiry-based activities available using the VLE. Chapter 5 also summarizes the technologies used in the development of the EVE Portal and details the implementation of the imaging component within the EVE architecture. Finally, Chapter 6 contains a discussion of the main conclusions drawn from the study and describes many of the outstanding questions which can be addressed by further related research.

1.6 Publications

Part of this work has been published or accepted for publication in various peer reviewed books, journals and conferences and are listed below.

- Raeside, L., Busschots, B., Waddington, S. and Keating, J. G. An online image analysis tool for science education. Computers and Education, Vol. 50(2):p.547–558, 2008.

- Busschots, B., Raeside, L., Waddington, S. and Keating, J. G. Web Information Systems and Technologies, volume 1 of 5, chapter: The VTIE collaborative writing environment P. 392–401. Springer, 2007.

- Raeside, L., Busschots, B., Fei, S., Keating, J. G. Integration and Communication of Process Support Tools in an online Virtual Learning Environment. ITB Journal, Vol. 13, P. 4–12. ITB, 2006.

- Busschots, B., Raeside, L., Waddington, S., and Keating, J.G., The VTIE collaborative writing environment. In Proceedings of the 2nd international WEBIST conference on web information systems and technologies, Vol. 2 (pp. 221-228), 2006.

- Busschots, B., Raeside, L., Keating, J.G., and Hoban, S. (in press). Formative evaluations of a virtual learning environment for astronomy education. Accepted Paper: Computers and Education, 2005.

- Keating, J. G., Busschots, B., Kelly, N., O'Cinneide, E. and Raeside, L. A Collaborative Writing Environment for e-Learning Environments. In Proceedings of IBM CASCON, Dublin, 2005.

- Raeside, L., Busschots, B., O'Cinnéide, E., Foy, S., and Keating, J. G., Empowering schoolchildren to do astronomical science with images. In Proceedings SPIE Vol. 5827, SPIE, p. 669–678, 2005.

1.7 Methodology

The EVE project was developed using a user-centered, iterative design methodology. The project began with a prototypical system which was repeatedly tested against the educational goals of the project in computer laboratories. The aim of the formative evaluations was to investigate whether it was possible to support inquiry-based activities using software prior to expending time and effort developing a custom-built VLE. The prototype VLE was logically split into software components and each component was evaluated for its contribution or hindrance toward the educational goals of the project. Each of the evaluation sessions with students was pre-planned at research team meetings and the educational goals of the sessions were clarified. In summary, each of the sessions had a topic for inquiry and the students were expected to produce team-based papers summarizing their research activities and conclusions. The papers produced had a paper outline similar to research journal papers with abstract, introduction, subject content and conclusion sections. The teachers who participated in the study were from the Kildare area, within the catchment area of the university. The schools were invited to engage in the research project through contacts established with the NCTE (National Center for Technology in Education) [Edu09]. All of the participating teachers were recommended by the NCTE national coordinator. The teachers who participated in the survey-based assessment were also recommended by the NCTE's national coordinator and were all employed in schools in the Kildare area (the university's immediate catchment area). Table 1.1 summarizes the demographics of the participating teachers. The students who took part in the Summer Camps and the CWE trials were also from the surrounding schools in the Kildare area. The enrollment process for students participating in the Summer Camps was inclusive, i.e., efforts were made by the organizing committee to balance the male/female demographics in order to promote participation by both genders (approximately 50/50 participation). The university also offered a number of free attendances to the Summer Camps, normally two per school and specifically for one female student and one male student. For the purposes of these evaluations the gender of each participant was considered invariant to the aims of the research project. This scientific writing process was designed to be totally inclusive of all students participating in the collaborative writing task regardless of their gender. Detailed analysis of gender contributions to the final papers and overall participation in the writing process was not recorded during the course of these evaluations. Gender specific information gathering using the VLE interfaces would certainly be achievable with minor modifications to the software, however, this was deferred to future work. Table 1.2 summarizes the demographics of the participating students.

Each evaluation included an introduction of the VLE and the aims of the sessions were outlined to the participating students. Much of the evidence gathered was based on observations made during the software trials, content analysis of the students' output and interfacing directly with the students and teachers for feedback. During all of the sessions only discrete note-taking was employed by the research team. Audio and video techniques were not employed to record the sessions as it was suggested by published experts on testing with children that these techniques can be a distraction to younger people if they do not have time to adapt to their presence. Observations and notes taken were discussed by the research team members at post-trial meetings. The EVE database recorded student discussions using the commenting component and the research papers produced by the students were also stored for later analysis. Feedback received from teachers regarding the goals of the evaluations was formalized at regular meetings which took place in the first year on a monthly basis. Each meeting lasted approximately two hours and an agenda of discussions for the meetings was posted online prior to the meetings taking place. A Web-based forum was also established so that the development team and the teachers could discuss concepts in between the evaluation meetings.

Content analysis of the student research papers was carried out on two separate occasions by the EVE research team. Initially the content analysis was carried out during the formative evaluations to allow the research team to establish the extent to which the objectives of each of the sessions were achieved. Specifically each student paper was read by members of the research team and assessed under specific categories (correlating to the session objectives) and each category was scored using Likert-type scales, Chapter 3 provides details of the content analysis carried out at the formative stages. The second content analysis of the papers specifically focused on the discussions which took place between the participants. The papers were read by members of the research team and the comments were categorized based on their apparent contribution to the overall objectives of the writing session, Chapter 4 describes this content analysis in greater detail.

Table 1.1: Demographics summary table for participating teachers

	Number of teachers	Profile
Teachers in Discussion Forum and VTIE Meetings	12	Qualified, experienced Known to National Coordinator of NCTE
Teachers in Survey Based Assessments	14	Qualified, experienced Know to National Coordinator of NCTE

Table 1.2: Demographics summary table for participating students

	Number of students	Age Profile
Summer Camp 2002	130	13–17 years
Summer Camp 2003	30	16–17 years
Summer Camp 2004	20	16–17 years
CWE Trials	15	15–17 years

Additionally, surveys were employed to gather data from the student participants during the laboratory testing of the software. The completion of the questionnaires was not compulsory. Furthermore, no attempt was made to coax the students and no time limits were set for the completion of the questionnaires. Pre-trial questionnaires were issued to students immediately prior to the session and the post-trial questionnaires were issued immediately after the session. Questionnaires were also used in order to assess the quality of the output from the students using the system. These questionnaires involved the distribution of 'packs' which contained 7 or 8 student research papers produced during the evaluations. These packs provided explanations of the objectives and activities of each of the sessions and various questions (mostly quantitative) were asked relating to the quality of the papers in general. The questionnaire packs also asked each teacher to assess each of the papers individually so that a score could be assigned to the quality of each of the papers produced. Each paper was given a unique identifier and at least two teachers were requested to assess each paper. These questionnaires were distributed to teachers participating in the project and were then distributed to suitably qualified colleagues who were willing to part-take in the assessment on a voluntary basis. This method of distribution ensured that the research team were assessing questionnaires completed by teachers not associated directly with the project in any way. The completed questionnaires were sealed in envelopes and returned to the project team by the participating teachers without their colleagues having viewed the responses. Some of the questions sought open-ended feedback from participants who wished to provide further explanations.

The data gathered during these user-centered software trials has been used to directly influence and shape the design of the EVE Portal as it exists today and have served to drive the innovation required to produce a VLE which incorporates collaboration, team-based writing and image data collection.

Chapter 2

Literature Review

2.1 Introduction

This literature review presents much of the available evidence that ICT has a defined role to play in education and that ICT can benefit student learning at the pre-tertiary level when the appropriate pedagogical methodology is applied. The review examines the current status of ICT use in schools with an emphasis on science learning and presents a number of innovative science inquiry learning environments, which have been developed and tested by well published researchers in educational technology. This review also presents much of the available evidence that supports the contention that pedagogical theories must be considered when developing software for educational use and that current knowledge in educational theory would strongly suggest that embedding a constructivist approach to learning within the software is most likely to succeed in maximizing student learning. There are several cutting-edge learning environments which support this underlying pedagogical paradigm and many of these constructivist-type environments are presented and reviewed herein. Finally, evidence in the literature from experts in educational technology is put forward which strongly suggests that learning environments which support collaboration between peers, within a constructivist paradigm, are of great educational benefit when attempting to present students with an authentic science learning experience. This review also establishes the research context in which the EVE project makes contributions and establishes the research foundation within which the EVE Portal was constructed and tested.

2.2 ICT adoption in Education

The premise of this research project has been that there is need to invest time researching the use of education at pre-tertiary level and that there is a need to investigate the optimal forms that software should take in order to affect change in ICT use at this level. Much of the available literature in the field supports this contention. VLEs have become prolific in tertiary level education and industry in the last few decades. E-mail and the Internet are integral to both industry and tertiary level. Students at tertiary level communicate frequently with their educators via e-mail and many students interact solely with their educators via Web-based portals such as Moodle and WebCT [Web07, Bla07]. Those of us working in the tertiary level sector are acutely aware of the increasing role of ICT in our everyday dealings with students, in fact, many courses offered are completely dependent on delivery via the Web and are termed "distance learning" courses. Adoption of new technology in the pre-tertiary education sector, however, is not nearly as integral, in fact, there is a great deal of evidence that primary and secondary schools lag seriously behind that of tertiary levels and industry in terms of ICT integration. Weller [Wel07] cites Brown and Jenkins [BJ03] who have provided statistics regarding the use of VLEs at tertiary level in the UK where "86 per cent of respondents from UK higher education institutions" reported "the presence of a VLE in their institution" [Wel07, p.2]. ICT plays a similar role in industry and among science professionals, however, it is evident from the literature that a similar level of ICT proliferation is not reflected in schools. For instance, in an extensive literature review by Osborne and Hennessy [OH03], they clearly describe the contrast between the use of ICT by professional scientists and those learning science at school: "ICT, so far, has radically transformed the nature of science itself for professional scientists, whose research activity has become dependent on routine access to sophisticated computer-based tools and resources. In contrast, the use of ICT in school science, on the whole, has yet to establish its transformative role" [OH03]. The use of ICT in industry spans well beyond IT related disciplines, for instance, e-mail is a ubiquitous form of communication within industry. The same level of ubiquity is certainly not evident within the school environment. According to a recent OECD report on computer use in schools [OEC08], only around 20% of students reported that they used computers "a lot" in schools. One of the main reasons listed by teachers for this was the difficulty in integrating ICT into classroom instruction. However, outside of the school environment the sub-adult community are among the most prolific users of ICT, for example, the Bebo [Beb08] website has been adopted by sub-adults in amazing numbers; according to the BBC Bebo boasted more then 22 million users in the first 13 months of its existence [BBC06], and yet, within their primary learning environment there is relatively little use of computer technology. In 2001, Mumtaz [Mum01] (from the Centre for New Technologies Research in Education at Warwick University), produced a report based on both qualitative and quantitative data to suggest that "children make more use of the computer at home than at school"; a similar but earlier report by Selwyn [Sel98] concluded that students use computers in the home to compensate for the "inadequacies of educational IT". These findings are reflected in reports published in relation to computer usage in Irish schools [SO08][Ire08]. In a recent OECD report [OEC08] only 24% of students were considered as frequent users of computers at school and Ireland was listed as the third worst country in the OECD region in this regard. A 2008 irish school inspectors' report also reported similar findings: "54% of inspectors' reports on lesson observations revealed limited or inappropriate use, or no use, of ICT in teaching and learning" [ES08, p.163]. In October 2006, the National Center for Technology in Education (NCTE Ireland) [SO08] published a report entitled "NCTE 2005 Census on ICT Infrastructure in Schools"; as well as reporting on infrastructure this report included information which related to the use of computers in schools. This report makes reference to the above mentioned OECD report [OEC08] which states that 24% of students in Ireland were described as frequent computer users at school, compared to an OECD average of 44%. Additionally, the NCTE census report states that "the average number of hours on-line per week was 5.8 in primary schools, 25.6 in post-primary schools and 9.9 in special schools". This certainly supports the contention that schools do not make wide use of online resources. The NCTE also reported on the provision of e-mail to students and teachers: "11% of special schools providing email accounts for pupils. At post-primary level, about the same proportions provided accounts to students in 2002 as in 2005 (16% and 17% respectively). At primary level, just under 5% of schools reported providing pupils with e-mail accounts in 2002 and 2005". The NCTE and OECD reports provide clear evidence that computers are certainly not seen as ubiquitous communications devices in the school environment. However, it is evident from the reports that the use of computers in schools is on the increase. When the data collected was compared to the equivalent 2003 report it was concluded that ICT in education is on the increase, for example, when referring to the level use of e-mail "at primary level and among special schools, the proportion that provided accounts for teachers doubled between 2002 and 2005, while in post-primary schools, there was an increase of about one-third". Additionally, the NCTE report provides evidence to suggest that schools are interested in acquiring software for ICT-based learning: "In 2005, more schools purchased reference materials on CD Rom/DVD than online". In that year, 74% of primary schools, and 47% of both post-primary and special schools purchased reference content in these formats. More primary schools (80%) than post-primary (59%) or special schools (65%) purchased subject-specific content on CD Rom/DVD.

The National Policy Advisory and Development Committee [AC08] (an Irish government advisory committee) have also published reports relating to the use of ICT in schools in Ireland. In a 2001 report it states that "less than one fifth of teachers use a computer for everyday teaching" and "39% of post-primary school teachers reported use of computers in school less than once a month or never". In a very recent article, Haydn and Barton [HB08] include statistics published by the British Educational Communications and Technology Agency in 2002 which stated that 60% of teachers in the UK were making little or no use of computers in their day to day teaching [HCF+02]. This suggests that the sub-adult education sector has not adopted the culture of use of computers for education at school. This report also concluded that the three most common uses for ICT in schools are "word processing, drawing/graphics and spreadsheets" and that "fewer teachers claimed to use educational software" in the classroom. These facts raise important questions for researchers developing and using ICT at the pre-tertiary level, for example, what makes ICT within the school environment less prolific than other environments?, and, what form should software take to maximise its adoption into the school environment?.

The general lack of uptake of ICT in the classroom evidenced in the literature is a concern, not only for teachers but also for the designers and implementers of software to be used in the classroom. This lack of adoption in schools has not escaped the attention of industry either, in a budget submission report in 2006 the ICT Ireland group [Ire08] reported that "Ireland is among the bottom three countries [in Europe] on the use of computers in the classroom. ICT Ireland welcomes the progress of the Broadband in Schools initiative. However, in order to maximize the potential of the Broadband in Schools roll out, the Government needs to develop a clear plan in terms of providing skills and access to appropriate devices and content. The dearth of digital content available for use in the Irish education environment needs to be addressed" [Ire08]. Increased research into the types of software that will succeed in changing the culture of ICT use in schools is of great importance for the future, academically, economically, and socially.

2.3 Computer use in schools

Even though there is not the same level of use of computers in schools as there is at tertiary level or within industry, it is certainly true to say that many schools are using ICT in limited ways in the classroom. According to a large portion of the literature, open-ended software such as word processors, spreadsheets and presentation software are used most widely in schools, although in many respects the computer is being used most frequently like an elaborate typewriter. Drenoyianni and Selwood [DS98] surveyed 37 primary teachers in the UK and reported that "the most frequently used piece of software is the word processor (95.1%), followed by the use of graphics packages (85.3%) and software concerned with information handling, such as databases (63.4%) and multimedia encyclopaedia (58.5%)". An inspectorate report for Irish schools recently provided similarly high statistics for use of the word processor: "The most popular type of application used was word processing (71%)" [ES08, p.161]. Squires (Southern Connecticut State University) and Preece (University of Maryland Baltimore County) [SP99] put forward the claim that word processors are good for use in schools because they are open-ended, they cite Papert, amongst others who "stress the need for open-ended exploratory authentic learning environments in which learners can develop personally meaningful and transferable knowledge and understanding" [SP99]. Osborne and Hennessy [OH03] also recognise the educational value of writing using a word processor since it "can support an iterative approach to planning or analysis" [OH03, p.21]. Frost, in a book entitled "The IT in Secondary Science Book", refers to spreadsheet software as having an astonishing range of functions [Fro02, p.32], and the word processor as a "powerful technology" as they can provide an excellent opportunity for students to work together [Fro02, p.53]. Frost, therefore, sees the value of using word processors for collaborations between students as they engage in writing tasks. Frost places a caveat on this view by stating that the expectation that students should start with a "blank sheet" and produce a full report is too daunting and he suggests that writing assignments should be planned and that the teacher should be involved in the formulation of the paper and provide templates where possible [Fro02, p.55]. Underwood and Underwood [UU90, p.9] also add to the body of evidence that word processors are greatly used in the school environment and have been for a great number of years. In this book they include a survey carried out by Smith and Keep [SK88] in which they concluded that "the use of word processing systems was almost universally popular" [UU90, p.9]. This point is echoed by McFarlane: "word processing is the most common use of computers in schools by a long way" [McF97, p.6]. In a recent article, Wegerif [Weg04] (from the University of Exeter) cites the Squires and Preece [SP99] paper mentioned above to support his view that word processors have a major role to play in education in schools. Papert has also acknowledged the use of word processors in the school environment and is supportive of the word processor when used in a "Piagetian" way: "The image of children using the computer as a writing instrument is a particularly good example of my general thesis that what is good for the professional is good for children" [Pap93b, p.30–31]. Papert goes on to say that it is not his vision that word processors be used to examine spelling and grammar, but that the word processor be applied in the same manner as it is by professional scientists, i.e., to acknowledge that "editing and re-editing" is part of the scientific writing process. Therefore, it is evident that the computer, used correctly as a writing tool can support very well the inquiry approach to learning. McFarlane [McF97] discusses in detail the "importance of writing and the role that it can play" in the development of literacy [McF97, p.108], she also refers to a report from the UK Department of Education and Science called the Kingsman Report [ES98] which outlines the importance of word processors in developing the literacy skills of school students: "its ability to shape, delete and move text" and "pupils are drawn into explicit discussion". The Kingsman report focused more on the language and literacy learning of English and certainly strayed from Papert's thesis that word processors should not be applied to simple grammar and spelling, however, as McFarlane points out it is equally true to say that the writing task in inquiry-based learning in science will promote discussion and interaction.

The importance of writing has been firmly cemented into the inquiry process of the EVE Portal. Moreover, the EVE Portal provides an online writing tool that incorporates the collaborative writing, peer engagement and structured preparation which has been called for by experts in the field. This thesis contributes one possible software exemplar for the supporting groups of schoolchildren and their teacher in a focused writing and inquiry tasks. The EVE Portal codifies the importance of writing and its importance to school-based inquiry, in fact, in comparison to many of the VLEs reported in the literature the EVE Portal places considerably more emphasis on the importance of writing and its role in authentic science learning in particular. The EVE CWE allows students to write in groups online; the CWE is used to summarize the investigations by students and provides mechanisms for peer and teacher feedback. Writing is used as a means to invoke discourse between students and teachers within the context of the inquiry-based task. The image analysis software component can be used to carry out focused research with images [RBWK08] and these images and related data can be included in the final research paper produced by the students. The EVE Portal takes advantage of the open-ended nature of writing but, significantly, it guides the teacher and the students during the writing task and directly supports the "editing and re-editing" [Pap93c, p.31] that empowers the child user and gives them an important "common sense of ownership of the end product" [McF97, p.116]. Additionally, students using EVE do not start with a blank sheet of paper (as Frost had cautioned [Fro02, p.55]); instead the process of designing the research paper is totally encapsulated in the project definition wizard. The EVE Portal, in contrast to the word processors used in schools today, has encapsulated collaboration into the writing task and is freely available and fully available online.

2.4 The role of Pedagogy in Virtual Learning

There are two main competing theories within education that manifest themselves in all discussions concerning ICT, namely, constructivism and instructivism. The instructivist (also known as behaviourist) view of education originates from the work of Skinner [Ski38]. Skinner's view of learning was that of the 'carrot-and-stick', whereby the student was an empty vessel to be filled with knowledge. This view of learning has certainly found its place within industry-based education but does not fit well with most modern views of education [Bru96, DAL+04]. The difference between these two competing theories is best described anecdotally by Papert [Pap93c] using an "African proverb" in the following extract from one of his seminal books:

> "If a man is hungry you can give him a fish, but it is better to give him a line and teach him to catch fish himself"..."Traditional education codifies what it thinks citizens need to know and sets out to feed children this "fish". Constructivism is built on the assumption that children will do best by finding ("fishing") for themselves the specific knowledge they need." [Pap93c, p.139]

Similarly, educational software that attempts to "teach" a topic and provide question and answer sessions to ensure that the prescribed content has been absorbed by the computer user can be seen as "instructivist" software, and those that attempt to support the active learning of the computer user through discovery and inquiry can be termed "constructivist" software. Papert goes on to suggest that the tools needed for such discovery are also of great importance, and that computers represent excellent tools for this form of learning. As Papert states, most of this thinking emits from Piaget's doctrine "that knowledge simply cannot be "transmitted" or "conveyed ready made" to another person" [Pia65]. Papert believes that the creation of suitable micro-worlds, in which students can explore, will foster a constructivist learning paradigm. Any in-depth literature review of pedagogy, particularly in the constructivist paradigm, inevitably references the work of Dewey [Dew38], Piaget [Pia65], Vygotsky [Vyg62], Bruner [Bru86, Bru90, Bru96], Papert [Pap93c] and Driver [Dri83, DAL+04]. Dewey [Dew38] was a philosopher and psychologist who sparked much debate about educational reform and is credited by many, including Papert, as the father of the constructivist-type thinking. As Fincher and Petre [FP04] explain in a very recent book entitled "Computer Science Education Research": "Vygotsky's ideas centered on the notion that knowledge and learning are culturally and societally constructed". Vygotsky believed that the child learner has a limited "zone of proximal development" (ZPD) which limits the amount of shifting from their current knowledge and that this construction of knowledge can be helped through social interaction with "more capable peers" [FP04, p.35]. Piaget developed a theory of "cognitive development" which defined four developmental stages of learning in children. Driver [Dri83] summarizes Piaget's theory as a sequence of "disequilibrium and subsequent equilibration" and that the "child is seen as the architect of its own knowledge" [Dri83, p.53]. Bruner was responsible for extending the ideas of Piaget and defining the model of learning, where the child will build on the knowledge it currently has in order to make sense of new knowledge.

Constructivism does not deny the need for direct teaching. Undeniably, every subject covered at school includes a body of knowledge which needs to be assimilated by the students. Constructivism does not claim to represent the "silver bullet" teaching method which will succeed in teaching all students. Bransford et al., are leading experts in the area of educational psychology and strongly support the constructivist approach, however, they acknowledge that the "goal of coverage [of a syllabus] need not be abandoned entirely" [BBC00, p.20] and that "attempts to teach thinking skills without a strong base of factual knowledge do not promote problem solving ability" [p. 22][BBC00]. Papert also cautions on the oversimplification of completely separating the information from the inquiry and states that constructivism "does not call into question the value of instruction as such" [Pap93a, p.139]. In fact, constructivism tries to support learning with minimal teaching effort by capitalizing on people's innate abilities to learn through experience and "doing", with the support of more competent peers. This contrasts starkly with memorizing and learning simply to pass an exam (instructivist approaches), however, as Papert states, “scientific process divorced from content is very abstract” [Pap93a, p.140]. An essential difference between the two approaches is that instructivists would advocate that in order for students to learn better, they must be taught better, whereas, constructivists would conclude that learning is an internalized process which may be improved by understanding a student’s current knowledge and facilitating the shift from the old understanding to the new, as described well by Leach and Scott [LS04, p.88]. As mentioned above, Vygotsky referred to this as the ZPD (Zone of Proximal Development) [Vyg78]. Successfully supporting science learning must attempt to find a balance between the need to acquire a body of knowledge and the need to apply knowledge learning to a problem so that it can become generalizable and reusable. A VLE which supports a constructivist paradigm should provide students (and their teachers) with an opportunity to explore their current thinking so as to facilitate the construction of knew knowledge from old knowledge. Leading experts who are endeavouring to build such environments refer to this as “making thinking visible” [Flo94][Lin06, p.46][BBC00, p.220]. The EVE Portal requires a body of knowledge to explore; the information can be retrieved from any number of sources whether computer-based or not, however, the aim of the EVE Portal is to support the inquiry process while also making the students’ thinking visible to peers and the teacher. The EVE Portal aims to support learning by encouraging students to explore their current knowledge of a topic through writing and seek feedback from peers and their teacher in a social constructivist manner. Research efforts of the students using EVE remain focused on the production of collaborative document and do not rely on the presence (or threat) of a final test to drive the process forward. Thus, learning within EVE ”occurs within a social context” [Kos96, p.270] and is certainly well grounded within a constructivist paradigm.

When these various important works and theories are viewed from a software development perspective it would be disingenuous of any educational software developer attempting to achieve any form of deep learning to develop simple "drill-and-skill" interfaces. The cohort of educational technologists who recognize the importance of educational theory have attempted to construct software that can at least address some of these educational constructivist goals.

For example, as discussed earlier, Dougiamas refers to "social constructionism" as the philosophy for the development of Moodle [Wil07]. Dougiamas, who holds an honours degree in Computer Science, felt so strongly about the influence of pedagogy in learning environments that he undertook a PhD in Education to understand the differing approaches to education, and how "ideas can be encoded in software" [Wil07]. Dougiamas expresses the opinion that educational concepts and approaches can be encapsulated in educational software. Dougiamas contrasts his approach to developing educational software with other systems that simply provide information followed by quizzes. As mentioned in the introduction section, how far Dougiamas has managed to encapsulate social constructivism is perhaps debatable [Wel07], however, there is no question that Moodle has certainly made an impact in the educational technology sector with more than 15 million [Moo06] registered users. It is certainly a reasonable hypothesis, when considering the success of Moodle, that considering pedagogy during the early development of educational software in conjunction with stakeholder involvement will increase the likelihood of acceptance by the end-user community. Similarly Dongming et al., [DHM05] refer to the need for conceptual models for learning environments to be "rooted in strong pedagogical principles". Dongming et al., continue by contrasting the instructivist (referred to as the "objectivist learning model") paradigm with the constructivist learning model. Boyle [Boy04] (director of the Learning Technology Research Institute) refers to the instructivist approach to educational technology as viewing the "computer as teaching" machine and the constructivist approach as the "computer as a basis for constructing learning environments". Boyle goes on to suggest that ensuring pedagogical quality is a challenge for educational developers. In a recently published literature review by Osborne and Hennessey [OH03] they include an entire section entitled "ICT use and pedagogy - an inextricable link". In this section they emphasize that software for use in schools must take account of the environment and current teaching practices if it has any hope of being adopted: “Successful integration of ICT depends then on development of an appropriate pedagogy” [OH03]. Squires and Preece [SP99] report that “for most educationalists, constructivism offers far more scope for realizing possible learning benefits of using information and communication technology”. In a recent article by Anastasiades [Ana03] (from the University of Crete), reference is made to educational software policies produced by the American Distance Education Consortium [Con07]. According to Anastasiades this group have defined principles for the development of educational software that is for both distance learning and face-to-face, the principles include the statement that “learning environments must include problem-based as well as knowledge-based learning”. This is an acknowledgment by ADEC that the pedagogical practices applied to a learning environment have an influence over the success of the tool, but specifically recommends the problem-based approach in conjunction with knowledge-based approaches.

After reviewing the literature it is overwhelmingly evident to those who are endeavoring to development software for use in schools that the encapsulation of a constructivist paradigm within software is the most widely supported approach and is endorsed by experts that have the educational objectives of the students as the central goal. The EVE Portal has been developed within a constructivist pedagogical viewpoint. It relies heavily on the production of research papers that are written by teams of students. These research papers provide a collaborative method for reflecting on learning outcomes and provide a means for students to assess their own learning experience. During the course of this thesis it will be shown that the focus of the EVE Portal has always been within the constructivist model of education as the entire VLE has been designed on the principle that students are at the center of the learning process and are directly responsible for the creation of the collaboratively written documents. In fact, it could be argued that the EVE Portal has a greater foundation in constructivism than some of the widely used environments since it is not an information portal and has not made any attempt to provide quiz-based assessment. The ability to assess student output is important to teachers and the assessment of the quality of the students' work within the EVE Portal has been shown to be achievable through examination of the student papers, this will be discussed in detail in Chapter 3. Therefore, the EVE Portal offers teachers an opportunity to guide students' exploration without losing track of the educational objectives.

2.5 Inquiry-based learning using ICT

In a recent workshop on inquiry-based learning Woodgate and Fraser [WSF07] (University of Bath) define inquiry as a "student-centered, active learning approach which is based around activities such as asking questions and solving problems". Woodgate and Fraser also put forward the thesis that science provides "an ideal context for inquiry based learning, as professional science practice involves the utilization of just such skills" [WSF07, p.2]. In an earlier publication, Woodgate and Fraser [WF05] define e-Science as the "use of ICT in education, to enable local and remote communication and collaboration on scientific topics and with scientific data". Science education can be viewed from different perspectives. There are those that see science as a body of knowledge to be assimilated by the would-be future scientist and there are those that view science as a process of discovery, a skill which can only be acquired through the participation in more open-ended investigations. The latter of the two approaches is recognized by most experts as being the most likely to foster deep learning. Driver believed that the foundations for this type of thinking are attributed to the work of Bruner [Bru63] who concluded that this type of approach "helps pupils to apply ideas to new situations" [Dri83, p.2]. According to Driver one of the positive shifts in educational approaches in the last few decades has been the "rejection of science as a catalogue of facts" [Dri83, p.2] and the recognition of the need for "pupils' own inquiries" [Dri83, p.74]. Osborne and Hennessy [OH03] describe the historical background for this change in thinking and use the example of Thomas Huxley (a famous British scientist who promoted science education) to put forward the point that "scientific inquiry was much more significant than content per se" [OH03]. It is this type of inquiry-based educational approach that underpins many of the existing open-ended VLEs, including the EVE Portal. The tenet of our e-Science inquiry-based approach is that the writing of a team-based research paper ties together all of the research activities of a group of students. This places the emphasis on the writing task, thus, students are free to access and include information relating to the task from a variety of sources, whether they are paper-based, online or in the classroom; in most modern schools there is no shortage of information available to students and the core skill to be acquired and practiced is the focused acquisition and summarization of the various information and data into some salient piece of work that is most important.

The idea that inquiry-based learning can be supported using ICT has been emerging for decades. The work of Papert [Pap93c] is still frequently cited by researchers who are developing constructivist software. Papert [Pap93c] developed the LOGO environment to engage students in activities and to learn from their experiences through experimentation. The LOGO environment allows young students to create computer programs and easily control the movements and behaviours of graphical elements and/or robotic hardware. LOGO achieves its empowerment by allowing the students to freely experiment and explore the parameters input and the effects on the behaviour of the hardware or graphics. The LOGO environment certainly demonstrates that computers have the ability to empower younger minds, however, the focus of this software was very specific to computer programming and the technology available at the time meant that there were practical issues with its deployment to schools including software installation and other related costs. LOGO was seen by Papert as heralding a new era of liberation from formal schooling, however, as McFarlane puts it: "Whether or not LOGO ever was the tool to change the face of education beyond recognition is debatable." [McF97, p.4]. Linn et al., [LDB04] creators of the WISE VLE, highlight the following important conclusions to be drawn from Papert's work: firstly, "pedagogy for teaching with technology needed substantial improvement" and "supporting students as they worked in small groups on computers demanded new approaches" [LDB04, p.10]. Secondly, they point out the limitations of the skills acquired by programming in LOGO stating that students struggled to apply the knowledge gained using the LOGO environment: "Criteria important in programming were not readily applicable to, for example, the design of an investigation of fruit fly genetics" [LDB04, p.10]. Papert is widely recognized as one of the pioneers of the use of computers using a constructivist pedagogy. In more recent times Papert [Pap00] has described how computers can support discovery learning. He describes how a young girl discovered the meaning of zero when she explored with the speed setting of a robot and made it equal to zero [Pap00]. The use of the computer helped her to form the idea that zero itself was a value. Papert states in this article that it is not the use of computers by children that is important, but formation of the "ideas" which come about while using the computer, and he states that "the constructivist use of computers increase the likelihood of such encounters" [Pap00]. It is this type of discovery learning which the EVE Portal intends to invoke through team-based writing tasks while also accepting that this discovery learning must be carried out in the existing school setting with the teacher as guide if it is to be successfully adopted.

Later learning environments, such as Computer-Supported Intentional Learning Environments (CSILE) utilized the networking capabilities of computers so that students could carry out investigations as groups rather than individually [SB94, TPR+92]. The CSILE environment enabled students to upload text or graphics (nodes) to a communal database, other students could then comment on the information stored by others. CSILE was designed as a collaborative learning environment within a Local Area Network. The CSILE environment, similar to the EVE Portal, attempts to give students a sense of the processes that real scientists engage in, including continuous peer feedback and long-term discussion which results in a high level of collaboration between the participants. The CSILE was, however, limited in its availability by the technology that was available in the early 1990s. The Internet now provides an ideal environment for team-based inquiry activities where groups of students, not necessarily co-located can work together to achieve a goal. The Internet is the medium through which most cutting-edge inquiry environments are being developed and the EVE Portal, and other similar Web-based VLEs, seek to avail of the Internet's accessibility as it provides a direct channel into the school environment.

Many inquiry-based environments currently exist, for example, Linn, Davis, and Bell [VLE07, Lin06, LDB04] have developed an inquiry-based science learning environment called Web-based Inquiry Science Environment (WISE). This environment contains a set of integrated tools to support and engage students in inquiry-based activities including collaborative analysis and reporting. Students using WISE have the opportunity to investigate and examine real world evidence and analyze real world controversies, specifically the environment engages students in the intentional process of "diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments." [Lin06]. WISE also provides an automated guidance system which prompts and hints to the students as they follow an inquiry process. Teachers can also get involved in the inquiry process by interacting with small groups of students and by customizing the projects. WISE shares many of the goals of the EVE Portal, however, the EVE Portal focuses the attention of each group toward the production of a final research document and provides the means to write and evolve a document using the CWE. WISE has evolved to become completely Web-based and "does not require installation" [LDB04], which has contributed to its ease of accessibility. This has been one of the main technical goals of the EVE Portal development since the project began; namely the provision of a completely Web-based solution simplifies deployment to the school environment and maximizes availability.

The difficulties of introducing a science inquiry system into the school environment have very recently been reported in detail by Underwood et al. [USLF08]. They report on the "hidden" work involved when attempting to create an "e-Science" learning environment for schoolchildren and their teachers. Their paper very clearly establishes many of the concerns and research questions that educational technologists face, in particular, those researchers attempting to make an impact within the school environment: "Teachers and learners need to have the knowledge and skills to make use of the technology within practical time and resource constraints of school life" and "if we are to move e-Science into the classroom as a routine feature of learning science, it is timely to turn our attention to the questions of what support is needed to enable teachers to take up the potential offered by e-Science". Underwood et al., also present the School E-Science Network for Study of Environmental Science (SENSE) environment as an example of an inquiry based authentic science learning environment. Using SENSE the students, teachers and scientists collaborated on a science project which involved "accessing data from remote sensing devices, gathering and sharing data using hand held sensors and the Web and communicating using chat and videoconferencing". This project also involved direct communications with experts via Web-based communications. The Web-based collaborations described by Underwood et al., are certainly rich in content and the level of communications and collaboration was very high, however, as Underwood et al., acknowledge, the teachers had reservations about the amount of "time, effort and skills" needed to run these types of inquiry-based activities. The EVE team have acknowledged these concerns by designing an environment that is simple in its use and in its learning objectives.

Another well published example of an inquiry-based learning environment is the Digital Document Discussion Environment (D3E) developed at the Open University [Lau03, SBS98, Sum00]. This environment allows the teacher to post a resource (usually a document) and engage students in discussions relating to the resources. This environment operates as an asynchronous network which allows students and teachers to enter discourse about a topic or article. Laurillard, head of the e-Learning Strategy Unit at the Department for Education and Skills and leading researcher in the field of ICT in education, describes the D3E as an environment to allow students to engage in online discussions and to communicate and feedback ideas relating to documents available to all members of the group. The environment is described as being analogous to a "reading group or seminar" except that the asynchronous nature of the environment has the advantage of providing "reflective responses" as opposed to the more "cut-and-thrust" nature of face-to-face discussion [Lau03]. This environment provides the educator with the ability to set a task for the group and have students then comment on their practice. According to Laurillard, this feedback and reflection leads to "intrinsic" feedback, an important factor in learning. This learning environment also provides scaffolded help to the student and provides "Guided investigation (e.g. descriptions of characters) and analysis of the relations (e.g. comparative evidence of social relations) between digitized source materials (e.g. poetry, artefacts), with model answers (e.g. academic's and experts' views) as feedback" [VLE08]. The D3E Webpage [VLE08] describes how the environment can be used in its "Full" form or in "Ubiquitous" form. The "Full" form allows the owner of a document to publish that document, for example, from a word processor into the discussion interface. This Web interface then provides discussion support for that document. The "Ubiquitous" form allows any URL to be imported in the discussion and for the discussion to center around that URL, thus providing the ability to discuss any digital document.

The D3E environment has been created using a clearly defined educational framework known as the Conversational Framework (CF) [Lau03]. The CF is of interest to researchers attempting to create environments for inquiry-based learning through discussion and discourse. Using this framework as a theoretical foundation, Laurillard specifies the essential characteristics for a successful inquiry-based learning environment. The CF is a framework for designing learning activities and is based on the "characteristics of an effective learning encounter" [Lau03, p.28]. The CF covers many aspects of effective learning. Laurillard believes that true learning must aim to address all aspects of the CF in order to maximize the learning capabilities of a VLE, she also describes the factors for an effective learning encounter including:

- Discursive Process: Student and teacher must be able to discuss the subject matter

- Interactive Process: Carry out some task relating to the subject and provide feedback on that task

- Adaptive Process: Links the theory to the practice, i.e., allows the student to adapt their actions based on the feedback and the comparison to the theory

- Reflective Process: The opportunity to reflect on the task and theory and adjust internal concepts to make the next experience more successful

Laurillard's work provides a means for us to define the type of environment we have constructed and also provides an opportunity for us to compare the types of learning activities which take place using the EVE Portal with other similar environments.

2.5.1 The EVE Portal inquiry-based learning environment

Similar to D3E the EVE Portal encourages interaction and communication between students and their teacher using the commenting context (a text based feedback mechanism used by student carrying out a group project). The EVE Portal, like D3E, provides the openness necessary for inquiry-based activities, i.e., it is not provided as an informational source, but to support the inquiry process. Laurillard [Lau03] states that the D3E VLE provides an "extremely powerful learning environment" and that it addresses the CF extensively by providing discursive, interactive, adaptive and reflective processes. Similarly, the EVE Portal provides all of these processes and also bonds these discussions and interactions into a final research document. The discursive process is supported by the commenting context; the interactive processes are supported via the assignment generation and completion; the adaptive process is supported through feedback by students' peers and by their teacher; finally the reflective process is supported through the production of a collaboratively written research paper that can be written over many days or even weeks. In addition, the EVE Portal formalizes the concept of a group and teams within the software and provides mechanisms to ensure inclusiveness within the group [BRWK07]. Laurillard states that learning environments like the D3E can “enable students to act in some way like scientists - experimenting, analyzing, discussing, comparing, interpreting” [Lau03, p.50]; the EVE Portal shares the aim of engaging students to do science and engage in discourse relating to the subject under investigation. The EVE Portal is designed so that the emphasis of the teamwork and collaboration carried out during scientific investigation is centered on defined projects, and the focus within those projects is tied to the production of a research paper. None of the existing environments within the literature has such a central focus on the written report and few provide the means within the software to define projects, teams, and to complete the writing process within an integrated environment.

2.6 Supporting Authentic Science Learning using ICT

Authentic science learning using ICT places the student in the role of the scientist. Since the beginning of modern science writing has been central to scientific advancement. Scientific investigations involve the formulation of hypotheses, the gathering of data to support or reject the hypotheses and finally the production of a written publication through which conclusions can be drawn. Nowadays, this process most often involves collaboration between peers and, therefore, collaboration with peers is central to authentic science learning. Mercer et al., [MDWS04] (Cambridge University), have conducted important research which has linked group-work to improved science learning. In this article they concluded that “under certain conditions computer-based activities for groups of children are effective in promoting the development of scientific understanding” [MDWS04]. In a very recent publication Mercer et al., [MDW$^+$07] have referred to this type of collaboration as "providing an authentic audience of peers for their writing"[MDW$^+$07, p.12]. Driver [Dri83] has referred to the fact that the modern view of science is that it is a "cooperative exercise as opposed to an individual venture"[Dri83, p.2]. The EVE Portal encapsulates the concept of collaboration through the CWE [BRWK06, BRWK07]. Authentic writing assignments, using a constructivist model should be delivered concurrently with student reading, investigation and research and would require the use of portfolio-based techniques as outlined by Haines [Hai04] who suggests that ICT is an essential tool in assisting peer- and self-assessment in authentic social constructive learning environments, be they virtual or real. The need for collaboration in authentic learning is also stressed by Erkens et al. [EPJ06, p.234]. The contention that computers can aid in this process is a view held by many well-published authors, including Barton [Bar04] who states that "discussions between pupils and the teacher, facilitated by the computer-based method, could support pupils to become more effective in describing graphical data, and hence in analysing the results of their experiments" [Bar04, p.37], but Barton also states that "we have yet to feel the full impact of the possibilities it [using computers in practical science] offers".

Schools are multicultural and are now equipped, for the most part, with a great deal of computer technology that can be better harnessed then they are presently to produce authentic science learning. Authentic science learning, according to McGinn and Roth [MR04], relates to teaching, enculturation and preparation of science students for competent and authentic scientific practice or utility in modern society, preferably within a social constructivist paradigm. Notable features of authentic science learning include the introduction of "developmental corridors" as represented in the Open Classroom or FCL [Bro04], optimal and supportive trajectories in science education relying on strong links between primary, secondary and tertiary curricula and emphasis on the importance of such trajectories from school to communities [MR04]. It is important that authentic scientific learning promote peer-group, student-teacher and other social interactions, for example, meaningful comparative discourse focusing on boundary objects (graphs, presentations, reports, etc.) resulting from visual representation activities. Peer groups discussion is particularly important as it assists identification of broad agreements and disagreements following supporting activities. Authentic science learning encourages the incorporation of selected experts, or expert groups with differing theories and practices, in dialogic social interactions to provide a realistic learning context for the students. The CWE has encapsulated within the EVE Portal a mechanism to test these interactions within an authentic science learning context. Laurillard [Lau03] states that learning environments like D3E can enable students to act in some way like scientists; the EVE Portal shares the aim of engaging students in completing science investigations, however, the EVE Portal also recognizes the important role that writing can play in authentic science learning and this coincides well with how teachers and students already use computers in the classroom. The investigating, experimenting, analyzing etc., are captured and summarized as one piece of research work in the same manner as the scientific community in general. The EVE Portal has collaboration at its core, in fact, the concept of the team has been fully encapsulated into the software and teams can be created and assigned to projects within the EVE Portal [BRWK07]. This type of collaborative approach is also at the heart of advancement in the scientific community. The literature provides a great deal of support for the contention that writing has an important role to play in supporting authentic science learning, much of this supporting literature is discussed in the next section.

2.6.1 Collaborative Writing in Science

Central to scientific practice is the production of written documents, which are presented to peers and the scientific community for review and discussion. An authentic scientific learning environment scaffolds the writing of such documents (planning, structure and content). Ideally, authenticity in the curriculum encourages different types of scientific writing and has the expectation that students are capable of reading and constructing different types of scientific articles intended for different audiences [MR04]. Collaborative writing, whether through ICT or not, plays an important role within scientific and technical communities. It is through writing that new theories are documented and from these new ideas emerge. It is common practice for large scientific or technical documents to be written by teams rather than individuals. Collaboration within scientific writing can have "real value" according to a book on writing for academic journals by Murray [Mur05, p.184]; she also states that allowing others to provide feedback on your writing can "help you to clarify a point in your argument; in fact, it can persuade you to clarify a point that you thought you had already stated sufficiently clearly" [Mur05, p.184]. In a book by Beer et al., [BM05] about writing in Engineering, writing documentation as a team will lead to "far more knowledge, skill, and creativity than you can bring to a project alone" [BM05, p.38], Beer et al., also state the importance of sharing work openly while collaborating so that the final document is both "unified" and "seamless" [BM05, p.38]. Additionally they describe how a collaboratively written document requires the team to communicate, coordinate, collaborate, cooperate and compromise. During the writing phase of an EVE project the schoolchildren use the CWE to produce a written research paper to summarize the findings from their investigations. The CWE allows students to provide immediate feedback to each other via comments giving the students some realistic experience of how scientific writing takes place. The CWE provides software support for students and teachers to:

- communicate via the commenting context within the writing interfaces

- coordinate the writing process by assigning teams and sections to each of the students
- cooperate in the decision making process by examining the various contributions made to the final document and work together to complete the document
- collaborate by sharing their findings within their team and allowing others to actively comment on their work
- compromise by accepting other student's comments so that the team can reach their goal

The CWE ensures that each student in a team provides input into the final research paper. The CWE, therefore, provides an environment through which each student can experience realistic aspects of writing as a part of a team. The following section examines many of the existing CWEs and discusses the EVE Portal CWE within the context of these other similar environments.

2.6.2 Collaborative Writing Environments

The development of software to support collaborative writing is not a new, in fact, there are several tools available including, Quilt [FKL88], GROVE [EGR91], SASSE [BNPM93], Collaboratus [LANJL02a, LANJL02b], CoDE [Pun06], TC3 [ERJ+05, EPJK02] and Wikis [BDH05]. Of the collaborative environments reported in the literature the TC3 appears to have most in common with the EVE Portal, although the context for the writing and the level of collaboration are different. The TC3 environment was developed at the Department of Educational Sciences at Utrecht University by Erkens et al., [ERJ+05, EPJK02]. The TC3 environment also places a central focus on the writing task and the tool supports collaboration in pairs rather than small groups of children. The TC3 provides an environment through which "pairs of students can write argumentative essays collaboratively. This environment combines a shared word processor, a chat facility, and access to a private notepad and online information sources". The TC3 tool is an application and is not designed to operate within a browser window and so loses much of the accessibility available via the Web, however, it does share with the EVE Portal the focus on writing that many VLEs with similar educational goals have overlooked. Collaboratus [LANJL02a, LANJL02b] is a CWE that has been evolving for a number of years culminating in the creation of a fully Web-based solution. Lowry et al., [LANJL02a] have constructed Collaboratus for use by US government employees in the writing of Department of Defense materials and have found that these tools help greatly in the reduction of the time it takes to produce quality documentation. While providing support for collaborative writing, Lowry's target population (government officials) is very different to the EVE Portal's target population (schoolchildren and their teachers). In this article Lowry et al., [LANJL02a] list thirty lessons from their experiences developing CWEs. Among the important lessons are that this type of software must be prototyped and field tested if it is to succeed. Also they state that the development of collaborative writing software should be iterative and that "following an appropriate process in CW is just as important as using the right technology" [LANJL02a]. Mitchell et al. [MPB95] (from the University of Toronto), reported on the use of a commercial collaborative writing tool with children in grade six. They reported that they were very encouraged by the use of the collaborative writing technology by the children and that the children produced a 32-page magazine, however, one of the design recommendations they had extracted from this trial was to "provide tools appropriate to the users' level of expertise". The CWE developed with the EVE Portal has been iteratively developed with direct involvement from schoolchildren and their teachers. This CWE has been developed to work in a Web browser since its inception, thus providing a more appropriate, custom-built collaborative writing tool for schoolchildren.

During the course of the EVE research project the emerging role of Wikis for collaborative writing in education has also been explored. Wikis are general-purpose pieces of software, which allow multiple people to collaborate in the creation of a single document or group of hyperlinked documents within a Web environment. Probably the best known example of a Wiki is Wikipedia [Wik08], an encyclopedia entirely written by the Internet community. Wikipedia is a Web phenomenon and is a well-publicized example of Wikis supporting collaborative writing on a global scale. Wikis are used in the school environment to facilitate collaborative work [Not06] and are making an impact within schools and universities [BDH05]; for example, Moodle [Moo06] contains a module to provide Wikis within its environment. Although Wikis can be used in many educational contexts, they were not designed specifically for this purpose. One of their great strengths is their flexibility; users can edit documents, hypertexts, and also the structure of these materials. Wikis are not currently designed to produce highly structured documents akin to those expected within some educational contexts; this can impede their use for some more formal applications. However, Wikis are being enhanced to provide a more structured canvas for students to work on [HLS05][DIZ06]. Furthermore, Lund and Smordal [LS06] stress the importance of software support for the teacher when developing future Wiki software for use in education. Unlike Wikis the EVE Portal CWE was not initially developed as a general-purpose tool, instead it had a very specialized role within an educational context. The CWE is built within existing pedagogical models of mentors/teachers, groups/classes, teams and projects. The environment encapsulates class, team and project management, online research and information gathering, resource sharing, and communication between team members and their teacher or mentor, as well as providing an interface for collaborative writing. The EVE Portal CWE and the related initial trials are described in detail in Chapter 4.

2.6.3 Encapsulating Collaboration in VLEs

The term "collaboration" is very broad, for example, Erkens et al., [ERJ+05] give the following definition: "A collaborative learning situation may be defined as one in which two or more students work together to fulfill an assigned task within a particular domain of learning in order to achieve a joint goal". Online Collaborative Learning Environments (CLEs) have received much attention in the recent literature, and in a recent editorial Ligorio and Veermans [LV05] describe a CLE as "a tool to enhance collaboration within the classroom as well as across classrooms". They argue definitively, from the outset, that CLEs can only be effectively used as a tool to support learning when meaningful pedagogical models are implemented. CLE is the generic term used to describe a variety of related frameworks (for example, Collaborative Virtual Environments, Powerful Learning Environments, Computer Supported Collaborative Learning, etc.) that have "adopted principles of student-centered, collaborative, and problem-driven learning". The importance of pedagogical design for collaboration is echoed by Schwartz [Sch05] who evaluates the Innovative Technology for Collaborative Learning and Knowledge Learning (ITCOLE) project. The ITCOLE project, which involved the collaboration of a number of European universities, was focused on "developing innovative pedagogical models, design principles and technology for collaborative knowledge building to be used in European education" [Lea08]. Schwartz believes that the underlying social, technological and epistemological infrastructures of classroom activity, when combined with appropriate Web-based environments facilitate scaffolded knowledge construction. The EVE Portal development endeavors to evaluate how well a VLE adequately supports social constructivist learning paradigms [DAL+04] in a multicultural authentic science context [Rot95]. According to O'Hara [O'H04] collaborative software can have the effect of "equality of opportunity", meaning that the dominant and experienced students are not the only ones to benefit from the software. During the course of this research the CWE was tested providing firsthand experience of what O'Hara was referring to [BRWK07]. The CWE encapsulated this "equality of opportunity" by providing an interface to ensure that participation in an assignment was team-based. The effect of this was to ensure that each participating student was required to provide input into the final research paper being produced by the team. These collaborative writing trials are detailed in Chapter 4.

2.7 EVE's Research Context

This literature review has concentrated on E-Learning and educational technology and has spanned many of the research topics that have driven this project. In this section some of the most pertinent questions are outlined and placed in the context of the EVE Portal.

- **Can ICT play a positive role in pre-tertiary science education, and, is there a gap in our understanding/knowledge of how to structure software to support this learning?**

  Much of the literature presented in this review would suggest that ICT can play a positive role in pre-tertiary science education. The literature would also suggest that ICT is currently being used ineffectively in schools and that there is a highly active research community attempting to properly define the optimal use of ICT to support learning using ICT at this level. Moreover, the evidence from the literature would suggest that there is a gap in current knowledge regarding the best way to incorporate software into existing educational institutions, particularly at pre-tertiary level. The motivations of the EVE project have been firmly established within the literature and the EVE Portal provides one possible exemplar for inquiry-based software environments at pre-tertiary education level.

- **What are the pedagogical approaches for supporting science education at pre-tertiary level?. Furthermore, do these pedagogical considerations have an impact on the likely success of software to support science learning at school?**

The literature suggests that there are two contrasting pedagogical approaches to supporting learning, namely, instructivism and constructivism. Recent literature from leading experts would strongly suggest that the constructivist approach is the most likely to effect deep learning. Additionally much of the e-Learning literature in this field suggests that software to support learning must take account of the pedagogical approach being applied if it is to be successfully adopted. The EVE Portal has been developed within a constructivist paradigm and endeavours to support authentic science learning within this paradigm. The development and evaluation of the EVE Portal has put forward empirical evidence that it is possible for an amalgamation of software components to support authentic science learning within a constructivist paradigm and the related publications have added to the literature in this area.

- **Given that much of the literature relating to science learning using ICT suggests that focused group writing, collaboration and feedback from peers can improve learning, how can software be structured to support these aspects of authentic science learning?**

Much of the literature presented in this literature review supported the contention that collaboration plays an important role in authentic science learning. Additionally there is much evidence put forward to suggest that focused group writing and appropriate peer communication and feedback can effectively foster science learning. The EVE Portal puts forward a unified, Web-based software solution to support many of these important activities. The EVE Portal, within the context of the literature, presents one possible exemplar for the support of these inquiry-based collaborative activities. This thesis contributes to the literature in this area by reporting that collaborative writing, team-based management and assignments, data collection and the role of the teacher can be successfully encapsulated in a single Web-based learning environment.

2.8 Conclusion

Following this review of the literature, it can be definitively stated that there is no consensus exemplar VLE for pre-tertiary education. There are many environments which attempt to deliver the correct balance between functionality and pedagogy but no single environment has made a significant impact yet. The Mindstorms environment is perhaps the most famous example of an environment to empower younger minds, however, as was discussed, the application of this environment was very narrow. The open-ended nature of the word processor has meant that most schools use such tools, however, the use of these tools is often superficial and lacking in deep learning. The Moodle environment has certainly made a serious impact at tertiary level and to some extent at pre-tertiary level, however, it cannot be said to have made real inroads into regular usage at school. This may reflect the self-directed, distance education arena in which Moodle operates best. Environments designed for tertiary level education and industry have not ported well into the pre-tertiary arena, this coincides with the position of many leading educational technologists such as Underwood et al., [UU90] and Linn [Lin06] that software for use in schools should be designed with the specific target population in mind and with input from teachers and schoolchildren in the development process from inception to deployment. The main inference that can be drawn from the popularity of the Moodle environment is that open-source fully Web-based solutions are the likely form that educational environments will take in the near future. The EVE Portal has been designed through extensive inclusion of teachers and schoolchildren from the early inception to its deployment and is a 100% Web-based solution for this target population. It is not claimed herein that the EVE Portal represents the only examplar for the use of ICT in schools, however, it is put forward, based on the post-evaluation analyses of the VLE, that the EVE Portal represents an innovative view of the form that such software may take in the future. The following chapters describe the EVE Portal and detail the components and evaluations that took place during the course of its development.

Chapter 3

VLE Evaluations

3.1 Evaluating educational software

According to Scanlon [HS04] evaluation of educational software is an area that requires a lot of research focus: "Looking at evaluation, it is interesting that so few studies of the use of ICT do more than describe uses of the technology"; evaluation should include "evidence of learning outcomes, detailed accounts of the process of learning and both students' and teachers' perception of the learning experience." [HS04, p.198]. The EVE Portal evaluations have spanned many of the evaluation requirements mentioned here by Scanlon. The educational goals of the software were evaluated through a survey-based assessment of the student output from the EVE Portal; this survey was composed of closed-ended questions relating to the quality of the output from the students. Other qualitative analyses took place on the observational evidence gathered during the formative evaluations and regular discussion forums with participating teachers. Additionally, each iteration of the VLE was critically analyzed and its successes or failures toward the educational inquiry-based goals were used as the driving force for further development. This chapter details the evaluations that took place on the early versions of the VLE which focused on astronomy and provides a case study which demonstrates how the evolution of educational software can be driven by educational goals.

3.2 Introduction

The first phase of the development involved the creation of a prototype VLE followed by formative evaluations by 161 children. The aims of these evaluations were the refinement of the VLE design and to determine whether the VLE could support the engagement of children in a scientific process. The evaluations included the gathering of data via laboratory observations, analysis of Project Reports produced by children and a survey-based assessment of these reports by independent teachers. This chapter details the methodologies applied when gathering these data and the results of the analyses of the data. The analyses of the data have lead to the conclusion that an aggregation of software components can successfully support children carrying out astronomy projects using a scientific process. This study also highlighted some usability and practicality issues which need to be resolved prior to deployment in a school environment. Finally, this chapter provides empirical evidence that the VLE has been perceived by participants to support learning.

There are many projects in existence that provide schoolchildren with remote access to robotic telescopes from their classrooms via the Internet, for example, Telescopes In Education (TIE) [tel08], the Faulkes Telescope [ft08] and the National Schools' Observatory [sch07]. However, in order to fully utilize these great resources for astronomy projects a range of additional software tools are required. Students need access to sky simulation software to allow them to plan their use of the telescopes, image processing software to allow them to cleanup and process the images they obtain, image analysis software to allow them to extract meaningful information from these images and software to allow them to easily report on their work. Although there is a large range of free software available which provides much of this functionality, it is very time consuming to sort through these software packages to find the ones most suitable for use by children. It is also not possible to make good choices without an understanding of the astronomy and imaging techniques supported by this software. The majority of this software is targeted at amateur and professional astronomers and, therefore, not specifically designed for use by children or their teachers. The Virtual Telescopes in Education (VTIE) project [HdF$^+$02] provided Primary and Secondary students and their teachers with a prototype Virtual Learning Environment (VLE) consisting of a complete suite of software to support astronomy-based science projects. The VTIE VLE was not dependent on the use of Internet telescopes, as it may be used to undertake projects based on astronomical images from any source. There are many free repositories of astronomical images available on the Internet, for example, NASA's SkyView [sky08]. This flexibility allows a broad range of experiments to be conducted with the VTIE VLE. The goal of VTIE, which was encapsulated in the VTIE SISTER process [HKS$^+$03], was to encourage schoolchildren to become aware of scientific process, and apply this process in scientific investigation. Writing is at the core of this process as the students' work culminated in the production of a written report. The VTIE process was straightforward: the students pose a question; formulate an observation to answer that question; make observations or measurements; analyze results and produce evidence toward the original question. Finally, each group produces a written project report summarizing their work. Although the VTIE VLE is astronomy-based, the process is generic; therefore, many of the components that make up the VTIE VLE are applicable to other experimental sciences.

3.3 The software development approach used for VTIE

It has been well established that a user-centered approach to software development produces usable, higher quality, interactive software. Preece [PSR94], for example, indicates that software design should "be user-centered and involve users as much as possible so that they can influence [the design]" [PSR94, p.46]; this principle applies equally to the development of Web-based software [Nie93, p.10]. Nielson [Nie00] and Badre [Bad02] both emphasize the need for user-centered design when developing Web-based software [Nie00][Bad02, p.10]. The formative evaluations described in this chapter, therefore, focused on aspects of user interaction as well as the overall learning objectives of the VLE. The research carried out by Druin et al., [Dru02] is of importance to developers of child-centered software. Druin's approach to child-centered design is at the extreme end, in fact, children have become design partners during the development of software applications [Dru02]. The resources available to the VTIE team did not allow us to involve children at the design partner level. However, as described in this chapter, children have been involved in this project from the formative stages as testers in laboratory environments. Children have remained central to our development strategy as later versions of the VLE are tested within the school environment. Although the laboratory environment has helped demonstrate that the VTIE VLE can be used to support astronomy projects (verified by independent teacher surveys and our own analysis), it must also be suitable for introduction to the classroom. Therefore, in later evaluations substantial continued involvement by teachers in the design and development will be required. As outlined by Crosier et al., [CCW02] involving teachers gives them ownership of the software as well as giving them the opportunity to align it with the curriculum they must deliver. The importance of involving teachers is also stressed by Underwood and Underwood [UU90, p.17].

The VTIE VLE is a substantial system with a diverse range of interfaces and interactions. Software development, therefore, has been broken into three distinct stages, with each phase producing a milestone prototype. It is the iterative nature of this project that supports the formative evaluation approach. According to Nielsen [Nie93]: "Formative evaluation is done in order to help improve the interface as part of an iterative design process. The main goal of formative evaluation is thus to learn which detailed aspects of the interface are good and bad, and how the design can be improved" [Nie93, p.170]. We would define formative evaluation as an opportunity to actively explore the use of the VLE and to assess the positive and negative results so that the software can evolve to meet the requirements of the students and teacher within the school environment. Dede (Harvard University Graduate School of Education) states that "Educational systems greatly benefit from learning about the failures, as well as the successes, of the attempted innovations of others" [Ded99]. The formative evaluation approach has been supported by leading experts in the HCI field [PSR94, Nie93, DFAB03, SP04]. Several recent publications have reported the success of this type of evaluative approach in the development of educational technology [PR99, Wes04, TPD03]. Each of these researchers stated that it was the goal of their project to experiment with new software so that the systems could be continually improved to better serve the educational goals of the end-user. Phelps and Reynolds [PR99] reported that the formative evaluation approach provided opportunities to highlight any "implementation obstacles" and helped to "improve design". Similarly, Triautafillou et al. [TPD03] reported that the "results of the formative evaluations were used to improve our system". It is apparent that formative evaluations differ in their aims to a comparative-type study. Comparative studies compare one system's success to another. These types of study tend to involve the use of a control groups to measure the depth of learning achieved by one classroom using ICT with another not using software support (as recently reported by Carle et al. [CJM09]). A frequent characteristic of such comparative studies is that they involve the testing of well established technology and compare results to control groups using traditional teaching methods or different technology. The evaluations that took place on the EVE system were exploratory rather than comparative. The Summer Camps provided an ideal opportunity to assess the success or failure of the software, however, the Summer Camps (being of a promotional and inclusive nature) did not provide opportunities to exclude certain groups of students (to act as control groups). Scanlon sums up very well the approach that was used to drive innovation in the EVE project: "An instructional designer could use information collected during a formative evaluation, such as details of learner's use of the system, to help improve the design" [Sca04, p.199]. The EVE research project described in this thesis formed hypotheses that were exploratory and experimental rather than comparative and, therefore, were well suited to the formative evaluation approach as described by leading experts. This formative study chose a “particular method” and “evaluated with reference to the learning purpose” [Rog04, p.142]. Future studies which aim to measure the degree of the learning impact of the EVE Portal will require the formulation of comparative hypotheses and a corresponding modification in experimental techniques.

The first milestone prototype evaluations described in this chapter have identified the core components and services needed in the VTIE VLE. The evaluations have also identified the suitability of the software components for use with children and identified acceptable user interface elements. The VTIE development team consciously concentrated first on testing with children without the presence of their teachers. This is in line with work by Druin et al., [DBB+98] who concluded that children will be more forthcoming when there are fewer authority figures present. In conjunction with these software evaluations the developers constantly engaged in curriculum and operational discussions with teachers and other stakeholders. These discussions, combined with the results of the formative evaluations, will guide the development of the first full implementation of the VLE. Following the recommendations of Jones et al., [JST+99] this implementation will then be 'deployed' in schools and re-evaluated and improved until the system is considered complete. The prototype VLE was evaluated during three Science Summer Camps held at NUI Maynooth from 2002 to 2004. In total the prototype was used by over 150 children. One camp was held each summer over these three years and VTIE delivered a different session using the prototype VLE at each. These sessions are described in detail in Section 3.5 below. The data gathered included observational data, participant comments, and 37 Project Reports produced by small groups of children using the VTIE Paper Writing Component. The information and data gathered has been extremely influential in shaping the first milestone prototype. Teachers have aided us in our evaluations by completing survey-based assessments on each Project Report written by the participants. The sections that follow describe the prototype VLE and the methodologies and environments used for the evaluations. Finally, the findings and observations are discussed, and the results from teacher assessments are presented. The chapter concludes with an outline of the plans for further development following these evaluations.

3.4 The VTIE Virtual Learning Environment

The aim of the VTIE VLE was to provide schoolchildren with a set of tools to allow them to complete astronomy projects. The fist step in designing the VLE was to define the components that would make up the complete VLE. The list of components is shown in Figure 3.1, which shows the UML (Unified Modeling Language) Component Diagram for the VTIE VLE at the time of writing. As well as showing the components that make up the VLE, Figure 3.1 also lists the activities supported by each component and the components on which each activity depends. It was expected at the time of these evaluations that the completed VLE would also contain additional components for telescope scheduling and site-user communication, these were not evaluated as part of this study and have been omitted from the Component Diagram for clarity.

The prototype VTIE VLE evaluated in this study was composed of the components and supported all the activities shown in the UML Component Diagram. The prototype consisted of an aggregation of separate software components which together supported most of the activities shown in Figure 3.1. The majority of the activities were supported by third-party software packages; however, the 'Create Paper' activity was supported by the VTIE Paper Writing Component which was written by the VTIE development team. The remaining activities were supported without the use of software, for example the 'Scrap Book' component was provided by supplying the participants with pens, paper and $3\frac{1}{4}$" diskettes. When selecting the software to support each of the activities, the aim was to maximize our use of free software. With the exception of MS PowerPoint© and the software for controlling the telescopes all the third-party software used in our prototype

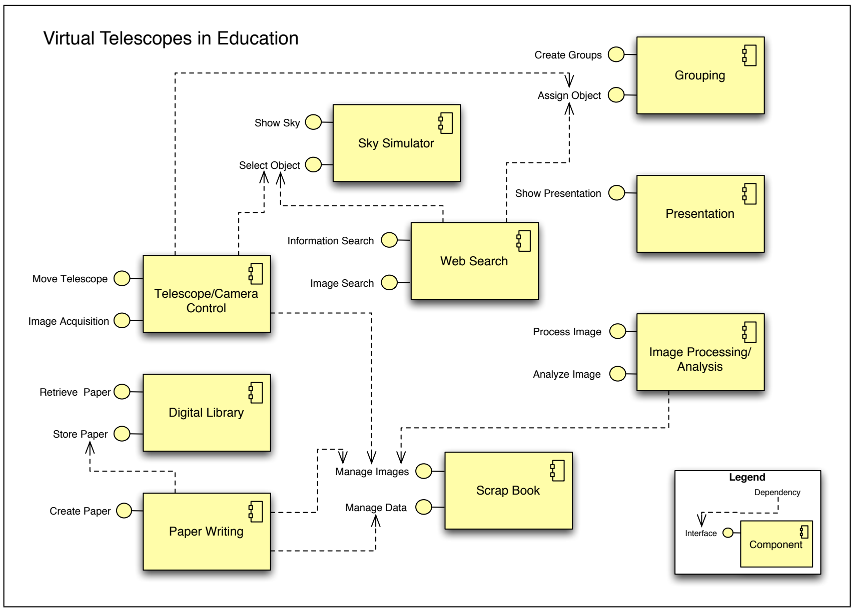


Figure 3.1: The UML Component Diagram for the VTIE VLE

VLE is free and available on the Internet. Table 3.1 shows how each activity was supported in the VLE. The prototype VLE evaluated in this study was the first step in the development process. These evaluations took place in a laboratory environment and not in a school environment; nevertheless, valuable information about the success of the VLE was extracted from these sessions. The results of this study have fed directly into the development of future prototypes which are better adapted to a classroom environment. Later evaluations will then feed into the development of the completed VLE.

Table 3.1: VTIE Virtual Learning Environment Components

Component	**Activity**	**Implementation**	**Year**
Presentation	Show Presentation	MS PowerPoint©	2002–4
Grouping	Create Groups	Performed Manually	2002–4
	Assign Object	Chosen from Hat	2002–3
Sky Simulator	Show Sky	SkyMap, TheSky	2002–3
	Select Object	SkyMap	2004
Web Search	Information Search	Google, Ask Jeeves	2002–4
		VTIE CD	2002
	Image Search	Google Image search	2002–4
		SkyView	2002–3
		VTIE CD	2002
Telescope/Camera Control	Move Telescope	TheSky	2002–4
	Image Acquisition	CCDSoft	2002–4
Image Processing/ Analysis	Process Image	CCDSoft	2002–4
	Analyze Image	CCDSoft	2002–4
		NASA VTT	2002–3
Scrap Book	Manage Images	$3\frac{1}{4}$" Diskette	2002–4
	Manage Data	Pen and Paper	2002–4
Paper Writing	Create Paper	VTIE Paper Tool	2002–4
Digital Library	Store Paper	VTIE Paper Tool	2002–4
	Retrieve Paper	VTIE Paper Tool	2002–4

3.5 Experimentation and Methodologies

In all, three iterations of the prototype VTIE VLE were evaluated. Although some of the software components were changed from year to year, the objectives of the VLE remained constant, i.e. to engage children in a scientific process and produce Project Reports summarizing their experiences. Each session had clear learning objectives that were presented to the participants before they used the VTIE VLE. All of the lab session activities were planned by the VTIE team prior to delivery. The VTIE VLE was used in three separate Science Summer Camps at NUI Maynooth between 2002–4. These camps were organized by the university science faculty with a view to promoting the uptake of science at tertiary level and largely targeted Secondary school pupils. The camps were held on the NUI Maynooth campus. A different theme was chosen for the astronomy sessions each year. A summary table giving the details of the pupil profile and the themes are shown in Table 3.2. Although there were many similarities in the way these modules were delivered, there were several key changes which were in part due to overall camp organizational changes, and in part due to experience gained in previous years.

Table 3.2: VTIE Astronomy Modules at NUIM Science Summer Camps

Year	**Theme**	**Telescope**	**Profile**	**Duration**	**Group**
2002	Spectrum	24" Mt. Wilson	130 (13–17)	3h	4–5
2003	Life of Star	14" Mt. Wilson	30 (16–17)	6h	2–3
2004	Galaxies	14" SoTIE Chile	20 (16–17)	6h	4–5

Profile refers to the number of participants, and the age range of the pupils registered for a specific module. Group refers to the number of pupils per group during the sessions.

In total, 161 children participated in VTIE astronomy modules. They ranged in age from 13 to 17 years with approximately equal numbers of females and males. However, these participants were not symmetrically distributed between the three years. In the 2002 Summer Camp, 120 children participated and all modules were compulsory, whereas in the 2003–4 camps participants could choose the modules they attended and 30 and 20 pupils respectively (approximately one third) elected to participate in the astronomy modules. This difference in numbers between the first year and subsequent years was partly due to participants being given a choice in the modules they attended as well as a dramatic drop in the over all number of students being admitted to the camps by the organizers. The organizers also took a strategic decision to only admit older schoolchildren (age 16–17) in 2003 and 2004.

The astronomy modules took place in the Department of Computer Science software laboratories. There were a sufficient number of workstations so that the children each had a computer. The working environment was consistent throughout the three years and facilitating staff, a Team Leader (VTIE project personnel) and several demonstrators (Department of Computer Science graduate students) consciously created an informal and relaxed working atmosphere for the participants. None of the staff were previously known to the children and all staff dressed informally and introduced themselves with their first names. Demonstrators were encouraged to make observations through participation and discrete notes were taken for later evaluation. Meetings took place following the laboratory sessions to discuss observations made during the sessions. Each demonstrator was charged with attributing a value judgment on the level of assistance requested for each phase of the session. A recorded value of '1' indicated little or no help was requested during that phase, and a value of '5' indicated that continuous or near-continuous assistance was requested. It was hypothesized that this type of participatory approach would yield better results as the participants would feel at ease.

Within each camp, multiple instances of the same astronomy session were delivered over several days and approximately 20 pupils participated in each session. Participants in each session had a similar age profile. The children were further subdivided into small groups of no more than five and no less than two per group. The groups were also randomly picked so that any existing group dynamics were eliminated insofar as possible. There was a minimum of one demonstrator per group. It was explained to the participants that the role of the demonstrator was to provide assistance and offer guidance on how the participants might accomplish each task.

Time constraints prohibited the pupils from carrying out all of the steps in the VTIE SISTER process [HKS+03], therefore, it was decided to remove the proposal generation phase and replace it with a simple process whereby each group chose an astronomical object to investigate in the context of a predefined theme. The themes chosen were: *The Electromagnetic Spectrum* (2002), *The Life of a Star* (2003) and *Galaxies* (2004). For the first two years, the children simply chose a preselected object from a hat. In 2004, however, the children chose their own object using sky simulation software. The participants' choice of object was constrained by predefined criteria relating to brightness and size. These criteria ensured that all objects were visible with the telescope the children used during the observation phase. The children used a different TIE telescope each year (an accident of scheduling): in 2002, the 24-inch TIE Telescope on Mount Wilson, California; in 2003 the 14-inch TIE Telescope (also on Mount Wilson); and in 2004 the 14-inch SoTIE Telescope in Chile. Figures 3.2, 3.3 and 3.4 show the various activities in each of the three astronomy sessions, the order and duration of the activities, and the flow of outputs from one activity to the next. All sessions started with an introduction of the module topic, the VLE was introduced, and some very basic astronomy concepts were explained by the team leader. This introduction included some general information on the telescope the children would be using. After the introduction the participants were broken into groups, each group then selected an astronomical object to study. In 2002–3 the groups randomly chose from a list of preselected objects, while in 2004, each group spent 30 minutes selecting an object using Sky Simulation software – this software shows astronomical objects visible from the telescope site at the time of the session. All modules included a research phase during which the participants assembled background information on their chosen object. The children also controlled the telescope and collected and processed telescope images during this phase. Finally, each group wrote a Project Report using the VTIE Paper Writing Component which automatically formatted the reports to look like a professional research paper (see Appendix A). These Project Reports were printed, and each participant was given a copy to take away from the session. As can be seen from Figures 3.2, 3.3 and 3.4 the output from each lab session remained constant, i.e. each group in each session produced a Project Report summarizing, in their own words, their activities and experiences during the astronomy session. The following three subsections describe, in detail, the operational aspects of each session in turn from 2002-2004.

3.5.1 "The Electromagnetic Spectrum"

The theme chosen for this camp was *The Electromagnetic Spectrum*. It was expected that the children would understand that all electromagnetic waves, for example, light and radio, are manifestations of the same phenomenon. Additionally the pupils were expected to learn that astronomers have instruments that can observe electromagnetic radiation outside of the visible spectrum. The pupils were also expected to understand why astronomers observe at many different wavelengths, i.e., that different types of information can be gained from images taken at different wavelengths. It was expected that this would become clear to the pupils when they superimposed images of the same object (their chosen object) recorded at different wavelengths using the NASA Visual Target Tuner (VTT) software. Figure 3.2 outlines the session structure, and includes the phases, the time allocated to each phase, and the software required for the activities in each phase. Before the session started, each participant was given a VTIE CD which contained reference material and some of the software that would be used throughout the session, for example, the NASA VTT [apt05]. The reference material contained a collection of hyperlinked Web documents. The participants kept

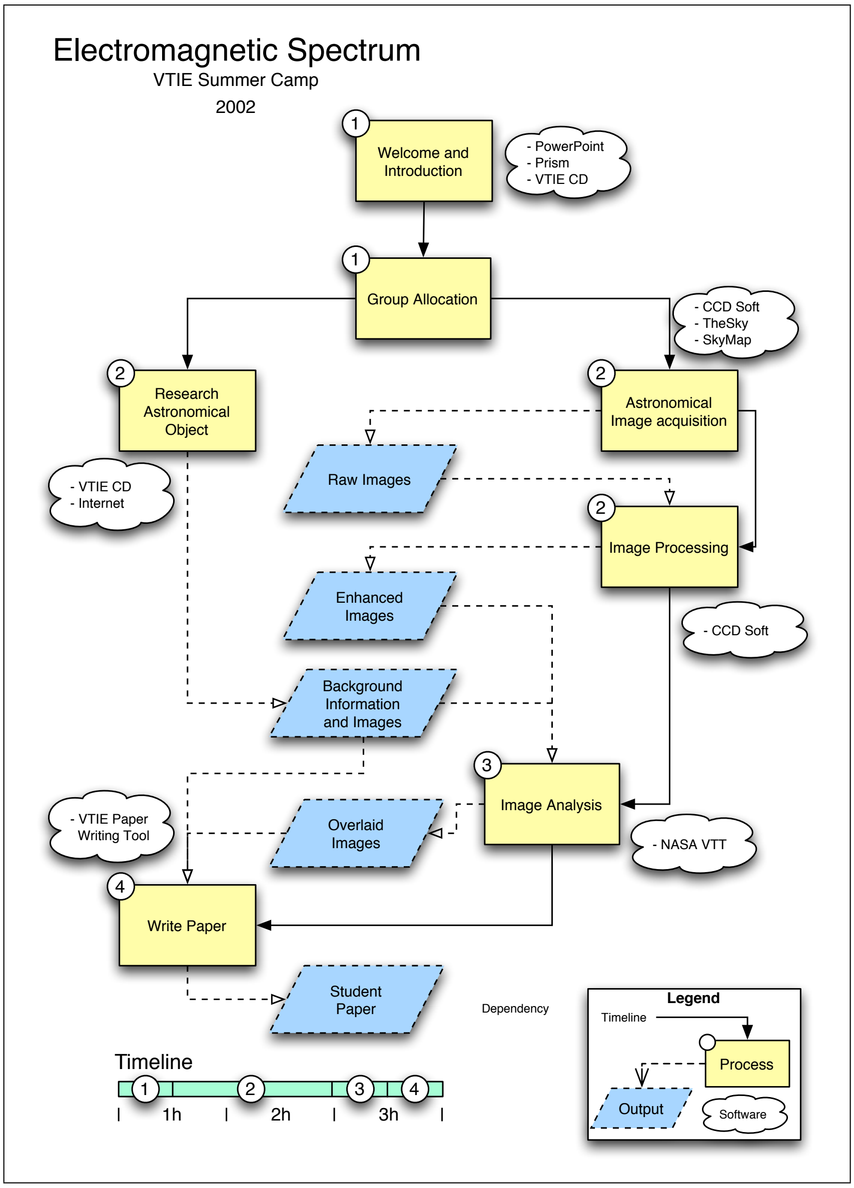


Figure 3.2: Summer Camp Activities: The Electromagnetic Spectrum

this CD, and were also given a *Milky-Way* chocolate bar to help 'break the ice' at the beginning of the session. The session started with the introductory phase during which the children were introduced to the electromagnetic spectrum. This introduction included a simple demonstration with a prism and a data-projector to project a spectrum onto a large presentation screen. Photographs of the telescope that would be used during the session (24-inch TIE Telescope on Mt. Wilson California) were also shown to the participants together with a current weather map for the area around the telescope site. Finally the children were also told that about the VTIE project and that the sessions they were taking part in were being used to test this software. Following group allocation and object selection, the children were expected to use the following sources to find out as much information as they could about their object and to collect images of that object at many different wavelengths: the VTIE CD, the Internet, and the 24-inch TIE Telescope on Mount Wilson. Two hours of the session were dedicated to researching the participants' selected objects. Since only one group could use the Mount Wilson telescope at any one time, and since there were four or five groups, each group got to use the telescope in turn for about 20 minutes. While one group was remotely controlling the telescope the other groups were researching their object or analyzing images they had already obtained. When using the telescope, each group was first required to obtain an image of their chosen object. In order to find their object the children had to find their object's coordinates and slew the telescope to those coordinates. Once the object was located, the children had to instruct the CCD camera on the telescope to take an exposure. The resulting image then appeared on the screen. The required exposure time varied depending on the object being captured, and it was up to the children to find a suitable exposure time through trial and error. Once they had obtained a good image of their object, they were free to use the remainder of their time on the telescope to look at anything they wanted. During the final stage of the session each group wrote a Project Report on their findings. The children used the custom-built VTIE Paper Writing Component to write their reports. This tool allowed children to concentrate solely on the content of their report as all the formatting was done automatically by the tool. This software presents the user with a straightforward, structured, Web form that allows them to enter all report content and meta-content in separate text areas. This tool was created in order to avoid situations where users focused more on the layout and aesthetics of their reports rather than the contents, as highlighted by Davies et al., [DO02, p. 102–124]. It was also possible to incorporate up to three images into the report. The Paper Writing Component automatically produced a PDF document that was formatted to look like a professional research paper (as shown in Appendix A). At the end of the week there was a prize for the group that produced the best report. The participants printed their papers and were each given a copy to take away from the session.

3.5.2 "The Life Cycle of a Star"

The Science Camp sessions in 2003 were twice as long as the previous year and were optional to participants. The extra time allocated to the astronomy module was used to visit the Experimental Physics department on campus where the children met a professional astronomer. Weather permitting, the children were also taken to the university observatory to directly observe the Sun with specialized solar filters using the university's 10-inch telescope. In this module, *The Life Cycle of a Star* (see Figure 3.3), the participants were expected to learn how stars are born, live and die. The children were also expected to understand where our own star, the Sun, fits into this life cycle. All of the pre-selected objects were in some way related to the life cycle of stars, for example, nebulae (clouds of gas and dust where stars form), planetary nebulae (dying stars), super nova remnants (dead stars), and galaxies (the places stars live).

As in 2002, the participants researched their object, used the telescope to obtain images of their object, and analyzed the images during the first half of the session. Our object pre-selection process and subsequent assignment, ensured that each group was looking at just one aspect of the life cycle of a star. In the second half of the session, particularly during the slide show and discussion, the children were introduced to the 'bigger picture' and could then place their object into this overall context. The visit to the Experimental Physics department further helped students to place their observations into context. Finally, during the report-writing phase participants produced a report using the same Paper Writing Tool as in the previous year.

3.5.3 "Galaxies"

The *Galaxies* module in 2004 was created because in the previous two years it was noted that the children demonstrated a fascination about galaxies, but had many miss-conceptions about them. During these sessions the participants were expected to learn about the composition of galaxies, the various different types of galaxies, and to understand the position of the Earth and the Sun within our own galaxy (the Milky Way). During the children's visit to the Experimental Physics department, they were expected to gain an understanding of the different tools that astronomers use to study galaxies. Figure 3.4 shows how the day was divided between working with the VTIE VLE and visiting Experimental Physics.

In contrast to previous years, the children were set 5 specific questions on galaxies in general and 7 on their chosen galaxy. This structured inquiry-based process focused the children's research while allowing sufficient flexibility for personal exploration. As with the previous two modules, the participants ended the day by writing and printing reports using the VTIE Paper Writing Component.

3.6 Results and Observations

Substantial information has been gathered through the course of our formative evaluations. This information has been obtained through laboratory observations of the VTIE sessions, through analysis of the contents of the children's Project Reports, and through a teacher survey of the children's Project Reports. Observational results were analyzed and discussed during meetings held following each session. The demonstrators observing in

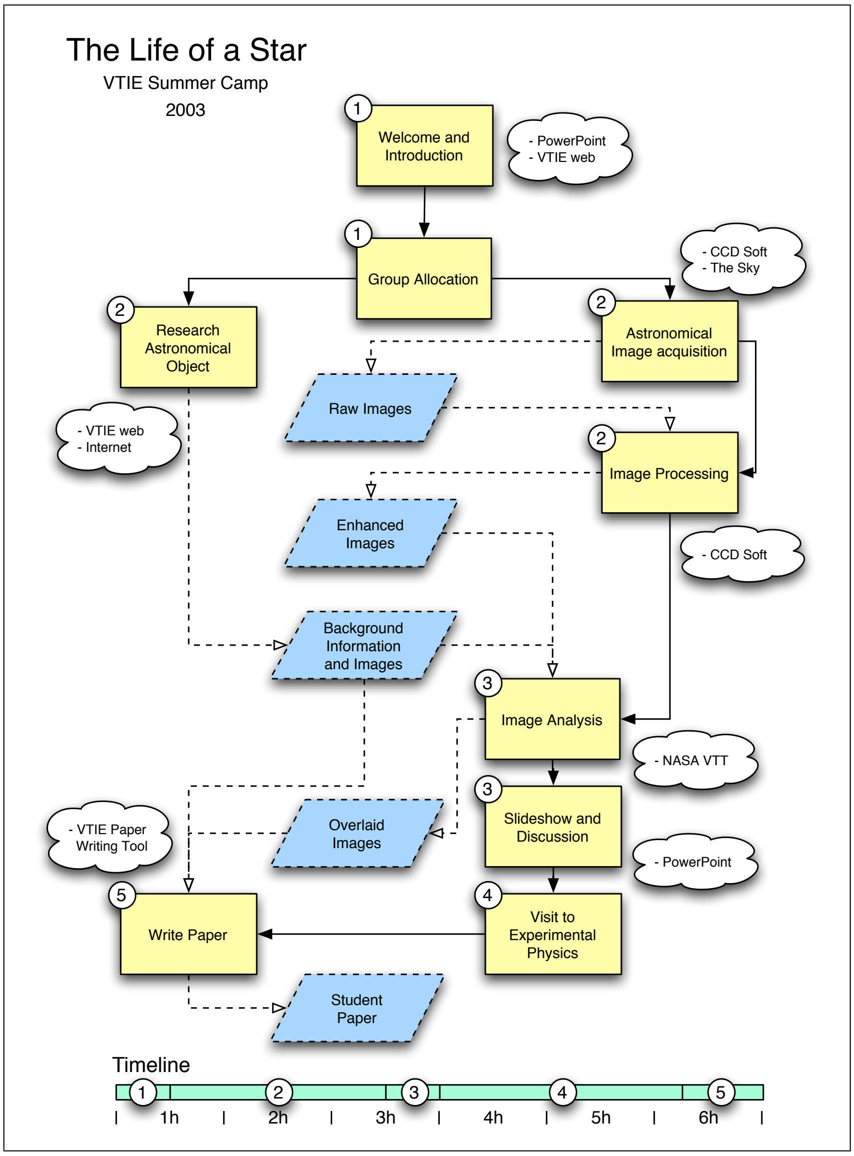


Figure 3.3: Summer Camp Activities: The Life of a Star

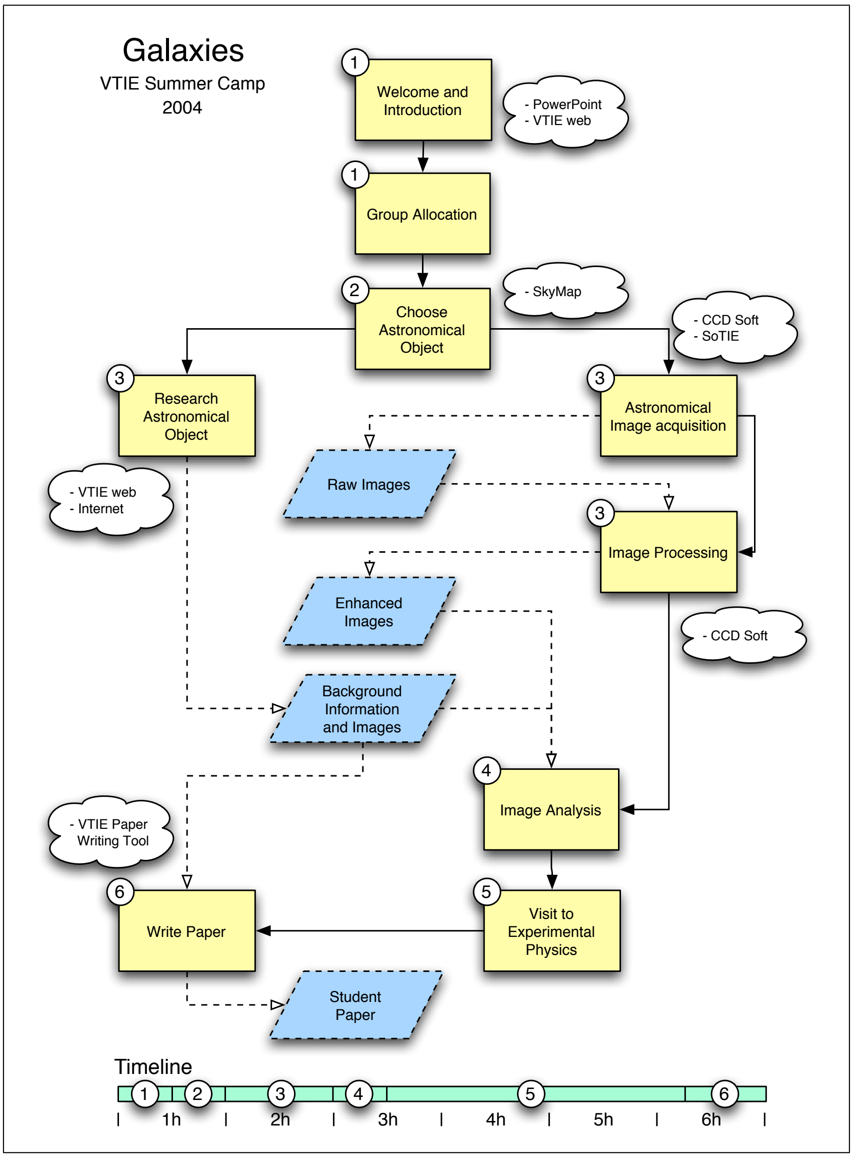


Figure 3.4: Summer Camp Activities: Galaxies

the laboratory were specifically instructed to observe the children's use of the VTIE tools during the laboratory sessions. Results were also obtained through our analysis of the output constant from all the laboratory sessions, i.e. the Project Reports produced by the children. Finally, 14 teachers participated in a survey-based assessment of the quality of the Project Reports produced by the VTIE participants. The following subsections detail the results, observations, and findings from these three sources.

3.6.1 Laboratory Observations

The results presented in this section are based on observations made during the Science Camp VTIE sessions at the university, as described in Section 3.5 above. The demonstrators were the main observers during the laboratory sessions. Each of the demonstrators was a post-graduate computer science student trained in software engineering techniques. The demonstrators were informed of the process that the children would follow, and they were asked to observe the children's use of the VTIE tools during the completion of that process. The demonstrators were instructed to record the level of assistance required by the children at the different stages of the process and to rank each of the VTIE tools heuristically in terms of the level of assistance required. VTIE development team members were also present during the sessions. Post-session meetings were held to collate all of the relevant information gathered during the sessions. A summary of the main findings from these observations ensues.

Table 3.3 shows the degree of assistance the participants requested from the demonstrators during each phase of the VTIE sessions in each year. The data in this table is derived from the post-session meetings and discussions with the demonstrators. Analysis of Table 3 shows that the children needed less help when researching their object in 2004 than they did in 2002 and 2003 (row 2 of Table 3.3). The only variation relating to how the children conducted their research was the introduction of a set of guiding questions to target the research in 2004. In previous years the demonstrators reported that the participants were continually asking them what areas they should be concentrating their research on, by providing questions to guide the children they needed much less assistance from the demonstrators during this phase.

In general it was observed that the children had difficulty achieving a smooth interactive experience given the diversity of the software tools in the prototype VTIE VLE. In order to complete their research the participants used a Web browser, to store information temporarily they used a text editor/word-processor, and to complete image processing and analysis they used stand-alone applications with a multitude of menu options. This result was not surprising as there was no consistent look-and-feel to the software, which was predominantly a collection of stand-alone programs written by many different people each with a different intended audience and notion of usability. Even with expert users to assist and explain the functionality of the software, the children spent much of their time trying to figure out how to use the software and tended to lose sight of their goals. The importance of consistency in constructivist learning environments has been emphasized by other researchers including Squires and Preece [SP99]: "Concepts and terminology should be used consistently throughout and application, and where possible they should be used consistently across applications". For instance, when the children used the image processing software they were prompted to enter background values and range values to enhance their images. As the children did not understand what these values represented, they were unable to provide meaningful responses. This was an important observational result for the VTIE imaging applications and may, to some degree, account for the high level of assistance required during this phase of the VTIE process as shown in row 4 of Table 3.3. The imaging tools currently used in the VTIE VLE make assumptions about the underlying knowledge of the user, knowledge that the children did not have. It was apparent that most of the participants understood the purpose of the imaging software and how the outputs related to the inputs but the tools impeded them. It was concluded that future imaging applications used in VTIE must be usable by children, be intuitive, and most importantly provide a context whereby the child-user can concentrate on the task at hand. The image analysis software developed as part of this research project was developed based on these conclusions and this is further discussed in Chapter 5 below.

As the children were each working at separate workstations it was very hard for them to share the information and images they found with the other members of their group. This was a major barrier to collaboration within the groups. Although floppy disks were provided to allow participants to share data, they required a lot of help with this because many of the children did not have the computer skills to find and manipulate the necessary files. Later versions of the VLE have addressed this limitation by providing a means of sharing data between members of a group without needing to leave the browser environment. Chapter 4 discusses the changes that were made to the VLE in order to achieve this seamlessness.

Table 3.3: Level of Demonstrator Assistance Requested by Children

	Spectrum (2002)	**Life of Star** (2003)	**Galaxies** (2004)
Choose Astronomical Object	-	-	3
Research Astronomical Object	3	3	1
Astronomical Image Acquisition	5	4	5
Image Processing	5	5	5
Image Analysis	5	5	1
Write Paper	2	1	1

The values in the columns above represent the average level of assistance requested by the participants, as measured by the demonstrators. A value of '1' indicates little or no help was requested, and a value of '5' indicates that continuous or near-continuous assistance was requested.

During the sessions it was observed that the less help the children required when using the software the more they appeared to enjoy the sessions. As soon as they needed to rely on the demonstrator's help to use the software, their interest levels dropped and they became distracted. This was particularly evident during the image acquisition phase of the process. The different ways in which the children interacted with the Telescope Control Software over the different camps demonstrated to us the effects of empowerment. In the first camp many of the children were too young to use the complex Telescope Control Software on their own so the demonstrators controlled it for them, this lead to some of the participants talking amongst themselves as their attention was drawn away from the software. In the second and third camps the children were allowed to control the telescopes themselves, it was very obvious that their level of focus and attention to the task was considerably better; their focus was on acquiring their images and exploring the night sky. The increased control gave them a greater appreciation of what was happening. Their conversations centered on the images they acquired and what to look for next. The children appeared to show greater interest in the astronomical image acquisition when they controlled the telescope and camera themselves, as their conversations were related directly to the activity. During discussions with the children there was a good level of understanding and appreciation of exposure time and the relationship to image quality, especially for faint objects; exposure times were discussed with the participants and they clearly understood that when acquiring images the exposure time was more important than the brightness of the astronomical object alone. This is consistent with research by Papert [Pap93c, p. 5] and later by Scaife and Rogers [SR99] who found that empowerment is an important factor in learning. The participants needed a lot of assistance when using the telescope control and imaging software (rows 4 and 5 of Table 3.3). As discussed earlier it was concluded that this difficulty was due to the fact that the software is targeted at adult astronomers and not children.

Finally, the participants needed very little assistance when writing their reports (as shown in row 6 of Table 3.3). This demonstrated that the children found the VTIE Paper Writing Component easy to use. The success of the output from the tool (the Project Reports) was later evidenced through content analysis and teacher assessments as described in the following subsections. Hence, our results have shown that the Paper Writing Component of the VTIE VLE served as a template for other components being developed in future iterations. A sample Project Report from 2003 is shown in Appendix A. From the outset, the emphasis was on report-writing as the core activity in VTIE, this provided focus for all the sessions and the software evidently did not impede the participants. The Paper Writing Component was so successful during the Science Camps that other university departments participating in the science camps requested use of the software for their sessions. Chapter 4 describes the latest version of this software which encapsulates the team management and collaboration which was lacking in the software during these trials.

3.6.2 Analysis of Project Reports

Each group of children that participated in a VTIE session completed a Project Report describing their work. As these reports were the only deliverables produced by the participants, they were an important source of data for our study. When analyzing these reports our aim was twofold. Firstly, to extract any information from the reports about the software and secondly, to investigate the degree to which students completed the tasks (see Figures 3.2, 3.3 & 3.4), indicating whether or not the VLE, with the level of support provided, was capable of supporting inquiry-based astronomy projects. Each Project Report was scored (by one member of the EVE team) using the following criteria:

1. Task Completion: In order for a group to be considered to have completed their tasks their report must contain evidence that the children attempted all the key activities prescribed for their session. In 2002 and 2003 the tasks considered key were Research, Image Acquisition and Image Analysis. In 2004 the tasks considered key were Research, Image Acquisition and the investigations of the spectrum carried out during the visit to the Experimental Physics Department. With one exception, each report showed evidence that the children attempted

each of the key phases. This demonstrates that our prototype VLE, consisting of an aggregation of tools, did, with the appropriate level of assistance, support astronomy education.

2. Research: Each Project Report was scored on a 5-point Likert scale from 'very poor' to 'very good'. Reports that showed no evidence of research were considered 'very poor' and reports that showed evidence that the children could merge information from a number of different sources into a coherent report were considered 'very good'. As described in Section 3.5.3 there was a substantial change in the organization of the research phase in 2004, with the addition of questions to guide the participants during their research. Although Table 3.3 clearly shows that this change substantially reduced the amount of assistance the children requested during the research phase it had apparent effect on the quality of the research the participants included in their reports.

3. Image Analysis: Each Project Report was scored on a 5-point Likert scale from 'very poor' to 'very good'. Reports that contained no evidence of image analysis were considered 'very poor' and reports that showed evidence that the children could extract information from the images and form conclusions based on this information were considered 'very good'. Few reports scored highly; reports predominantly scored 'average'. This category also had the lowest average score of all the categories scored on the 5-point Likert scales. Table 3.3 indicates that, in the two years where the Image Analysis phase was considered key, the children requested a lot of assistance during this phase. This indicates that the participants found this phase particularly difficult and further development of the VLE would need to address this if the educational goals were to be met.

4. Use of Images: The Paper Writing Component allowed participants to include up to three images in their Project Reports. Each report was scored on a 5-point Likert scale from 'very poor' to 'very good'. Reports in which no images were included at all were considered 'very poor'.

Reports in which images were used but the images were not related to the content of the report were considered ‘poor’. Reports showing evidence that participants chose their images carefully, referenced them in the text of their report, explained their relevance and gave the images informative captions were considered ‘very good’. There was a strong correlation between this criterion and the report’s over all score. Reports that scored well on this criterion all scored well overall; reports that scored poorly all scored poorly overall.

5. Tool Usage: The reports were scored on a 5-point Likert scale from ‘very little’ to ‘extensive’. On average, the groups scored highly under this criterion (86% scored ‘average’ or better with 54% scoring ‘significant’ or ‘extensive’). This indicated that the tools provided as part of the VLE are useful to the participants within the context of the objectives and are sufficiently usable for the children given appropriate assistance.

In addition to analyzing the reports for task completion every sentence in every report was examined for references to the tools used and to identify positive and negative comments made by the children in their reports. No report made reference to the quality of the software and only 19% even mentioned the software at all. These references were contained in phrases such as *“The telescope was directed by remote through the Internet using software called ‘thesky’.”*. This implies that the software was in some respects transparent to the process. Although Table 3.3 shows that the children needed a lot assistance when using the software this need for assistance was not their over-riding experience of the sessions. This claim is further backed up by the fact that a significant number of reports contained language that suggests that the children had a positive learning experience during VTIE sessions (see Table 3.4). This is also consistent with the results of the teacher survey described in Section 3.6.3. In the first camp (2002) the organizers asked the participants to complete an evaluation form in which they were asked to rate each of the sessions they attended at the camp. The VTIE session was one of the most popular sessions, second only to a Chemistry session on the creation of explosions.

Table 3.4: Sample Quotations from Project Reports

Participants that believed they learned:

"So in conclusion we found the nebula very interesting and we learnt a lot of interesting facts."

"We have learned through this research that the universe ca nbe viewed at many different wavelengths and looks very different in each"

"In conclusion we can say that we learned a lot more about astronomy than we had already known"

Participants who had a positive experience:

"We are truly fascinated by the vast magnitude of information which this subject covers and we are definately hoping to return next year."

"We made some really fascinating observations."

"We also discovered how wondrous and deep the sky is."

"Overall we enjoyed the whole experience."

Evidence of understanding:

"People have guessed that there is a black hole in the galaxy because it is giving off large amounts of x-rays, We were able to varify this ourselves."

Evidence of lack of understanding:

"In this image of the Nebula there is no Nebula! This means that the Nebula must be like a vacuum"

The quotations in this table are taken directly from the Project Reports written by the participants and were not edited to correct spelling, grammar or punctuation.

Many of the reports showed evidence that the participants achieved the astronomy-based learning outcomes described in Section 3.5 . There were only two reports which showed clear evidence that the children did not understand what they were writing about, these reports contained factual errors or descriptions that showed lack of knowledge, for an example see Table 3.4.

Although our formative evaluations were concerned with requirements gathering and analysis and not specifically with learning outcomes, it was observed that the participants indicated in their reports that they had learned during the sessions. 43% of the reports contained the phrase *"We learned"* and many reports contained even more explicit indications such as the examples shown in Table 3.4. However, in the absence of pre-tests in the knowledge domain it cannot be definitively shown that the children did actually learn.

3.6.3 Teachers' Assessment of VTIE Project Reports

A survey-based assessment was carried out pertaining to the Project Reports generated by the participants at the VTIE Summer Camps. This survey-based assessment was distributed to experienced schoolteachers from various Primary and Secondary level schools. The survey was carried out in order to obtain independent professional opinions on the quality of the product produced by children using the VTIE VLE. The survey contained questions that were mostly closed-ended, however, there were some opportunities provided to participants to expand on the reasons for their responses, Appendix B contains a detailed listing of the data gathered from this survey-based assessment. The survey was also distributed in order to assess whether teaching professionals believed, in the absence of pre and post testing, that the reports contained some evidence that learning objectives of the VTIE sessions were achieved. The teachers' professional opinions provide an excellent indicator with which to qualitatively measure the work produced by children using the VTIE VLE in comparison to work generally expected from children within the given age group(s). A total of 14 teachers completed the survey-based assessment and a total of 37 Project Reports were assessed. Each report was assessed by at least 2 teachers. The teachers that participated in the survey were not associated with the VTIE Summer Camps. Copies of the survey were distributed locally to Primary and Secondary schools and then further distributed by teachers to other colleagues willing to participate. All names were removed from the reports to ensure the privacy of the individual participants and to avoid possible teacher-pupil recognition. Each participating teacher was provided with a pack containing a minimum of 7 Project Reports, descriptions of the VTIE sessions (including Figures 3.2-3.4), and a short questionnaire to be completed by the teacher.

Analysis of the survey results showed that the teachers unanimously held the opinion that the reports contained evidence of learning of the subject matter, were generally above the average expectation for the age group of the children, and that the children collectively demonstrated an understanding of the topic presented in the laboratory sessions through their writing. The teachers were also asked to assess the level of data analysis that was evident in the reports, all of the teachers agreed there was at least 'some' evidence of data analysis contained in the reports they had assessed. The layout and appearance of the reports was rated very highly by the teachers, in all, there was a 93% consensus that the reports looked 'good', this was further broken down into 7% were judged to be 'average', 57% 'good', and 36% 'very good'. These results are consistent with observational evidence that the Paper Writing Component was very successful in achieving a high standard of presentation among all of the participating children. Approximately 66% of teachers believed that reports of a similar high quality appearance could not be produced by their pupils in the same time period using standard word processing tools. This result provides supporting evidence that the VTIE Paper Writing Component was successful in its objectives (see Section 3.6.1). All of the teachers agreed there was at least 'some' evidence of a logical/scientific approach contained in the reports, these opinions were further broken down into 38% believed there was 'some' evidence and 62% believed there was 'lots' of evidence of scientific process in the reports. This result appears to reinforce our assumption that schoolchildren would be able to successfully participate in a scientific process through the VTIE VLE. Finally, when the teachers were asked to grade each report in their pack on a 5-point Likert scale (ranging from 'very poor' to 'very good'), the teachers responded with overwhelmingly positive results: 43% of the reports were rated 'very good', 42% 'good', 14% were rated 'average', and only one report was rated as 'poor'.

The results of the survey were extremely encouraging. Although the population spread was limited, there are strong indications from the survey results that the VTIE process was successfully applied through the VTIE VLE. These survey results have served as input into the next version of the VLE and will provide a comparator for further evaluations of the reports produced using the VTIE VLE. Future summative evaluations to assess learning outcomes will require a greater population spread and must also include some form of pre and post tests for the participants.

3.7 Conclusions

Our evaluations have shown that a VLE consisting of an aggregation of independent software tools adequately supported the VTIE scientific process for science-based projects. The surveys from the independent teachers clearly show that the participants successfully completed the camps. This is further supported by our own analysis of the project reports produced by the participants.

Our evaluations have also highlighted a number of problems with VLEs consisting of an aggregation of independent software components like our prototype VLE. It became clear during our evaluations that the divergence of software tools within our prototype would inhibit the introduction of VTIE to schools. The high levels of assistance required by participants during some of the phases (see Table 3.3) would not be practical in a normal school environment. For these sessions there was a demonstrator/participant ratio of 1:5. Also, installing many separate pieces of software on each computer in a school environment is time consuming and impractical. The success of the Web-based Paper Writing Component provided us with a model to follow for the rest of the VLE, since it is both practical and successful.

The negative effects of the lack of support for collaboration in the prototype tested (as shown by our observations of the sessions) has led to the development of a new version of the Paper Writing Component that is inherently collaborative and is described in the next Chapter. The new version allows students at separate workstations to work together on the same report simultaneously. Additionally, these observations have led to the development of a software component to allow students to easily share images and text with the other members of their project group, also described in the next Chapter. The importance of teacher involvement in the production of successfully integrated educational systems has been extensively reported, for example, Underwood et al., [UU90, p. 17] point out that it is the teacher that will ultimately allocate the "block of time" in their schedule to allow children to use the school's computers, and they will only do this if the software is good enough, flexible enough, and integrates into the curriculum. During these evaluations, the VTIE team took on the role of teachers by conducting teacher-led sessions with participants. Of course, the participation of teachers will be necessary for future iterations of the VTIE learning environment, and as a result of the formative evaluations presented here funding was secured from the (Irish) National Centre for Technology in Education (NCTE) to involve twelve local schools, including teachers and pupils in further development activities. It is apparent from this research that considered formative evaluations on early prototypes provided vital insight into VLE development and have shaped the future course of this project. The teacher surveys provided strong evidence that the children who took part in the VTIE sessions at the Science Camps had a positive learning experience. Our analysis of the Project Reports produced by the participants further supports this conclusion. This shows that the objectives of the VTIE project are achievable. The combination of rapid prototyping and formative evaluation has provided valuable information that has guided the future development of the VTIE project, hence, this approach can be confidently recommended to others developing VLEs for schoolchildren. The VTIE system was designed to engage students in an inquiry-based scientific process, the initial versions of this software focused purely on astronomy-based learning. Since the completion of these evaluations the aims of the VLE have veered away from the acquisition of images from telescopes and the VLE has been modified to address wider e-Learning and e-Science applications. These evaluations have been used to drive the innovation which has taken place during the development of the EVE Portal which are described in detail in the chapters that follow.

Chapter 4

Encapsulating Collaboration and Team Management in EVE

This chapter introduces an online Collaborative Writing Environment (CWE) developed for use by schoolchildren and their teachers. This CWE forms a subcomponent of the EVE Portal which has been developed following the formative evaluations stage described in Chapter 3. The CWE described herein encompasses collaborative writing, automated virtual team allocation, online resource sharing within virtual teams and the facility for teachers to guide the research activities of the participants via template generation and direct message interaction. The CWE encapsulates within the VLE a variety of modifications that were necessary prior to deployment within a school environment. We report on the results of the initial user trial of this CWE involving a total of 15 school students between the ages of 15-16 years. We conclude that our research has lead to the development of an intuitive and innovative set of online interfaces that collectively provide an environment through which teachers and their students can plan, prepare, and produce truly collaborative research papers.

4.1 Introduction

The EVE team have been focused on the development of online learning environments for the past five years. We are concerned with the development of software tools to support education within a social constructivist paradigm as described by Bruner [Bru96] and Driver [Dri83, DAL+04]. The development of the EVE Portal has been at the center of our research activities over the past three years in particular. The EVE Portal has been designed to engage schoolchildren in an inquiry based learning activity, which culminates in the production of a written document that summarizes the experiences of groups of schoolchildren. The software development process used for the development of the VLE has been an iterative and user-centered one which has been shown to be very successful by leading experts in the field of usability design [PSR94, Nie93, Bad02]. The work of Druin et al. [Dru02], has also influenced our design and testing strategy, however, resource limitations have meant that children were included as "testers" rather than "design partners" [Dru02]. The production of a written document by the schoolchildren has always been an essential component of the learning activities within the VLE; this has led to the development and refinement of a writing tool. The requirement for a writing tool was identified through extensive user testing of the VLE; however, the initial writing tools had no support for collaboration. We identified the requirement for software supported collaborative writing in much the same way as described by Hoadley [LDB04] during the iterative development of various science education environments: "although collaboration was not a central feature of this project in the beginning, through iterative refinement we came to understand how structuring collaboration was the most powerful way of scaffolding the students' science learning in the design". During previous iterations of the VLE we have relied on the manual allocation of students to teams prior to the commencement of the writing activities. This manual allocation process has now been ported to the Web via Project Management Interfaces. This chapter provides a detailed description of the functionality provided by the CWE, which incorporates the required collaborative writing support and team allocation processes.

This chapter also provides a summary of the initial user trials of the CWE which were an adjunct to previous user testing and focused specifically on the newly encapsulated features of the software. Previous user trials of this VLE have relied heavily on observations made during testing; this was also the case for this session. Our observations have been followed up by post-trial development team meetings to analyze the effectiveness of the software within the context of the learning outcomes for the session. Prior to this trial it was hypothesized that the students using the CWE would experience the need to: communicate, coordinate, cooperate, collaborate and compromise. It was also hypothesized that the students would successfully produce four collaborative research papers and that each student would have contributed some writing to their team paper, i.e., the CWE would improve on the inclusiveness for participants when compared to previous sessions. Finally, this trial would provide an opportunity to test the newly introduced team management and project management functionality in a laboratory. The sections that follow present an in-depth literature review, detail the components and interfaces of the CWE, analyze the effects of the encapsulation of collaboration and team management into the writing environment and report on the observed and reported experiences of the students using the CWE.

4.2 The CWE Writing Approach

During the writing phase of a project the schoolchildren use the CWE to produce a written research paper to summarize the findings from their investigations. The CWE allows students to provide immediate feedback to each other via comments. We have found that this provides the students with a realistic experience of how scientific writing takes place as it models the peer-review approach which is very much part of how science innovation is driven. The CWE provides software support for students and mentors/teachers to:

1. communicate via the commenting context within the writing interfaces
2. coordinate the writing process by assigning teams and sections to each

of the students

3. cooperate in the decision making process by examining the various contributions made to the final document and work together to complete the document

4. collaborate by sharing their findings within their team and allowing others to actively comment on their work

5. compromise by accepting other students comments so that the team can reach their goal

Various ways to approach and organize the collaboration between students were considered by the research team. For instance, both Sorby and Bulliet [SB06] and Beer and McMurrey [BM05] list three basic ways to produce collaborative documents:

1. Divide a document into sections and have each team member be responsible for that section.

2. One person writes an entire document and passes it on to the other team members until a final edit is produced.

3. Selecting a manager to coordinate activities, another member gathers the information together and drafts it, and finally a good writer is left to produce a final draft.

Zammuner [Zam95] identified a number of organizational approaches, some relating to pairs of collaborators, while others involved larger groups. Three basic variations were identified, as shown in 4.1. The methods and organizational scheme adopted in the CWE is equivalent to the third organizational approach shown in Table 4.1, additionally, the CWE adopts the first method of collaborative writing listed by Beer et al. [BM05], and Sorby et al. [SB06]. While there are arguments in favour of the adoption of all of the above strategies, Zammuner [Zam95] contrasted success in producing written work by students working individually, with those working in collaboration patterns 2 and 3, reporting that "The most significant changes (usually improvements) in the quality of revision operations occurred when the revision was carried out cooperatively rather than individually". He suggests that this was because the 'outsider' would provide immediate feedback, similar to that provided by another person in a conversation, unlike in the usual solitary process of writing. As noted by Erkens, et al. [ERJ+05],"Collaborative writers need to test their hypotheses, justify their propositions and clarify their goals. This may lead to increased awareness of and more conscious control over the writing and learning process". Following these investigations we decided to design the CWE so that authors can produce document sections individually and to allow other authors within the same writing team to feedback comments on the other sections being produced. The results of this trial will help to assess whether this approach to collaborative writing is successful in supporting the production of collaborative documentation with groups of schoolchildren.

Table 4.1: Organisation of Collaborative Writing - Zammuner

Initial draft	**Revision**	**Final version**
Group/PairA	Group/PairB	Group/pair A
Group/PairA	Group/PairA	Group/Pair A
Individual	Group/Pair	Individual

4.3 The CWE and Wikis

The development of software to support collaborative writing is not new, much important literature regarding collaborative writing using computers dates back to the 1980's [RKB+89]. Examples of collaborative writing tools include: Quilt [FKL88], GROVE [EGR91], TC3 [EPJK02], SASSE [BNPM93], Collaboratus [LANJL02a][LANJL02b], CoDE [Pun06] and Wikis

[BDH05]. A number of these environments have already been discussed in Chapter 2, however, it is Wikis that have the closest approximation to the CWE, given that they are completely Web-based and attempt to support collaborative writing in multiple contexts. However, unlike Wikis our CWE has not been developed as a general-purpose tool, instead it has a very specialized role within an educational context. The CWE is built within existing pedagogical models of mentors/teachers, groups/classes, teams and projects. Within the CWE projects take the form of research activities that revolve around the production of structured written reports. The environment encapsulates class, team and project management, online research and information gathering, resource sharing, and communication between team members and their teacher or mentor, as well as providing an interface for collaborative writing. The CWE has also been designed to provide easy integration of other tools, for example, data and image analysis tools. Table 4.2 provides a summary of a comparison between the CWE and Wikis.

Table 4.2: Comparison of CWE with Wiki

Functionality	**CWE**	**Wiki**
Supports Collaborative Writing	Yes	Yes
Web-based	Yes	Yes
Supports Version Control	Yes	Yes
WYSIWYG editing	Yes	Yes
Supports team management	Yes	No
Supports control of report structure	Yes	Yes
Integrated Messaging System	Yes	No
Integrated resources gathering and sharing	Yes	No

It is clear that the CWE and Wikis share the same technological space and share many of the same writing goals, however, the educational context of the larger EVE Portal makes the CWE a specialized tool within an educational context.

4.4 Motivation for building a custom CWE

The EVE CWE is not merely a collaborative writing tool like many of those described above it is an environment that attempts to address many of the shortfalls identified during the formative evaluations of the initial versions of the VLE. Importantly, the CWE tightly couples the inquiry-based activities of the students to the production of a collaborative research paper within a specific educational context. Within the literature we have reviewed, none of the VLEs within a similar educational context, place such an emphasis on the production of a collaboratively written research paper while additionally providing a mechanism to support the inquiry-based process and the production of a paper from its inception to its completion. The CWE was designed specifically to be accessible from within the school environment (using a Web browser) and provides the teachers and students with a straight forward mechanism for storing and sharing all project related data, resources and progress persistently. The Scrapbook component is central to this sharing capability, students and teachers alike can share resources collected through online investigation of a research topic, these resources may be stored and assigned ownership for future use and reference. The Scrapbook component is described in greater detail in section 4.5 below. Central to the support of the inquiry-based process is the requirement for consistency and flow within the VLE as a whole. Previously the VLE was composed of an amalgamation of software components that successfully supported the inquiry process; however, it was evident that the diversity of software was not maximizing the user experience. Skadberg and Kimmel [SK03] have investigated user experience via the Web and the consequences of providing an interface that gives the user a positive "flow" experience. Skadberg and Kimmel refer to the work of Csikszentmihalyi [Csi90] who originally defined the term 'flow' as a loss of awareness, a total involvement in an activity and the sense of being absorbed in the task and environment. Significantly Skadberg and Kimmel describe one of the main consequences of achieving flow at the user interface, as increased learning: "First when people are in a state of flow they tend to learn more about the content presented in the Website" and secondly "the increased learning leads to changes of attitude and behaviour including taking positive actions". This opinion of the importance of flow is echoed by Squires and Preece [SP99], in this paper on the evaluation for educational software within a constructivist paradigm they state that users "appreciate a smooth flow of interaction". They also refer to literature [Alt93] that suggests too much extrinsic feedback like "error messages, hints" etc. can hinder the flow achieved using constructivist educational software. In order to record the reported experiences of the students while using the CWE, a questionnaire was issued to the students immediately prior to commencing this trial, and a subsequent questionnaire was issued post-trial. The post-trial questionnaire was issued in order to capture the experiences of the students using the CWE and the development team was anticipative that the students would report that they had at least a positive experience.

Another central motivating factor for the development of the CWE was to maximize equality of opportunity in the writing task for the participating students. This type of equality of opportunity is advocated by Papert [Pap93c], creator of LOGO. McFarlane also refers to concerns about "less assertive" members of a class while using ICT and how they may be excluded from the task by the "over-assertive" members [McF97, p.10–11]. Mercer et al., [MDW+07] also echo these concerns in a very recent book on ICT in language learning. During extensive user testing using various software components to create collaboratively written Webpages they observed that it "was common for one child to make all the decisions about how to proceed while the others watched" [MDW+07, p.3], and that the "child controlling the mouse made unilateral decisions" when their inquiry activities were not adequately supported [MDW+07, p.9]. Our initial versions of the VLE were thoroughly tested and it was observed on many occasions that the students with the high-level of competency with computers often controlled the writing task by physically placing themselves in front of the terminal. As a result of this the development team was motivated to create a writing environment that would at least ensure that all students in the writing team would get an opportunity to interact and contribute to the document.

The literature reports that teachers are under constant pressure to achieve curricular objectives. Teachers rarely find the time to experiment with new software and cannot be expected to expend energy incorporating educational technologies that do not explicitly cater for these objectives. VLEs must provide mechanisms to deal with these realities. These classroom time pressures can mean that interactions with software can often be brief and disparate. Underwood and Underwood [UU90] stress the importance of considering curricular pressures: (teachers must) "decide on how much of their time can be spent on supporting computers" and offset that to the cost "to other curricula areas" [UU90]; the tight coupling of the written output to the inquiry-based activities in the EVE Portal assists the teacher in justifying time spent as there is continuous focus on a tangible team-based output within the supported process. The previous evaluations of the VLE revealed activities that needed to be integrated into the software in order to make the VLE classroom compatible including: the allocation of student teams and the persistent storage of team related information, the storage of project related resources such as images, the design of the research paper and the assignment of students to sections and the online evolution of the document through feedback mechanisms. All of these have now been captured within the CWE which increases the likelihood of adoption of this software into schools.

There are also some important technical motivations for the development of this custom-built software. The EVE CWE has been implemented within the technological framework of the VLE, thus ensuring consistency of interfaces and plugability of possible future components. Architecturally, the EVE Portal applies the Struts framework which is based on sound software engineering design practices and thus future enhancements and further component development can be tightly managed [Spe03]. Finally, the EVE Portal has been designed with formal input from teachers; the participating teachers stressed the importance of licensing issues regarding the use of software in schools. The custom-built CWE ensures that the EVE Portal can be provided free of charge and eliminate licensing and cost issues. The CWE detailed in this chapter has provided the research team with an opportunity to explore the extent to which inquiry-based software can meet the needs of teachers and their students. The following sections describe the components of the CWE in detail, summarize the questionnaire responses from the students that took part in the trial and reflect on the observations made and conclusions drawn from the trial.

4.5 The EVE CWE

The CWE provides interfaces to support both teachers and students throughout the writing process from project design through to publication of the students' work. The CWE can be considered to consist of three components:

1. The Project Design and Management Interfaces
2. The Scrapbook
3. The Writing Interface

While the CWE has only been tested within the area of astronomy education all of the sub-sections and team allocations are completely customizable by the teacher, thus giving the CWE a great deal of flexibility for use within many contexts and subject areas. The writing process starts with the teacher designing the structure of the projects in conjunction with the students. This design phase of a project is expected to be completed in class with the teacher showing the students the project document structure using a data projector. The design of a project is represented graphically and as the project design is manipulated the visual representation changes. This same visual representation of the project is used throughout the rest of the process in both the teacher and student views. Once the structure is defined it is referred to as a project template and can be saved for re-use in the future. Figure 4.1 shows an example of the visual representation of a project template. This project template may then be used by the teacher to create project instances and assign students to these instances. The teacher divides the group/class into teams and assigns one team to each project instance. Within each project instance each section is assigned to a single student who then writes that section. All members of the team and the teacher can view the current state of each section and a *messaging context* allows them to provide advice and help as the student works from an initial draft toward a final version. Finally, when the teacher is satisfied with the project instance (i.e. the finished article) it may be published in HTML and PDF format.

4.5.1 Project Design Interfaces

The Project Design Interfaces allow the teacher to manage and control their projects and project templates and manage their student teams within the CWE. They can create teams, edit teams, create templates, edit templates, create projects and view the progress of their students. In order to ensure the anonymity of participants no information about students is retained at the server. Students are referred to within the system as Student 1, Student 2 etc. However, the teacher can print a hard-copy of a table of student numbers and manually insert the students real names for record purposes. Figure 4.2 shows a sample printout from a group project. Projects are created using a direct manipulation interface, the teacher clicks to add and edit sections and a graphical representation of the project template updates in real time to show its current design. Project templates consist of global thoughts/notes and sections. Each section has a title, optional initial content and thoughts/notes for that section. When creating a project assignment from a template the teacher is presented with a four-step wizard. In the first step the teacher is requested to input the name of the project, identify the class/group that will do the project and input the number of teams the class/group will be split into. Figure 4.3 shows the Webpage presented in the first step. The second step allows the teacher to name each team, Figure 4.4 shows an example of this Webpage in use. By default the teams are named Team 1, Team 2 etc., but the teams may decide on their own names, perhaps as a first team building activity. The third step, shown in Figure 4.5, allows the teacher to specify which students go into each team. Finally, the fourth step presents the teacher with a graphical representation of the template chosen but with extra features to allow the teacher to assign students to the different sections. At this point the teacher can edit the design of the project (Figure 4.1) by adding sections, removing sections, editing sections and thoughts and editing the title. When the teacher is satisfied with the design and student allocations project instances are generated, one project is generated for each team. Students can then commence writing their document while using the Scrapbook tool to add images and resources and using the commenting context to constantly feedback information to each other.

4.5.2 Sharing Resources using the Scrapbook

The Scrapbook provides students and teachers with a personal portfolio to store information and resources persistently. The current version of the Scrapbook has been implemented as a browser extension so that it is always available to the students and teachers while they are browsing the Web (Figure 4.6 shows the Scrapbook loaded into the left pane of the browser window). At any stage during the writing process it is possible to drag and drop text, links or images onto a drop zone and add them to the Scrapbook. The students and teachers can also create notes as they work and save those into their Scrapbook. Teachers can make any of the information in their Scrapbook available to students and students can share any of their information with the others in the team. All information stored in the Scrapbook is actually stored persistently on the server. The student/teacher may move to any other Internet-linked computer and their portfolio will always be available to them. The teacher can also see the contents of all the students portfolios and can delete any scraps deemed inappropriate. Each scrap also stores the URL from which it was saved so that the teacher can view the source of the student information. The Scrapbook also interfaces directly with the writing interface. This makes it as easy as possible for students to incorporate the resources they find on the Internet into their reports. The teams can decide between themselves which of the images and resources will be added to the final paper by simply selecting the Add to Paper option in the Scrapbook. Only the resources that are specifically selected for inclusion in the final paper will be included in the team report.

4.5.3 The Writing Interface

Once a project instance has begun students and teachers are presented with a graphical representation of the project as described above. The writing view of each section of the project document can be accessed simply by clicking on the required section. In the writing view all of the sections of the paper appear as tabs across the top. In this view the contents of the current section appear in the main area of the page below the tabs, Figure 4.7 shows an example of the writing interface in use. Students may load the writing view and see a read-only copy of the content of all the sections in the project but can only edit the sections to which they have been assigned. When editing a section the student is presented with a WYSIWYG (what you see is what you get) editor that allows them to generate their content. The WYSIWYG editor available within the writing interface provides minimal formatting features; students can make text bold or italic and can create bulleted and numbered lists. This limited editing capability is sufficient for the writing purpose, and was provided after it was observed in initial versions of the writing tool that students wasted a lot of time procrastinating over how the document should look when there was a vast array of formatting options. Similar opinions have been expressed by Davies and O'Sullivan [DO02] and Lowry et al. [LANJL02a] who report "We observed that when groups conducted CW with traditional word processors, their focus was diverted from their primary task of drafting their document as a team, because they tended to worry about font sizes, formatting, and other document minutia when they should have been creating substantive content." In the writing view the students can also see all comments made by the other students in their team and by their teacher on their section. They can also add a new comment about another section of the document. At any time during the writing the teacher can see the contents of all sections in their project/projects. The teacher can also see all the comments that have been made on the document and can add additional comments to each section to guide the students. The writing interface also provides access to a simple version control system for each section. Two backup versions of each section are stored, one the student controls and one the teacher controls. The teacher and the student can see both backup versions if required. The student's backup version is automatically updated each time the section is saved; the teacher's backup must be manually updated by the teacher. The student can choose to revert to their backup version at any time; the teacher's backup version should be updated by the teacher only when the teacher feels there has been sufficient progress by the student. This mechanism ensures that if a student accidentally makes a major mistake and looses good work in both the current and backup versions the teacher can still restore the section to the last teacher-approved version of the section. The commenting context is the main source of feedback that students have within the writing interface. Each student can view the work of others in their group and the commenting is used to express opinions between team members about how each section is progressing. This constant feedback from peers ensures that the students are writing a document that is evolving through teamwork. It also provides the teacher with a mechanism for tracking the evolution of the document from its starting state to its final state. The commenting context makes it possible for the collaborative writing to take place in a variety of ways; for instance, collaborative writing can take place between students who are not co-located.

4.6 User Trials

The formative evaluations established that the inquiry-based learning activities were adequately supported by the software using an amalgamation of

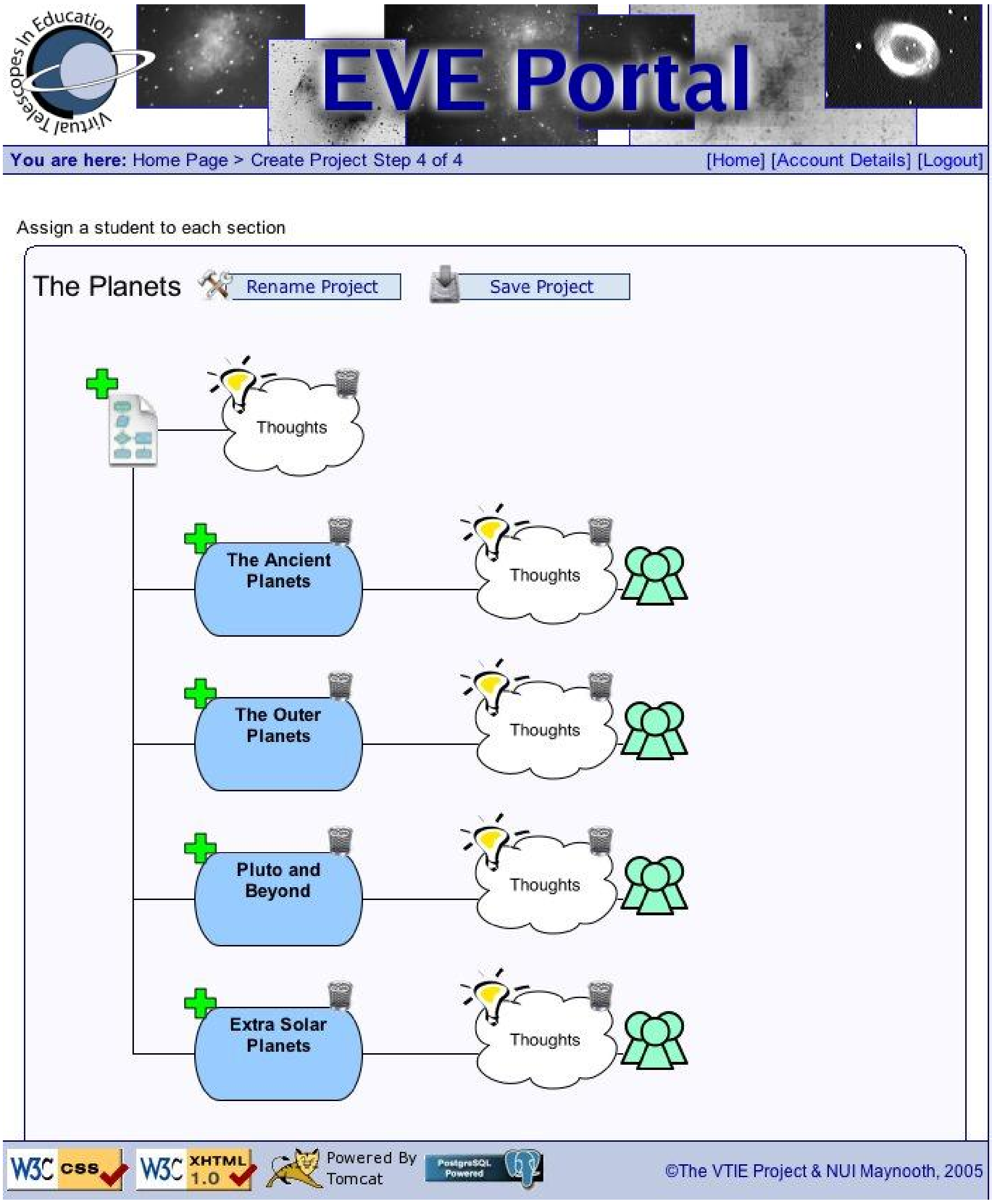
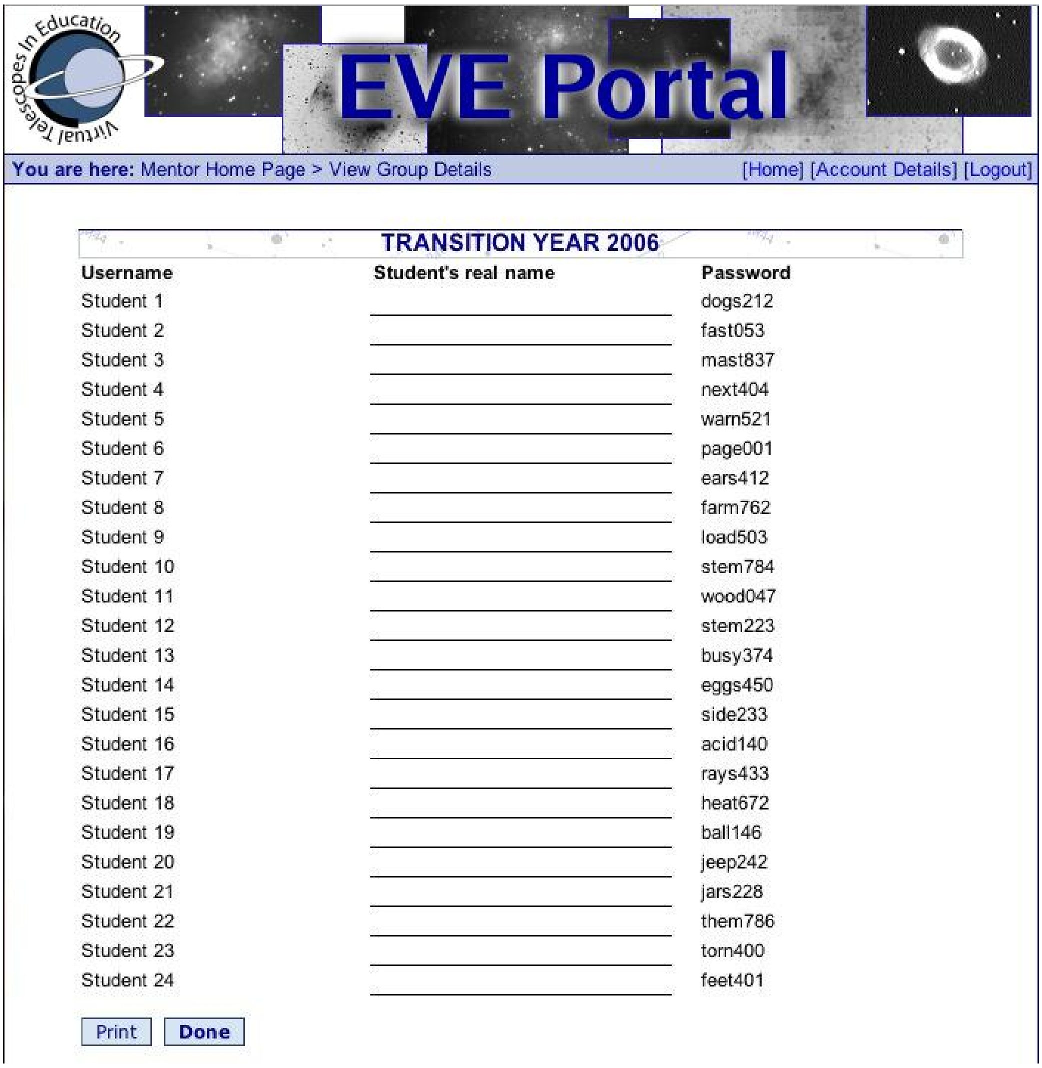


Figure 4.1: Screenshot of CWE project template



TRANSITION YEAR 2006

Username	Student's real name	Password
Student 1		dogs212
Student 2		fast053
Student 3		mast837
Student 4		next404
Student 5		warn521
Student 6		page001
Student 7		ears412
Student 8		farm762
Student 9		load503
Student 10		stem784
Student 11		wood047
Student 12		stem223
Student 13		busy374
Student 14		eggs450
Student 15		side233
Student 16		acid140
Student 17		rays433
Student 18		heat672
Student 19		ball146
Student 20		jeep242
Student 21		jars228
Student 22		them786
Student 23		torn400
Student 24		feet401

Print Done

Figure 4.2: Teacher printout of group details

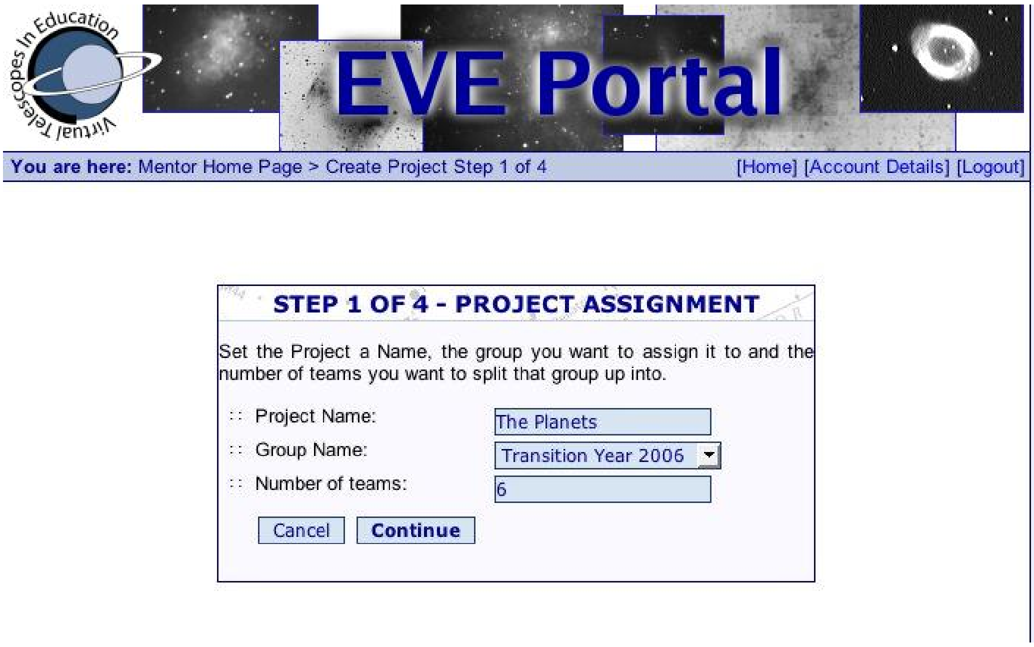


Figure 4.3: First step of project design wizard

Figure 4.4: Step two of project wizard

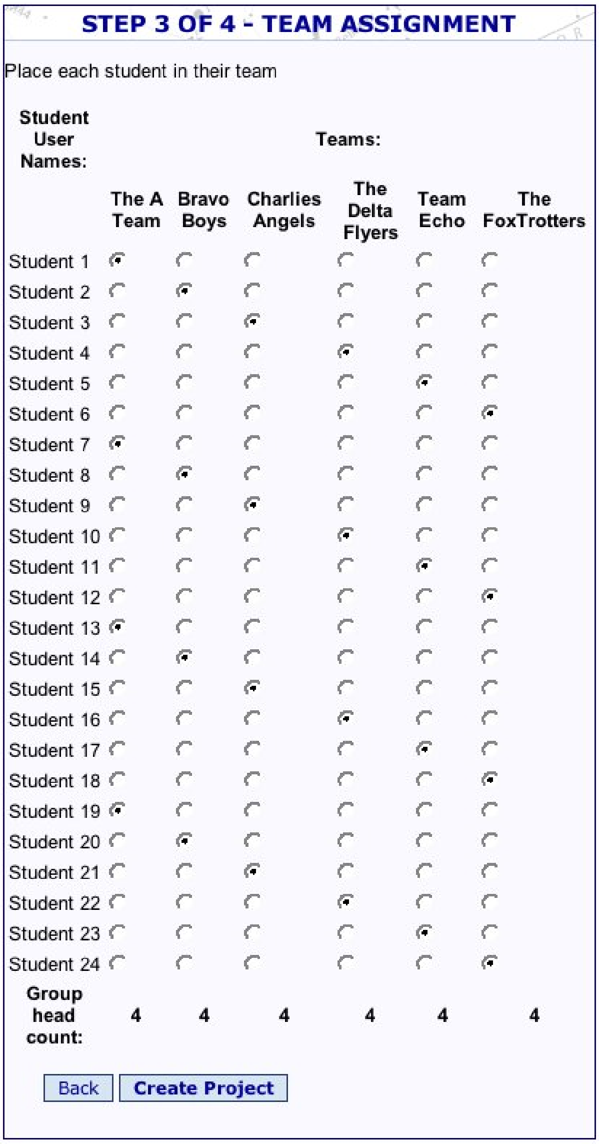


Figure 4.5: Third step of project design wizard

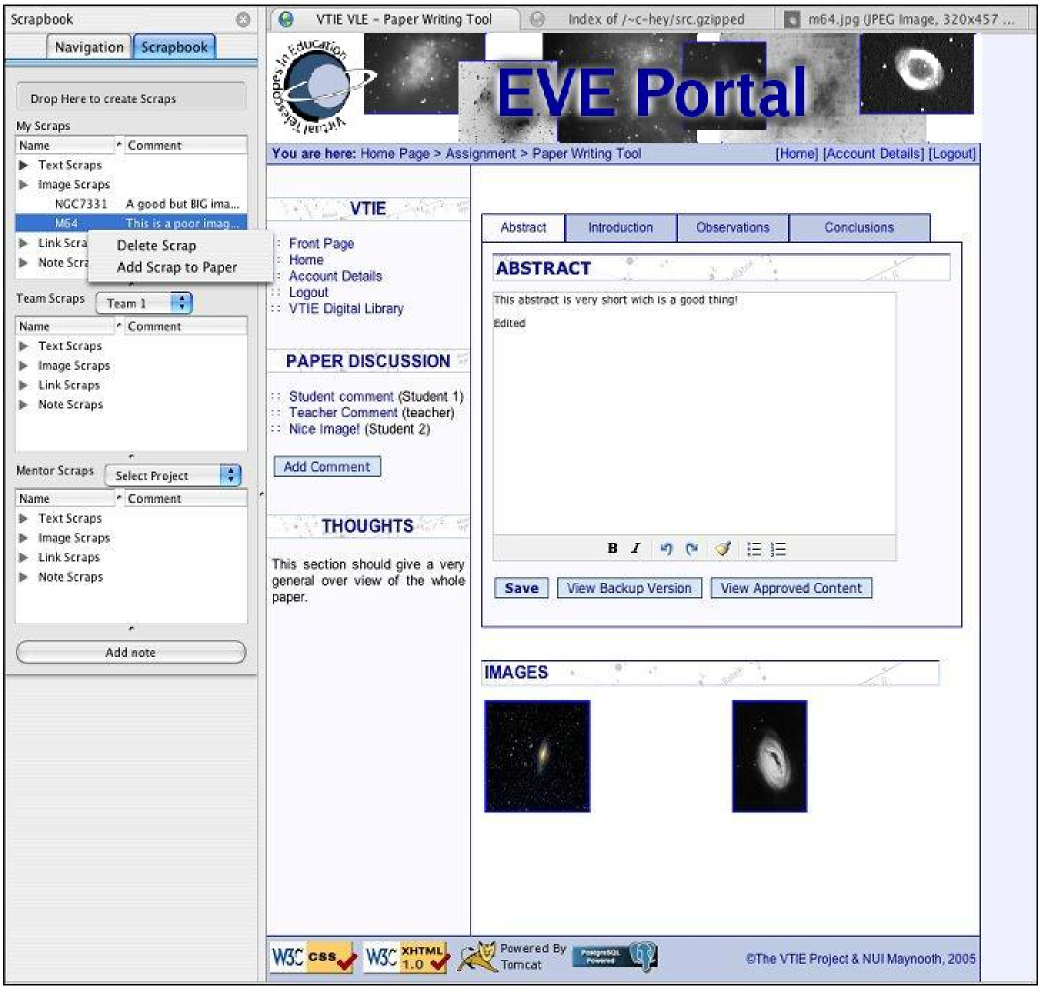


Figure 4.6: Adding and sharing resources using the Scrapbook

software tools. It was, however, also concluded during the evaluations that the lack of collaborative support and team management facilities would hinder the introduction of this VLE to the school environment. The incremental enhancement of the Paper Writing Tool has led to the development of the CWE. The aim of the trial described in this chapter was to assess the ability of the CWE to adequately support the newly encapsulated collaborative writing and team management functionality. As mentioned in the intro-

Figure 4.7: The document writing interface

duction section, it was hypothesized that the students using the CWE would experience the need to: communicate, coordinate, cooperate, collaborate and compromise. It was also hypothesized that the students would successfully produce four collaborative research papers and that each student would have contributed some writing to their assigned section, i.e., the CWE would im-

Figure 4.8: The project design interface

prove on the equality of opportunity presented to the students compared to previous sessions. Assessing the success of the CWE would rely heavily on observational evidence. Observation (and ensuing post trial analysis) has played a major role in the iterative development of the EVE Portal to date and has proved to be a valuable methodology to the research team. In our experience observation is a very effective tool when followed by extensive post-trial analysis and discussion. The role of observation has been recognized by leading educational technologists including Scanlon: "A number of studies have shown that observing learners working with technology can be a very productive way of exposing ideas and learning processes" [HS04, p.191]. Much of the advancement of this VLE has been steered by the detailed analysis of observational data. Additionally the research team issued pre- and post-trial questionnaires to the participating students during this trial. The aim of the pre-trial questionnaire was to record the profile and previous experience of the students. Recording the profile and previous experience of the students was considered important as it would help to establish these students experiences with ICT (and in particular collaborative writing software) were not exceptional. The aim of the post-trial questionnaire was to establish the students satisfaction level with the CWE and to assess in a non-intrusive manner whether any change in the level of knowledge of the subject matter had taken place. This non-intrusive approach had been applied in previous sessions as it helped the students feel relaxed. The research team made a conscious decision not to over-test the participants so that the students could be given every opportunity to freely explore the subject as a team without feeling pressurized to produce some result. Druin et al., [Dru02] have reported that the child user should not be treated in the same manner as adult users and that the children should be made feel that they are in control of the activities. Software testing involving children should offer them control over their environment, as this allows the researcher to learn more about what they want or need from the technology.

4.7 Method

This was the first time that collaboration was formalized within the software and we attempted to assess the impact of the automation of the collaboration and team management activities. The students involved in this trial were using the VLE for the first time and had not previously used the CWE. The research team members were present during this trial in order to gain firsthand feedback on the successes or failures of the CWE and to provide encouragement and assistance to the students when requested. One of the team assumed the role of facilitator during this trial. Ordinarily, this role would be assumed by the students teacher. Section 4.8 below details some of the observations made by the team during this session. The students participating in the trial were issued questionnaires prior to the trial; these were used to record the profile of the students. After the trial a further questionnaire was used to assess their experiences of using the tool, and various other criteria as outlined in Section 4.9 below. 15 students (aged 15-16 years) took part in this trial, which was carried out in a computer laboratory. An overhead projector was used so that each of the students could become familiar with the appearance of the CWE. Additionally, the students were able to observe the creation of the project, project teams and document structure. The session began with an introduction to the students of EVE and the CWE that was being tested. It was explained clearly to the students that it was the CWE software that was being assessed (not the students knowledge of astronomy or computers). The first action taken by the facilitator was to divide the students into groups both physically and virtually using the Project Design Interfaces described in Section 4.5 above; specifically, this involved the use of the team allocation Webpage as shown in Figures 4.4 and 4.5. Each student was allocated to one computer and would remain at that computer for the duration of the trial. The facilitator also explained to the students that they would be producing a document within their teams during the course of the session using the CWE. The facilitator used the Project Design Interfaces to create a project assignment about galaxies, using the Webpage shown in Figure 4.8 to design each of the sections of the document to be produced by each team. Each student was then assigned a particular section of their document to edit from a choice of four possibilities: Introduction, Our Galaxy, The Big Bang and Summary. The allocation of each team member to a section of the document was achieved using the team allocation Webpage shown in Figure 4.1. Following the assignment of sections to each student, the students used the Internet to investigate the topic of Galaxies. Each student was able to view a read-only copy of the other sections being produced within their team using the writing interface shown in Figure 4.7. Additionally each of the students had the opportunity to feed comments to each other via the commenting context available in the writing interface. Thus, the students continued to research their topic and make comments on each others work in a highly interactive manner. Concurrently, students who found interesting images or textual explanations of their topic used the Scrapbook, shown in Figure 4.6, to share resources. The following subsections describe the observations made by the team during the laboratory session. We also describe the types of interactions that took place using the CWE and detail the results of the student pre- and post-trial questionnaires.

4.8 Laboratory Observations

This trial provided an opportunity for the research team to assess the effectiveness of the CWE software to support collaboration. The research team observed the use of the CWE by the schoolchildren over a two-hour period. The limited amount of time available for the trial meant that the writing task itself was compressed to approximately one hour. Firstly, it was noted that the students using the CWE did not have difficulty with the writing interface; most of the difficulties were related to the gathering information to include in the final paper. Most notably, in this session every student participated in the writing process to some degree. The software performed in such a way that each team member was obliged to provide input individually and provide feedback to each other in order to produce a collaboratively written document. This was the most encouraging observation made during this session since this was the first totally inclusive writing experience we had observed since the research project began. Contrastingly, in previous sessions the dominant and confident students were the ones who wrote most of the content of the final research paper by physically placing themselves at the terminal. Interestingly, we observed that the concept of a team within the software environment did not present difficulties for the students. This was perhaps because the students were also sharing the same laboratory during the trial. However, despite their proximity to each other the students still made a number of computer-based comments on the work taking place. Additionally, the students were able to participate in and observe the formation of the project and the project sections via the overhead projector. Although the sections were prescribed the students responded well to the task as it was presented. Finally, it was observed that the students who were writing the introductory and summary sections had the greatest difficulty in commencing, as they had to wait for sufficient input from other team members before they could begin to form a synopsis. It was also noted that the students used the opportunity to communicate using the commenting context within the CWE and that most of the students used the Scrapbook to store images relating to their task. The click-and-drag capability of the Scrapbook was successful and the students had little difficulty in the gathering and sharing of resources. Interestingly, it was observed that students who used the Scrapbook to share images also exchanged comments about the images and resources they had retrieved using the commenting context. The following sections detail the results of the pre- and post-trial questionnaires completed by the students participating in the trial.

4.9 Student Questionnaires

Prior to the trial the students were issued with a questionnaire to aid the team in their assessment of the profile of the students. The questions were generally closed-ended, although there were some opportunities provided to expand on responses, details of the data gathered from the questionnaires are supplied in Appendix C and Appendix D below. The following areas were examined using this questionnaire:

1. ICT: This was considered likely to influence the degree of ease with which they would be able to work with the CWE.

2. Collaborative Learning: This was recorded since studies suggest that prior experience of collaborative learning and/or guidance beforehand (especially writing tasks) is an important variable in successful collaboration.

3. Astronomy in general and of galaxies in particular: This was recorded in order to assess if any knowledge learning had taken place during the course of the trial. Following the trial the students were given a second questionnaire to complete in order to record their experiences while using the CWE. Some of the questions also related to the students knowledge of astronomy and galaxies.

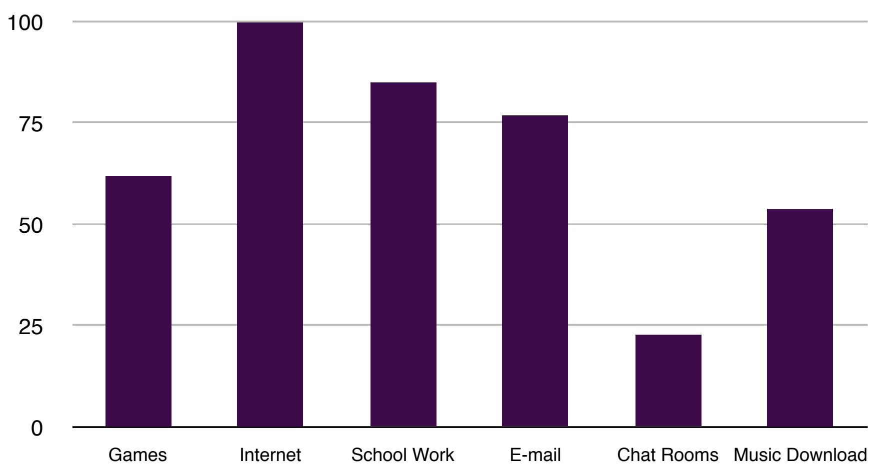


Figure 4.9: Student use of computers

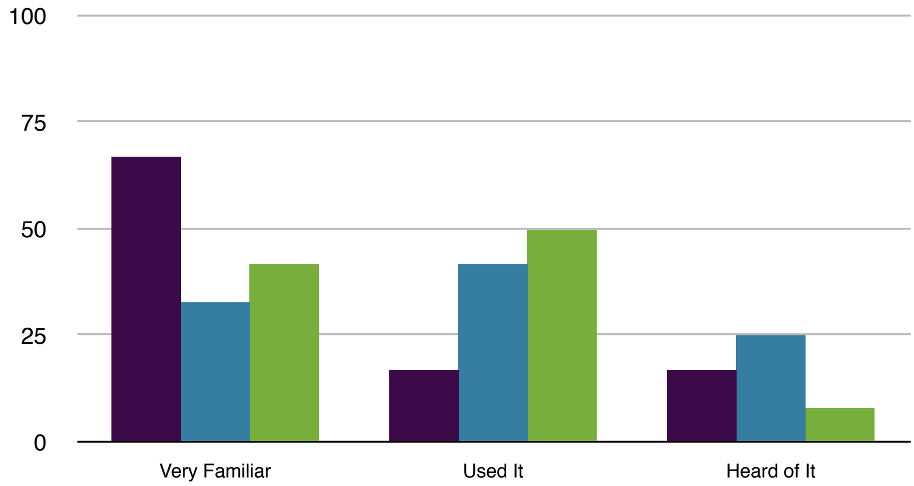


Figure 4.10: Familiarity with Word processor/Spreadsheet/Presentation

4.9.1 Pre-trial questionnaires

Thirteen students (eight female and five male) completed the pre-trial questionnaire. All of the students reported they had access to a computer at home. The students reported a variety of ways in which they used the home PC. As shown in Figure 4.9 the most popular usage was accessing the Internet while only three students reported that they visited chat rooms. While all students reported that they were very familiar with searching the Internet, varying degrees of expertise were reported for three other commonly used computer activities, i.e. word processing, spreadsheets and graphs, and slide show presentation software, Figure 4.10 summarizes these responses. Unsurprisingly, the greatest degree of familiarity was with word processing software, this correlated with much of the available research mentioned in Chapter 2 above. A larger number of students considered themselves to be very familiar with slide show presentation software than with spreadsheet software.

All of the students reported that they used computers as part of scheduled computer classes. None of the students were members of computer clubs.

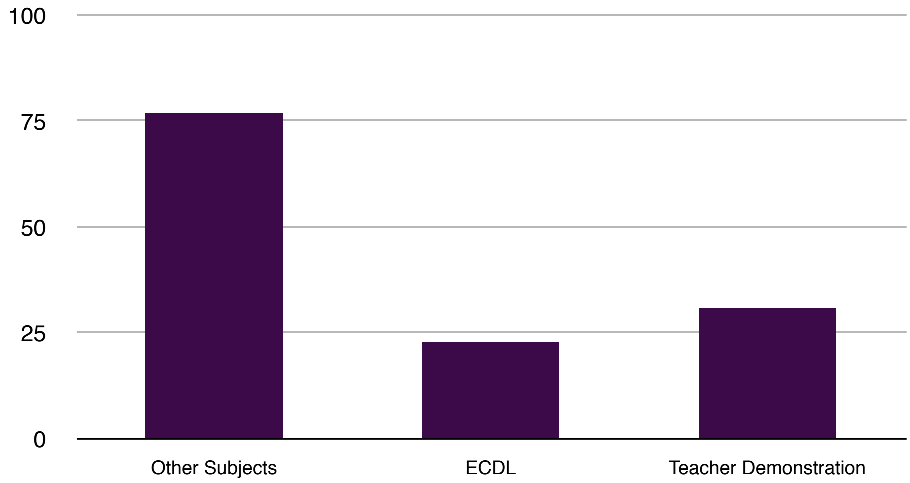


Figure 4.11: Student use of computers in school

Ten students (76%) reported that a computer was used in classes other than those specifically time tabled as computer classes (Figure 4.11). When the students were asked about their experience collaborating with others the entire cohort reported that they had worked with other students on projects, although the reported frequency did vary within the group (Figure 4.12). When the students were asked to describe their experiences of working with others, all of the students considered the experience of working with others to be at least quite helpful. When the students were asked whether they had collaborated outside of the classroom all of the students reported that they had had this experience. The most common form of collaboration was participation in team games. The other common collaboration was in debates (76% of the students). When the students were asked about prior knowledge of astronomy, seven students reported that they had studied some astronomy before this trial, with two having studied Sun-spots (for a Young Scientist competition project), three Venus, one stars and planets, and one The Moon and The Solar System. However, none of them displayed any significant degree of knowledge about the topic of the trial (galaxies). Eight students

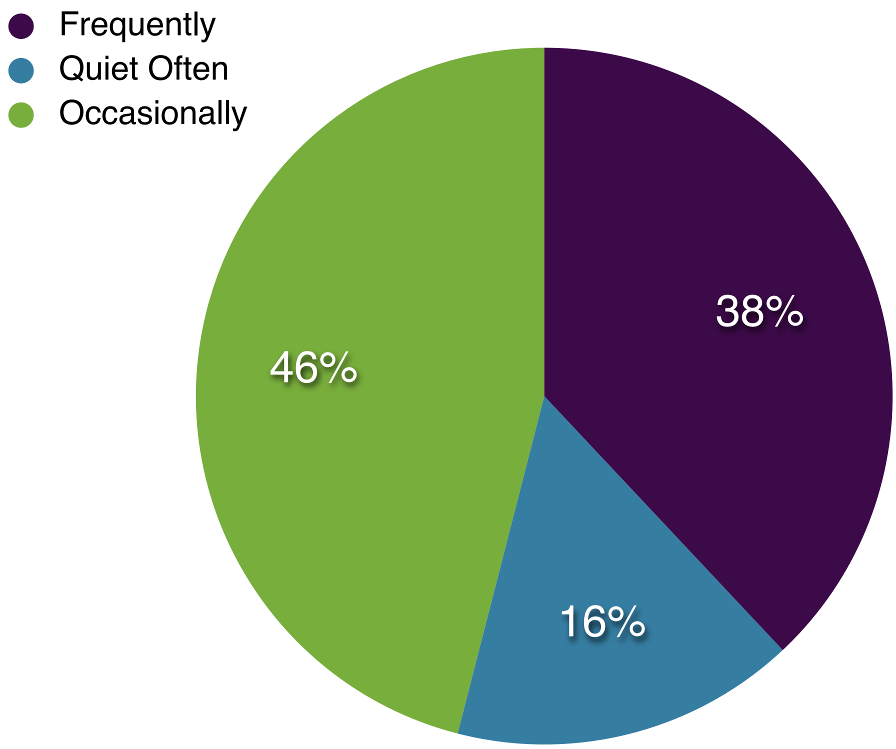


Figure 4.12: Student experience with collaboration

stated that galaxies had many stars. Only three students offered any further information through the open-ended response section, one naming The Milky Way and noting that there were millions of galaxies, while another referred to planets and an explosion (possibly a reference to The Big Bang), and one stated that a galaxy was "something in astronomy".

4.9.2 Post-trial questionnaires

All fifteen students taking part in the trial completed at least part of the post-trial questionnaire. When the students were asked about their enjoyment of using the CWE when compared to writing by hand, none of the students considered the experience of using the CWE to be less enjoyable than writing

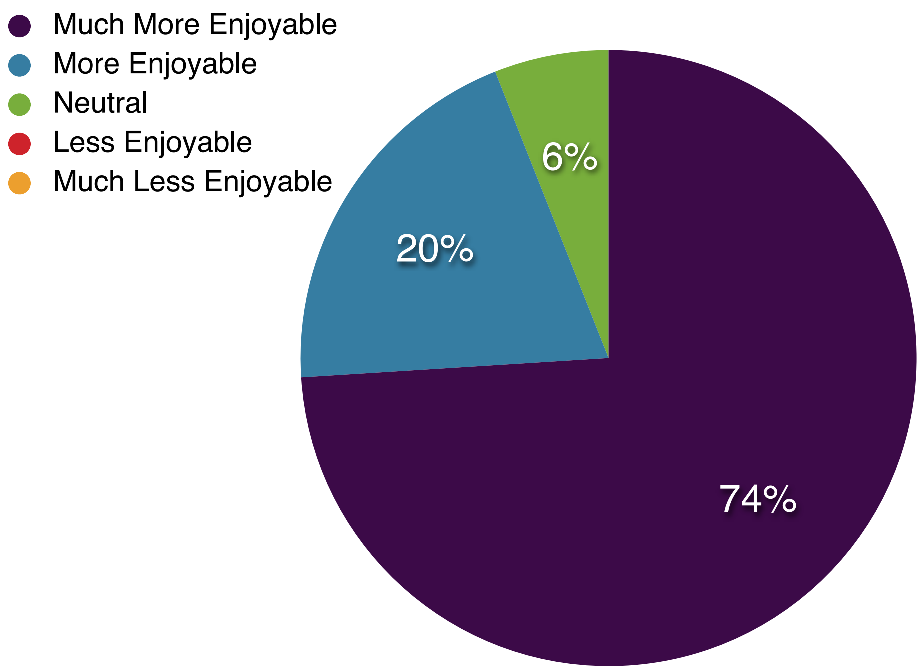


Figure 4.13: Student experience with the CWE

by hand and a majority rated it as being much more enjoyable (Figure 4.13). Fourteen of the fifteen students reported that they were pleased with the final paper produced by their group. Indeed, as was observed in many of the previous EVE sessions, all of the students were keen to receive their own printed copy of their work after the session to take home. Students reported that the activity in which they engaged most during the session was requesting assistance from a mentor. This may be taken to be reasonable as none of the students had any prior experience with the CWE and so questions were very likely to arise. Use of the commenting context to comment on other sections was reported to be the second most common activity. This suggests that the students were indeed collaborating actively in the production of their paper using the interfaces (76% reported use of the commenting context to comment on others' work).

When the students were asked to state three things they knew about galaxies after completing the trial, the most common comment was that galaxies were very large objects. The comments ranged in clarity from "lots of stars" (similar to the pre trial findings) to the more detailed responses such as "400 billion stars" (much more specific than the pre trial questionnaires). Information provided about the types of galaxy again showed a great variety from "colorful/nice to look at" through to the four main types of galaxy: spiral, elliptical, irregular and "peculiar". Of the nine comments made about "our galaxy" six of these merely gave the name (Milky Way) although one of these noted that it is "the galaxy in The Solar System". Two of the students reported that The Milky Way is a spiral galaxy while the final comment was "there are 20 stars per person in our galaxy". Interestingly, all of the Big Bang related comments came from two of those who wrote this section of the paper. Both stated the term and also mentioned Edwin Hubble. The other two Big Bang students made no reference to the main focus of their area of study. Comments recorded by mentors suggested that this section was regarded by the students as the most challenging.

4.10 Assessment of the communication between students

The CWE persistently records information exchanged been the participants of a writing task, including commenting data exchanged between students during the writing task. This persistent storage is essential for adoption within the school environment as it enables the teacher and students to save the project state and project data for future access. Furthermore this data can also be used for post-trial analyses. This section presents some of the data recorded during this trial. It was envisaged that this recorded data would be used to examine the hypothesis that students would be required to communicate, coordinate, co-operate, collaborate and compromise using the CWE. It became evident following the trial that the amount of data collected would not fully address this hypothesis and that further extended writing trials would be required for this to be done. However, in order to

Table 4.3: Table of selected student comments

Team	Section	Peer comment	Comment type
1	Introduction	mistake brian there are over 200 billion stars not 200 million! Change that	Editorial
1	Our Galaxy	There is a mistake in the last paragraph you have nyths instead of myths, and you have lokked in the first paragraph	Editorial
1	Introduction	you said there are 4 mian types of galaxies - its main	Editorial
2	Introducation	U spelled universe wrong	Editorial
2	Big Bang	wow amazing	Indirectly Relevant
2	Our Galaxy	Yeah, I know, it's so cooooooool , isn't it	Indirectly Relevant
3	Summary	I don't know what Im doin' i cant remember anything	Concerns
3	Our Galaxy	I have no clue at all!!!! im so dumb right now	Concerns
3	Summary	hows the summary going for ya jayne?	Concerns
2	Introduction	Hi Ciara	Conversation
3	Introduction	Hi! Havin fun?	Conversation
4	Introduction	hello	Conversation
1	Our Galaxy	hello thats super work	Praise
2	Big Bang	It's looking good	Praise
2	Summary	well done, well done	Praise
3	Big Bang	thanks, thanks Conor	Praise

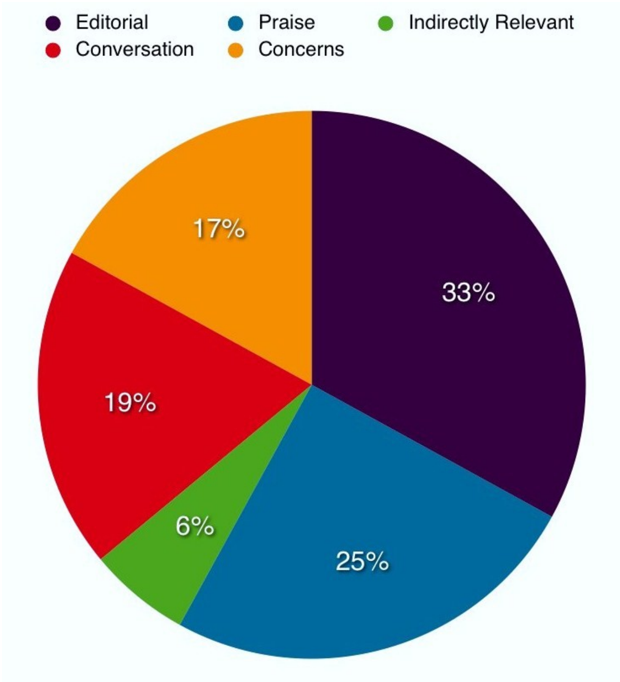


Figure 4.14: Pie-chart of student comments

assess the extent of communications that did take place between the students during this session the informal exchanges which occurred were analyzed. A total of 37 informal exchanges were recorded by the CWE during the session. Three of the four teams made repeated use of the commenting context, while only one use (greeting a colleague) was made by any member of the fourth team. A limited content analysis was undertaken of these interactions, using a simple classification system, as follows:

1. Editing/revising comments: anything which suggested changes to the output. Initial inputs and responses were included.

2. Encouraging/praising comments: all of those which commented on work, without making any specific suggestion for changes.

3. Indirect relevant: comments on content, but not suggesting any change

to the paper.

4. Greetings/other comments.

5. Concerns: comments that were expressing concerns about the writing tasks.

A more complex classification system, such as that adopted by Barile and Durso [BD02] was considered, but the relatively short time span, limited options and the different nature of the EVE project made several of the options, for example, "novel topic ideas" inapplicable. In contrast to Barile and Durso it was decided to include greetings within the analysis as these represented familiarization by the students with the CWE before actual content issues arose. The data shows that the largest proportion of comments related to editing the draft, approximately 33% of the comments related to changes in the document (Figure 4.14). Many of the comments related to grammar and spelling, thus demonstrating, albeit to a limited extent, that students made direct comments on the work of others. Each comment related to specific aspects of the paper being produced and so supports the contention that the students were genuinely engaged in the task at hand. Table 4.3 provides an unedited sample of the comments made during the writing task. The exchanges ranged from a single comment pointing out spelling errors (of the word "universe" and "myths") to a long exchange relating to the number of stars in the universe. This team interaction clearly demonstrated that the commenting context was intuitive enough for the students to focus their comments on the task rather than difficulties with the software. It was also noteworthy that many of the comments used shorthand spelling similar to that used in mobile phone text messaging. 25% of the recorded comments were made offering encouragement and praise to fellow team members, for example "Looking good", "Nice work, keep going". This data indicates that teams were generally supportive of each other within the software environment and that the CWE successfully facilitated this feedback. A number of students utilized the commenting context to express their doubts about the task, for example "I dont know what Im doing" or "Im so dumb right now".

In total, 17% of the recorded comments were classified as concerns. This data provides some evidence that the CWE provided a forum for students to express their views and that those views largely related to the task at hand, whether positively or negatively. The lack of confidence expressed via the CWE reinforces the belief that the less assertive students did become engaged in the task. The CWE also provides the teacher with the ability to monitor and participate in these exchanges and consequently provide appropriate support, guidance and supervision where appropriate. Indirect relevant comments made were admiring of the images placed in the Scrapbook by other group members and would indicate a degree of enthusiasm and interest in the writing task.

The communications tracking and classification certainly demonstrated that there was communication between the students using the CWE and that the great majority of the communications were relating to the writing task. In particular the editorial comments provide evidence that there was an attempt to communicate as a team within the context of the writing task. The high proportion of editorial comments would also indicate that some level of cooperation was evident within the teams, however, many of the comments were relating to spelling errors rather than substantive document content. The recorded exchanges between the students demonstrated one clear instance where the students were presented with an opportunity to amend the content of their section. Specifically, there were several attempts within Team 1 to change the facts and figures relating to the number of stars in a galaxy. However, the resulting document did not contain the change that was requested by some of the team members. The recorded exchanges provided an excellent insight into the nature of discourse that arose during the writing task. The research team have come to the conclusion that in order to draw definitive research findings with regard to the hypothesis that the students would communicate, coordinate, cooperate, collaborate and compromise would require more precise mapping of comments made in relation to the evolution of the document over the course of a more extensive writing task. Additionally, we hypothesize that the data gathered would be of more significance if the participating teams were not co-located as this would ensure that all of the interactions and communications relating to the document would be captured within the CWE database tables.

4.11 Conclusion

The research team relied heavily on observation as a methodology for the continuous improvement of the VLE. As with previous trials each team successfully produced a paper using the writing tool. Encapsulating the collaboration within the software had the effect of increasing the inclusiveness of participation in the writing tasks when compared with previous tests. This increased inclusiveness was evidenced by the contents of the student research papers and through observation. Each student remained at their designated terminal for the short duration of the trial and yet each team produced a paper that had information relating to the subject matter in each section. The pre-trial questionnaires established that the profiles of the students participating were not exceptional and that their experience with similar software was limited, thus adding weight to the conclusion that the CWE was successfully adopted. The students reported that they enjoyed the experience of using the CWE to produce a team-based research paper. We were satisfied and encouraged that the students enjoyed the experience, however, we acknowledge that links between the enjoyment using the CWE and the learning will require a wider study.

The encapsulation of team management within the CWE successfully modeled the previously manual activities of assigning student to their writing teams and monitoring progress. Significantly the newly encapsulated roles and role-based assignments did not appear to inhibit the production of the research papers when compared to previous trials. Although the communications between the students were recorded and analyzed, we have concluded that the hypothesis that the students would be required to communicate, coordinate, cooperate, collaborate and compromise to produce their document has not yet been fully addressed. Future trials should include more extensive writing tasks and teams that are not co-located so that more precise conclusions can be drawn about the role that the commenting context and the other interfaces play within collaborative writing tasks. We conclude that our research has lead to the development of an intuitive and innovative set of online interfaces that collectively provide an environment through which teachers and their students can plan, prepare, and produce truly collaborative research papers. The EVE Portal, via the CWE, now formalizes the role of teamwork in the writing process and provides mechanisms to allow the teacher to monitor the progress of the students. The research team can now turn our attention to testing these aspects of the EVE Portal within the school environment and to exploring ways to further support student writing within the VLE led the previously manual activities of assigning student to their writing teams and monitoring progress. Significantly the newly encapsulated roles and role-based assignments did not appear to inhibit the production of the research papers when compared to previous trials. Although the communications between the students were recorded and analyzed, we have concluded that the hypothesis that the students would be required to communicate, coordinate, cooperate, collaborate and compromise to produce their document has not yet been fully addressed. Future trials should include more extensive writing tasks and teams that are not co-located so that more precise conclusions can be drawn about the role that the commenting context and the other interfaces play within collaborative writing tasks. We conclude that our research has lead to the development of an intuitive and innovative set of online interfaces that collectively provide an environment through which teachers and their students can plan, prepare, and produce truly collaborative research papers. The EVE Portal, via the CWE, now formalizes the role of teamwork in the writing process and provides mechanisms to allow the teacher to monitor the progress of the students. The research team can now turn our attention to testing these aspects of the EVE Portal within the school environment and to exploring ways to further support student writing within the VLE.

Chapter 5

Incorporating Imaging into the EVE Portal

5.1 Introduction

This chapter describes an online image analysis tool developed as part of the iterative, user-centered development of the EVE Portal. As described in Chapter 3, the VLE provides a Web portal through which schoolchildren and their teachers create scientific proposals, retrieve images and other resources, and produce collaborative scientific papers summarizing their learning experiences. Detailed analysis of these research papers identified some shortfalls toward the goal of producing authentic scientific engagement. The absence of data collection and data analysis within these research papers was disappointing despite having scheduled time for this activity and having several imaging tools available. The post-evaluation analyses have enabled the development team to identify specific design issues with the previous VLE and have shaped the design of the new custom-built tool. This chapter also describes the technological framework of the EVE Portal within which the imaging tool has been implemented and includes details of the implementation of the core functionality provided by the tool. The performance of the imaging tool will be born out through content analysis of future collaboratively written student papers.

5.2 Motivation for the Imaging Component

The EVE Portal aims to support a seamless inquiry-based process and each component in the EVE Portal must be designed so that it is suitable for use in the school environment. Specifically, each component must be designed and implemented to accommodate the target population, i.e., schoolchildren and their teachers. Achieving a completely Web-based solution has been one of the main technical goals of our development since the EVE project began, this is important for accessibility, familiarity and ease-of-use, particularly to encourage its acceptance by teachers. The EVE Portal has the aim of engaging students to "do" science and engage in discourse relating to the subject under investigation. The experimentation and analysis possible using the EVE Portal has been enhanced following the development of the imaging component described in this chapter.

The initial version of the EVE Portal focused on astronomical images. Astronomical images can be truly spectacular and have the ability to spark the imagination of participants and thus have provided a great medium to explore the role that images can play in the engagement of schoolchildren in scientific discovery. Imaging in astronomy relies heavily on a data format standard known as the Flexible Image Transport System (FITS) which has been used by astronomers since the 1970s [GC02][HFG+01]. As well as optionally storing an image within the visual spectrum this format contains header information useful for astronomical analysis, including: information about the telescope where the image was taken, time-based data, data associated with the field of view and information associated with the coordinates of the region in the sky where the image was taken. This rich source of data can be extracted from the image using the EVE imaging tool. Students can perform a variety of scientific inquiry-based activities using this extracted data within the VLE and can generate additional data using this imaging tool. The measurement data generated by the tool are similar to those found in many astronomical image analysis tools, for instance the LTImage software produced by the Schools Observatory [sch07]. The EVE imaging tool, however, is not intended as a standalone software component for data collection and analysis, it is completely integrated within the inquiry-based process supported by the entire suite of tools in the VLE. The imaging tool can only be used within the context of a project assignment, therefore, the emphasis on report writing and inquiry remains central. The image data collected using the tool are centered on the elementary measurements of length and angle and, therefore, can be applied readily to Science curricula. The following sections detail the design and requirements gathering for the imaging tool and also describe the implementation details within the underlying EVE architecture.

5.3 Requirements elicitation for the imaging tool

In the formative stages of the Portal development the teachers and their students provided requirements and helped to evolve the VLE through use of the environment and through direct input into the project. This has resulted in the development of the CWE, Scrapbook and commenting context. Together these software components link the team allocation, research, writing and analysis phases into a software supported collaborative process. The imaging tool described herein is part of this amalgamation of software components designed to support collaborative research projects. The formative evaluations, described in detail in Chapter 3, were used to incrementally development the EVE Portal and its various components. This initial study also attempted to highlight usability and other practical issues to be resolved prior to deployment in a school environment.

The observational data gathered played a particularly important role in identifying shortfalls with the software and the production of new requirements to be included in later iterations. These observational data were the main source of requirements elicitation for the imaging component. These data showed that the demonstrators reported the image processing phase of the sessions as requiring near-continuous assistance. As a result this phase was identified as problematic by the EVE Portal development team. Possible causes for this near-continuous assistance were discussed during post-evaluation meetings, and it was concluded, based on observations that the students were confused by the many image modification options available when there were only a few functions that were relevant to the objectives of the sessions. The requirement to reduce the level of processing options available in the imaging tool was therefore elicited and a design decision was made to make only the necessary processing options prominent. According to the data, the image analysis phase also required near-continuous assistance, however, the exception to this was the Galaxies sessions. This was mainly due to the fact that the image analysis was a purely visual examination of the image in the Galaxies session, i.e., the complexity of the image analysis phase was reduced. The development team made another design decision for the new imaging component, namely, to make the measurement functions more visible and easy to accomplish for the novice user.

In conjunction with the gathering of observational data a thorough content analysis of the student research reports was undertaken. The results of this analysis also had a direct influence on the design of the imaging tool. Each group of children that participated in a session completed a Project Report describing their work and these reports provided a means to investigate the degree to which students completed the tasks as laid out in the lesson plans. Each Project Report was scored under five different criteria; one of these was criterion was directly relevant to the requirements elicitation for the imaging component. Specifically, each report was examined for the level of image analysis information it contained (scored on a 5-point Likert scale from very poor to very good). Reports that contained no evidence of image analysis were considered very poor and reports that showed evidence that the children extracted information from the images and formed conclusions based on this information were considered very good. Few reports scored highly; reports predominantly scored average. This category also had the lowest average score of all the categories scored. In the two years where the image analysis phase was considered key, the children requested a lot of assistance during this phase. This analysis indicated that the imaging phase would require software which was more appropriate for use by schoolchildren.

Apart from any of the analysis carried out, we, as educators, were not of the opinion that the students had met our expectations for image data collection in any of the sessions. None of the student reports contained measurement data acquired using the imaging tools provided. There were several clearly defined measurement activities planned by the team prior to the sessions, for example, we had originally intended for the imaging phase of the Galaxies session to contain the measurement of the angular width of a Galaxy. However, the difficulties in achieving even the simplest processing tasks meant that these activities were not even attempted. The measurements themselves are not complex, but the difficulties with the software prevented participants from beginning these tasks. It is possible that the expectations for the image data collection and image data analysis were not reasonable. Nevertheless, these evaluations clearly demonstrated to us that the VLE was not providing a suitable platform from which to begin to explore the scope of image data collection and analysis possible. There was no prospect of successfully mapping the angular movement of astronomical objects given that the students were finding it so difficult to format the images for display. It is hypothesized that the new imaging component detailed in this chapter can provide a more appropriate software platform for exploration of the scope of image data collection and analysis using the VLE. The custom-designed imaging tool better equips the research team to assess the level of expectation we should have for students in future sessions. The success of the initial trials of the CWE have demonstrated to us the effectiveness of the evaluation approach employed; similarly the imaging tool must undergo further focused testing to ensure that we have come closer to our goals. Table 5.1 provides a summary of the main observations relating to the imaging activities, the requirements elicited from these observations and the design responses to those observations.

In addition to the requirements elicited from the laboratory observations some general requirements stated by the participating teachers also influenced the development of the imaging tool. For example, the teachers stated that the entire VLE should be free, require no installation, be easy to use by students/teachers and should involve teamwork and collaboration. The third-party imaging tools used in the evaluations inhibited the EVE development team's ability to satisfy these general VLE requirements, particularly the installation and collaboration requirements. Finally, delivering a fully integrated imaging tool simplifies the process of making the images persistent, thereby, making it possible to carry out data collection over extended and disjoint periods of time.

5.4 Imaging in Astronomy

Imaging in astronomy relies heavily on a data format standard known as FITS which has been used by astronomers since the 1970s. The FITS standard is not limited to storage of images in the visual spectrum, it was developed to store many types of data of interest to scientists, e.g. spectral data, text tables, binary tables etc. Importantly, a FITS "image" (ordinarily stored with .fits file extension) can also store information about the region of the sky where the image has been captured, as well as information about the telescope used and the object targeted. This data is stored within data structures held in the FITS file known as HDUs (Header and Data Units). Using FITS image data it is possible to retrieve real world coordinates for reference pixels and generate a coordinate map for each pixel within the image. It is, therefore, possible to determine the real world coordinate of each pixel within a FITS image included in a student's assignment. It is also possible, using FITS header data, to locate astronomical objects captured within the field of view of the capturing telescope (the resolution of the CCD camera fitted to the telescope is a limiting factor). It is the richness of information within the FITS images that allows schoolchildren to carry out experimentation using the EVE imaging tool. The ability to readily locate astronomical objects using a suitably intuitive interface empowers schoolchildren to explore the night sky within EVE and beyond. Fortunately, Java APIs are available to simplify the process of retrieving image data from FITS files (these are described in section 5.8 below). FITS images retrieved from the telescope CCD cameras are rarely suitable for analysis as they contain many defects and imperfections, often due to atmospheric conditions. Many of the images retrieved from telescopes have been automatically pre-processed (generally includes the subtraction of a dark-frame). Applying image filters and other image processing techniques can vastly improve the visual quality of the images before the analysis takes place [SM02]. Therefore, there was a fundamental requirement that schoolchildren must be able to perform basic image processing tasks quickly and easily prior to the analysis of the images.

5.5 Functional Overview of the Imaging Software

The imaging tool provides an integrated means for image related data collection and thus enhances the authenticity of the scientific inquiry within the VLE. The image measurements are based on length and angle measurements, which are frequently used in astronomy and in many other subjects. This section provides a functional overview of the imaging tool from the user's perspective and the full implementation details are contained in later sections. The imaging tool provides the following functionality:

5.5.1 Viewing FITS information

The FITS image standard is not compatible with many of the most popular browsers and cannot be rendered in their native format. The imaging tool, therefore, carries out an image conversion on each FITS image and displays a browser compatible representation of the image in the browser window. The original FITS image is stored at the server where the header information is read and returned to the browser in XML format when requested by the user.

Table 5.1: Problems associated with the imaging activities

Observed Difficulty	**Example**	**Requirement Elicited**
Imaging tools made assumptions about knowledge of user of the user	Manual entry of threshold values	Provide simple options, minimize manual entry, build for child user
Students found it difficult to swap from the broswer to standalone software	Students had multiple windows open, all with different interaction styles	Produce tools that operates within the existing portal (improve cohesiveness)
Students found it hard to load images and it was difficult to share/move images	Students were forced to walk around the lab with disks and pendrives	Fully integrate imaging with Scrapbook and CWE allowing easy sharing/loading
Students only used the imaging tools to make objects look nicer	Student requested frequent help when searching menu options	Simplify the imaging options and make the measurement options prominent
Every team included images in their paper but not possible direct from imaging tools	Each research paper produced contained at least one image despite difficulties	Provide simple mechanism for inclusion of images into research paper
Virtual collaboration not achievable with standalone tools	Imaging tools hampered virtual collaboration with reliance on manual swapping between applications	Make virtual collaboration possible with fully integrated imaging tool

5.5.2 Basic Image Processing

FITS images are not always in a state which shows pertinent details to the observer. The imaging tool provides some very basic image processing functionality to the user, including enhancement, sharpening and thresholding. A slider bar controls the thresholding so that manual entry of arbitrary values by the user is not expected. The provision of the slider bar prevents the students "putting in impossible values", a point raised explicitly in a journal article by Squires and Preece [SP99]. The simplicity of the options available reduces the level of complexity for the schoolchildren and makes the measurement options more prominent.

5.5.3 Mapping image coordinates to equatorial coordinates

Equatorial coordinates locate astronomical objects in the sky using two coordinates, namely, the Right Ascension (RA - clockwise angle on the horizon) and Declination (DEC - vertical angle from the horizon). The imaging tool retains a copy of the FITS header information at the server; this includes the coordinate header information where available. The student can retrieve the equatorial coordinates for a corresponding x and y pixel location on the image simply by double-clicking on the desired image location. Retrieving these coordinates enables the students to carry out computations, for example, the angular size of a galaxy can be measured by recording the coordinates of the extremities of the object and calculating the number of degrees the object spans. Figure 5.1 shows an example of these data retrieval function in operation, the equatorial coordinates were returned as RA of 159.0583 and DEC of 41.9451183335.

5.5.4 Pixel length measurement

The imaging tool supplies a simple one-click mechanism for measuring the length in pixels between two points in an image. The schoolchildren select the

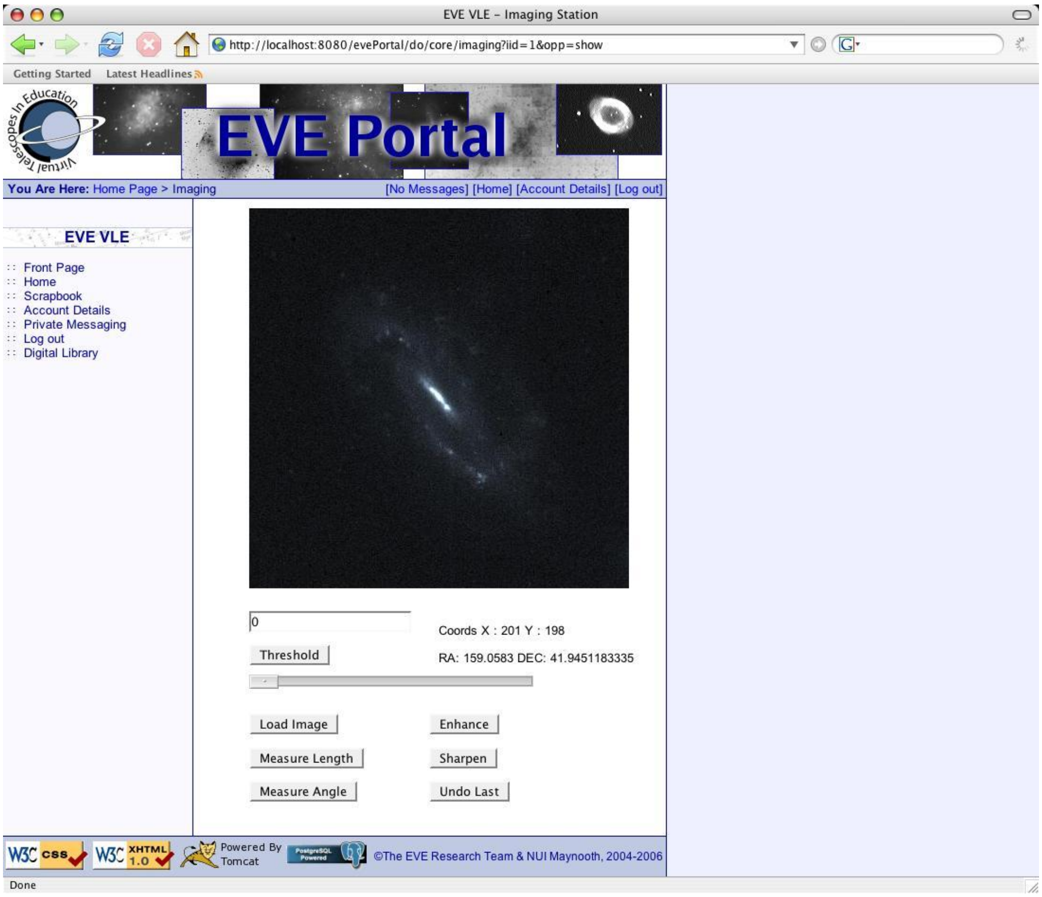


Figure 5.1: Mapping of image coordinates to equatorial coordinates

measure length option and then place a cross hair at the starting point and another cross hair at the finishing point. The pixel length is then displayed in a data window. These length measurements can be used to compute angular size and angular distance measurements.

5.5.5 Angular measurement

Finally, the imaging tool provides a single-click angular position measurement function. The student can use this to measure the position angle of one astronomical object relative to another. Figures 5.2, 5.3 and 5.4 show the sequential change of position angle of Titan (Saturns largest moon) relative to the planet. The angular measurements are generated by placing three cross hairs on to the region of interest in the image. The initial angular measure in this example was recorded as approximately 159 degrees relative to the planet; the subsequent measurements show how the position angle of the moon relative to the planet changed over time. This example illustrates how the imaging tool can be used to track the change in Titans angular position relative to Saturn over time. The imaging tool can be used to measure the angular position of any object in an image relative to another. This data can be used to simply show that moons orbit planets, or this data could be used to prove the hypothesis that it takes 15.94 days approximately for Titan to complete one full revolution of Saturn. Tracking the change in position angle of objects from within the VLE provides a variety of experimental case studies from the very simple to the potentially complex. The complexity of the experiments is dependent only on the availability of images and the imagination of the teacher and the students. A sample experiment is described in Appendix E below.

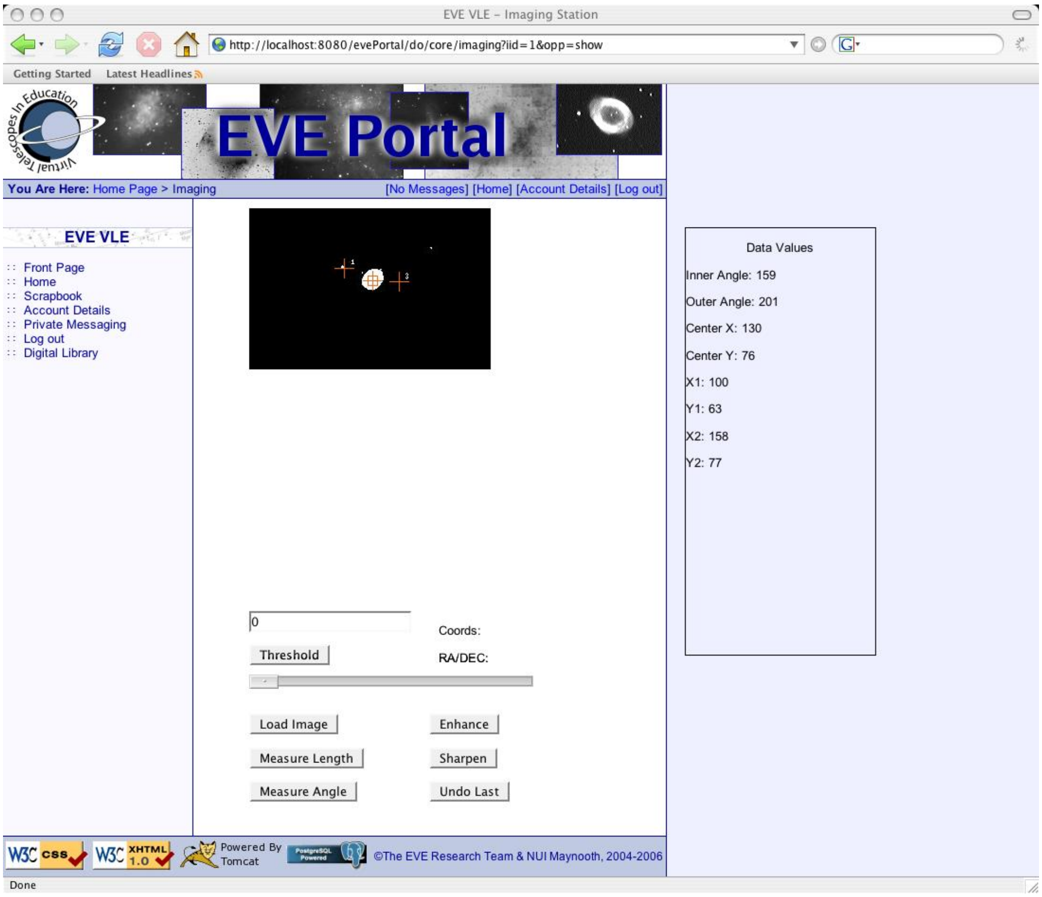


Figure 5.2: Angle measure of Titan relative to Saturn

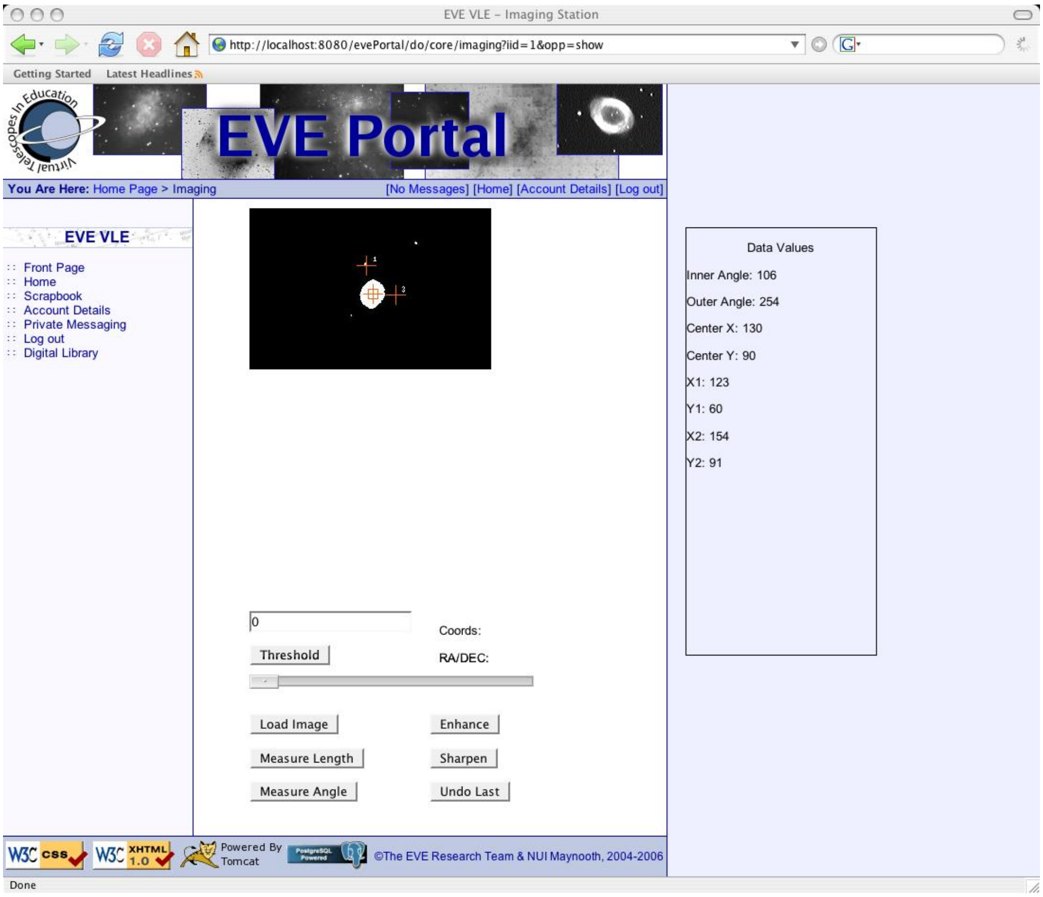


Figure 5.3: Angle measure 2 of Titan relative to Saturn

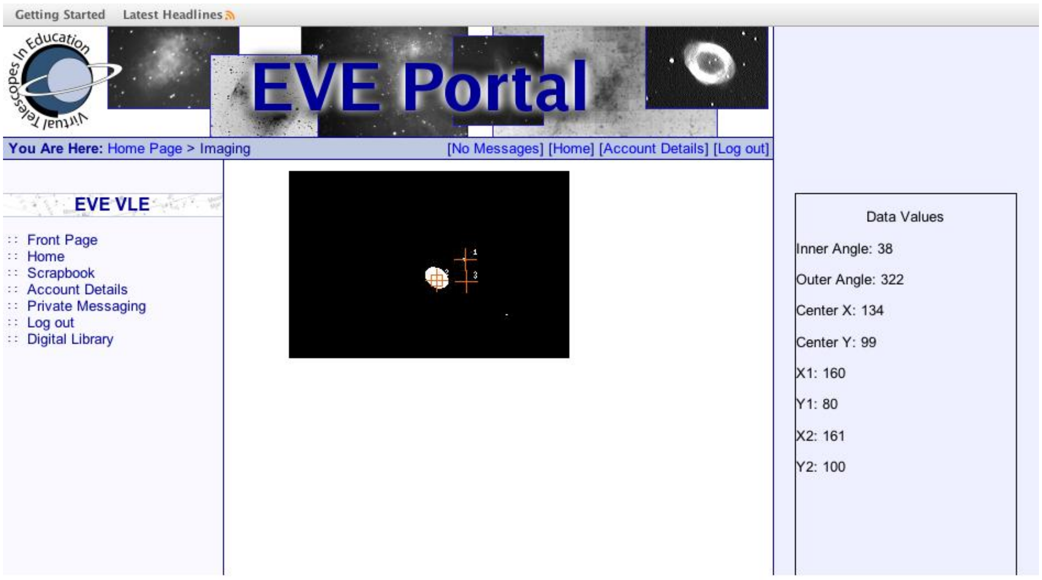


Figure 5.4: Angle measure 3 of Titan relative to Saturn

5.6 Technology Overview

The EVE Portal is a Java-based solution that has been constructed to operate within the Firefox Web browser [get06]. The EVE Portal has been architecturally constructed using the Apache Struts 1.1 framework [apa06]. The Apache Struts framework (part of the Jakarta project) is open-source and is based on the Model View Controller 2 (MVC2) design pattern which offers a well structured architecture through which new software can be seamlessly introduced [jav06, Spe03, HDFW03]. The Struts framework enforces the MVC pattern by completely separating the view from the model. The controller takes the form of an XML-based mapping between the model and the view. The Struts framework specifies the use of *Action* classes in order to implement the changes to the model. In order to meet the Struts framework specification new components added to the Portal must follow the Struts framework by implementing functionality as extensions of the Struts *Action* class and mapping those classes to client-side interactions. The imaging component in the EVE Portal follows this specification and implements the image processing and image analysis functions through inheritance of the Struts *Action* class and by providing mappings to the *Action* classes within the portal's XML action mappings. The imaging software described in this chapter supports basic image processing to students carrying out image-based analysis and basic image analysis functions such as length and angular measurement as outlined in Chapter 5 above. This chapter provides a detailed description of the implementation of the imaging tool within the EVE Struts implementation.

5.7 EVE Struts-based Technology

Within the Struts framework The View is composed of JSP pages complete with custom tags. The Controller is realized as a servlet called the *Action-Servlet* which dispatches requests to the appropriate *Action* class as defined in the *struts-config.xml* action mapping file (see Figure 5.5). Adding a new component to the Struts-based EVE Portal, therefore, involves the creation of new component-specific *Action* classes and editing the EVE *struts-config.xml* file to ensure that the request received from the view is correctly dispatched to the correct *Action* class. The diagram in Figure 5.6 summarizes the Struts framework in action.

The implementation of the imaging tool within the Struts framework involved the creation of *Action* classes to display FITS images, to process images and to retrieve analysis related image data from the FITS header files (see Figure 5.7). The *ImageHomeAction* is the Struts *Action* class which has the responsibility for displaying the current image within the client Webpage. This includes an image conversion which is abstracted from the user. Every Struts request has a response, this response is normally a forward request to another JSP page, however, the *ImageHomeAction* sets the response type to a binary image type. Thus, the image layer within the client window can display the current selected image to the browser window directly from the Struts request. The *ImageProcessAction* is the Struts *Action* class responsible for carrying out image processing requests. These requests are distinguished using form parameters which are defined using form-bean specification in the *struts-config.xml* file. The successful completion of an image process action results in the forwarding of the request to the *ImageHomeAction* class which results in the modified version of the image being returned via the response reference. Finally the *ImageAnalysisAction* class is the Struts *Action* class responsible for the display of the image data which maps the pixel coordinates to the WCS coordinates of the FITS image, if available. This action class receives a request with the parameters as defined in the form-bean specification in the *struts-config.xml*. These parameters include the x and y coordinates of the location selected on the image by the user. The result of this action is a forward to a JSP page which builds an XML file representing the WCS data retrieved. This XML data is returned via an AJAX request that was sent from the client when the user selected the analysis action. Figure 5.7 provides a summary of the implementation of the imaging tool within the Struts framework. UML class diagrams of the imaging and analysis actions are also shown in Figure 5.8 and Figure 5.9.

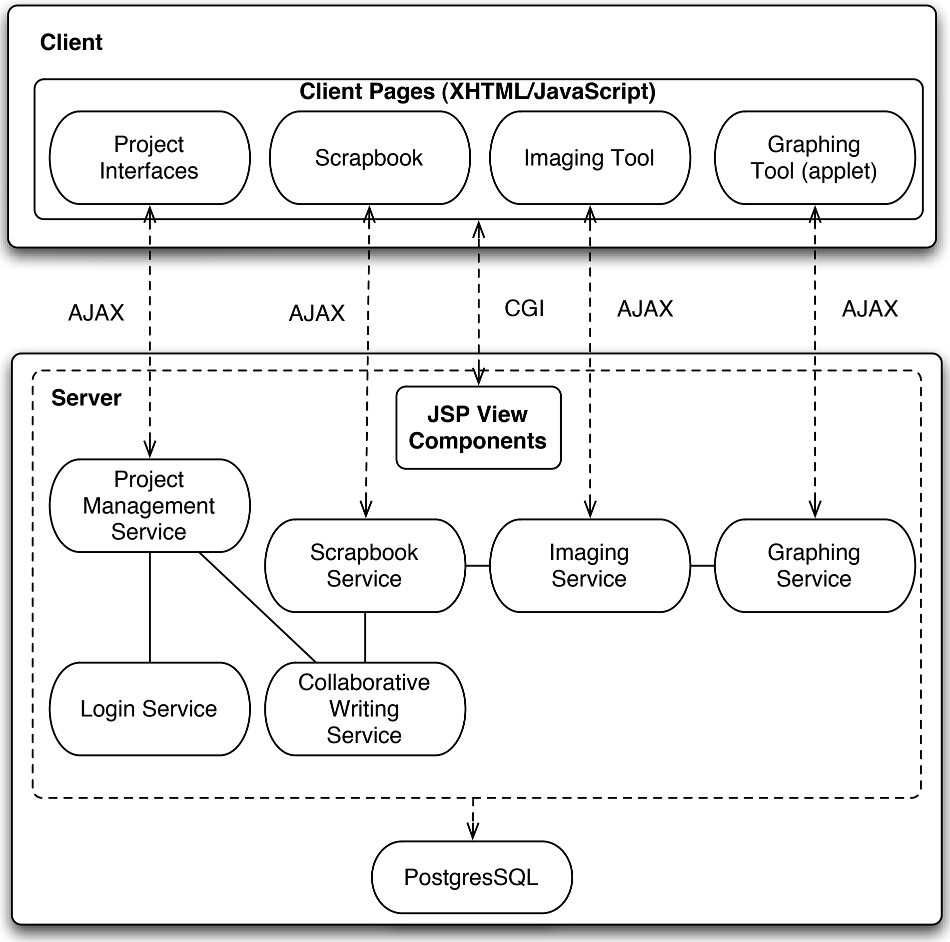


Figure 5.5: Architectural overview of EVE Portal

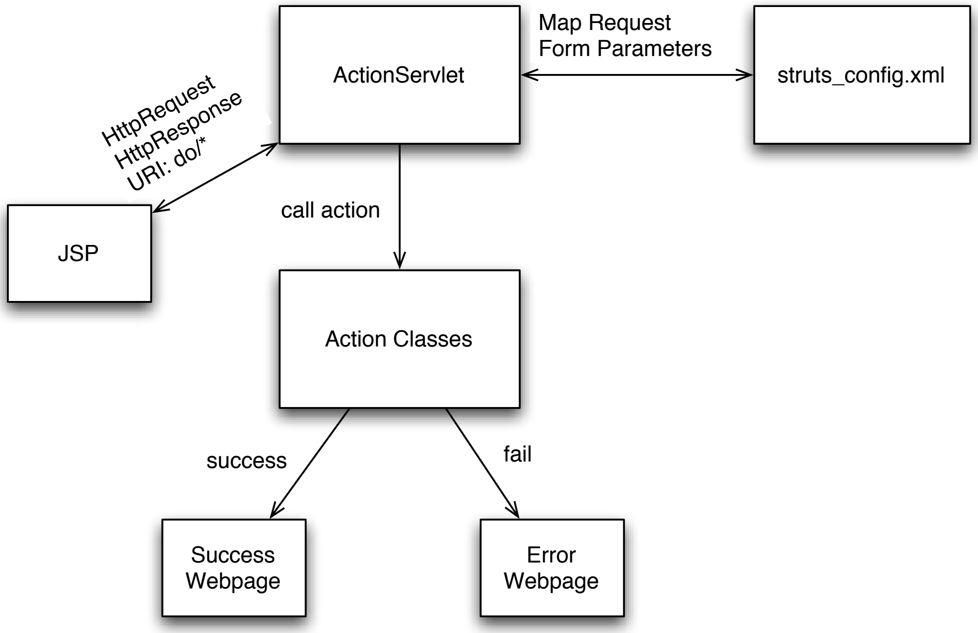


Figure 5.6: Overview of Struts framework in operation

The EVE Portal has been designed so that projects can span over extended periods of time. It is important that pertinent data gathered during the imaging data collection phase be persistently stored and associated with the image and the project. Persistent storage within the EVE Portal is carried out using a globally accessible PostgresSQL database. Access to the EVE database is carried out in a unified manner using Java utility classes designed at the architectural level. This ensures that each of the software components can achieve database access without having to implement the low-level code statements to store and share information and that the database access is centrally secured and controlled. The EVE utility packages also provide unified access to various session-related information such as direct access to information relating to the current users and user groups. Communication between the various components within the VLE is achieved using XML. The

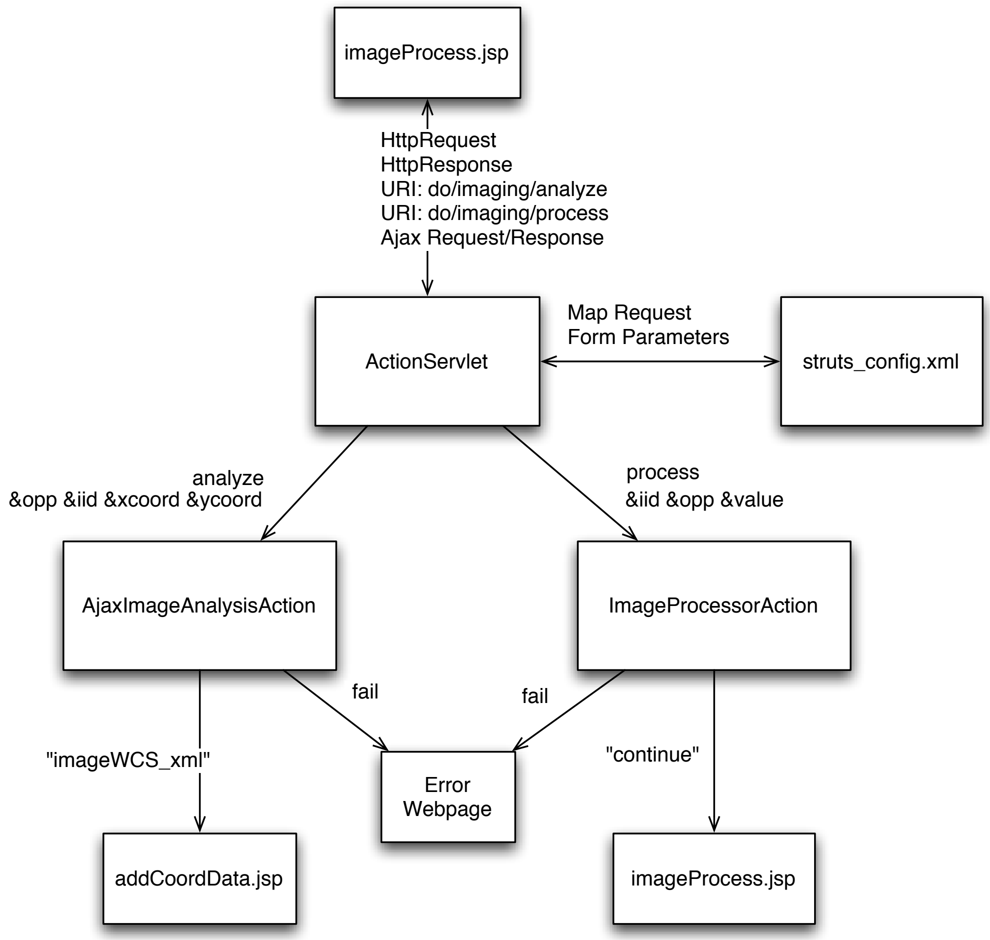


Figure 5.7: Overview of Imaging implemented within the Struts Framework

front-end communicates with the server is achieved using AJAX [xul06] and the server-side components use the JDOM package [API06] to produce and parse the XML. The XML data are used to represent data passed between tools and between the client and server.

As can be seen from the UML Component diagram shown in Figure 5.10, the imaging tool has a single front-end Webpage to interact with the user. The client window displays all of the available functionality to the student

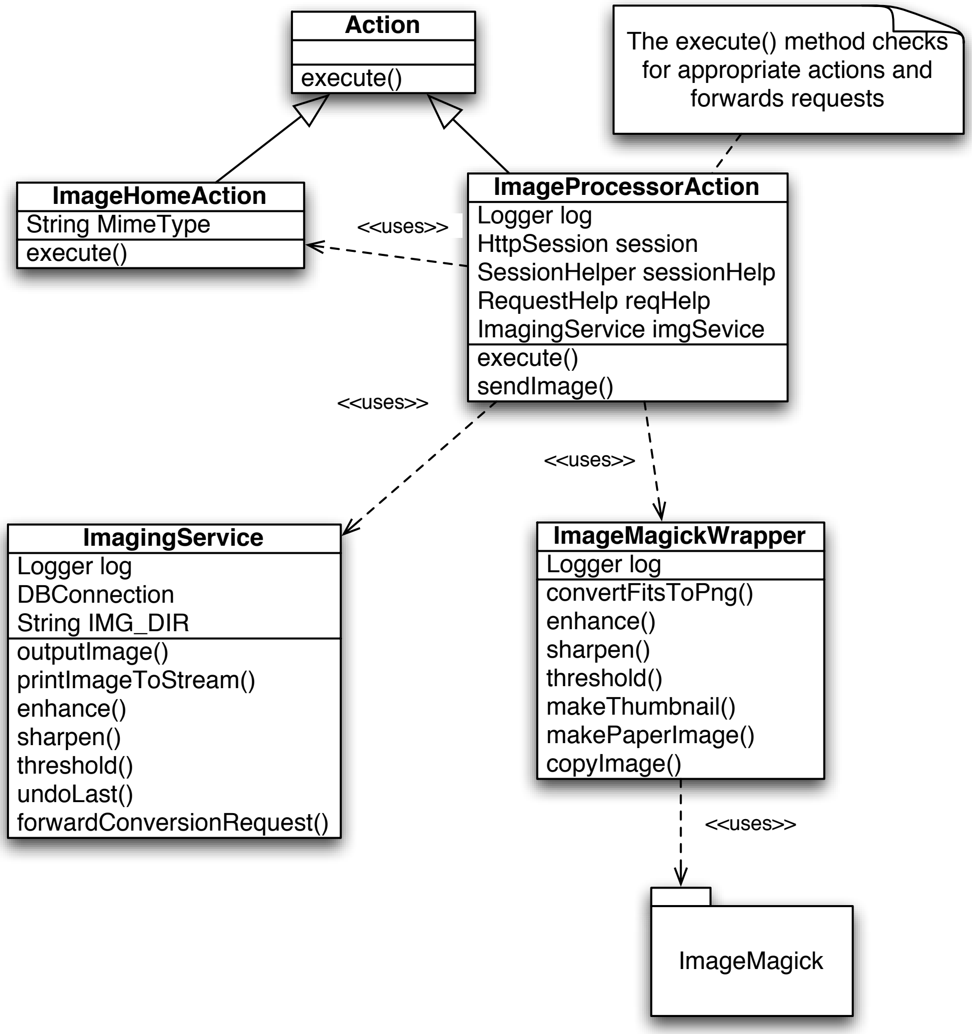


Figure 5.8: Detailed class diagram of image process action

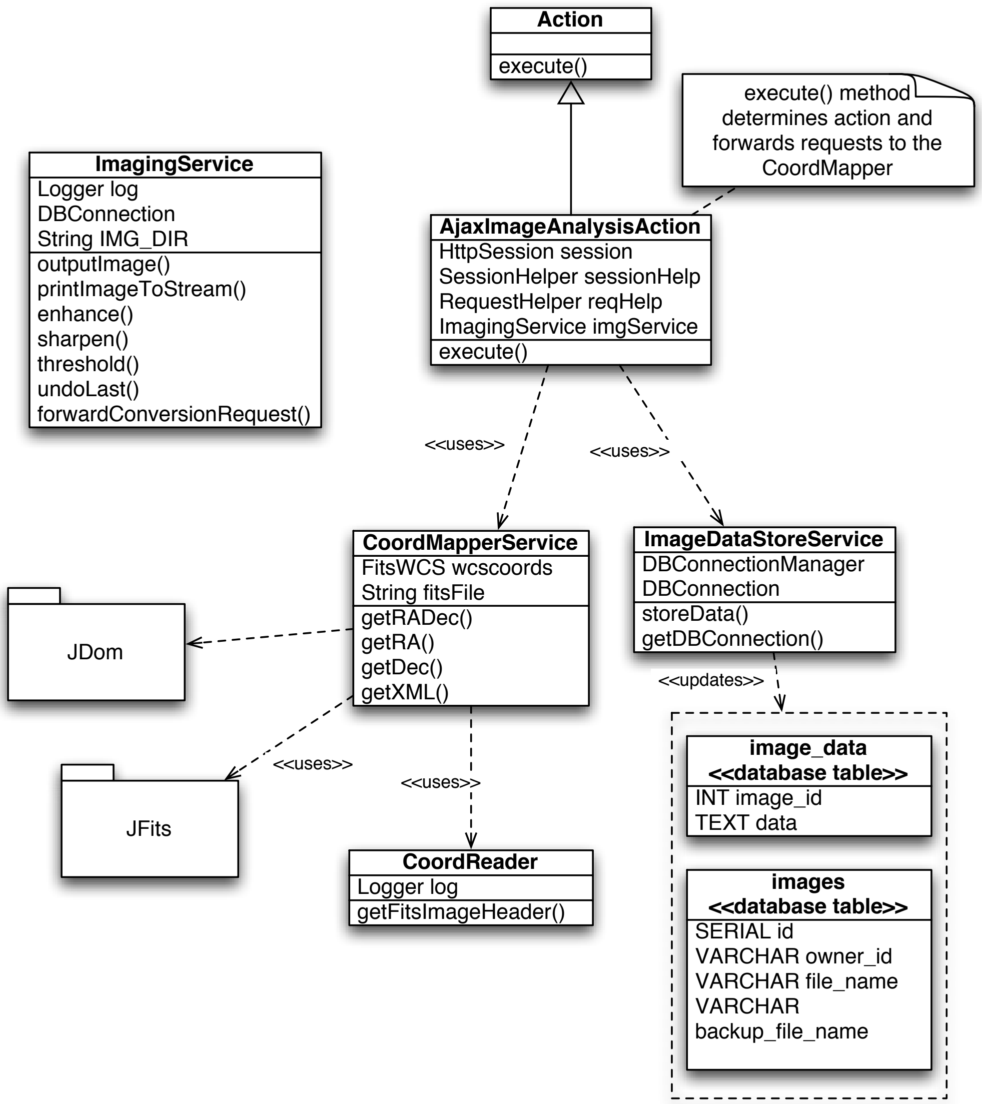


Figure 5.9: Detailed class diagram of image analysis action

user. The client is implemented in JSP and JavaScript and allows students to select the action they wish to perform using various form buttons. The image processing components rely on a Java API called ImageMagick [ima06]. This provides a complete set of image processing functionality for image conversion and manipulation. When a client wishes to display a FITS image in the client window the server automatically converts the FITS image selected into the Webpage compatible format and returns the converted image for display in the client window. Image uploading and storing are centrally controlled by the Scrapbook component; when a user selects an image to upload from the Scrapbook the image loaded is associated with the user that is currently logged in, this ensures that a student's work remains persistent allowing maximum flexibility in the completion of the analysis tasks. The image management component also allows the user to undo the last image processing action by storing a retrievable back-up copy of the image prior to the modification taking effect. Once the image is displayed in the browser window the student can select any of the image processing and analysis options available at the GUI.

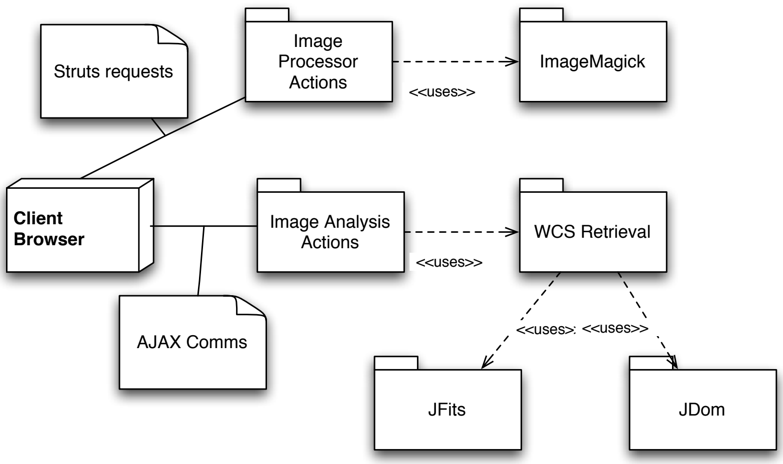


Figure 5.10: Component Diagram of the Imaging Tool

5.8 Imaging System Implementation

The following subsections describe in detail the implementation of each of the functional requirements of the imaging tool.

5.8.1 Implementing basic image processing using Struts actions

The client window of the imaging tool contains a CSS layer to display the current image. The system maintains the original image size and aspect ratio to ensure that the FITS data returned is as consistent as possible with the original image. Once the representation of the FITS image is viewable in the browser window the user may choose to process the image. The image processing available has been limited since the normal image processing requirement simply involves enhancement and/or thresholding. The image processing functions are enabled by associating a Struts-based URL to the image source and once an edit request is received the source is updated with the modified image. The imaging Struts action uses the ImageMagick API to achieve the binary image modification. A back-up of the original image is stored once a modify request is received, this is used to supply an undo option should the user be dissatisfied with the outcome of the edit. Once the image modification is complete, the new image is displayed in the browser window by overriding the URL for the image source. All of the image processing actions are carried out using this mechanism and the UML sequence diagram in Figure 5.11 provides an example of the sequence involved in an enhance image operation.

5.8.2 Implementing Imaging measurement functions

As outlined previously, the students analyzing images rely on two basic measurements, namely, angle and distance. The measurement of angles is achieved by applying vector mathematics and the distance measurements are achieved using a combination of the equatorial coordinates retrieved and

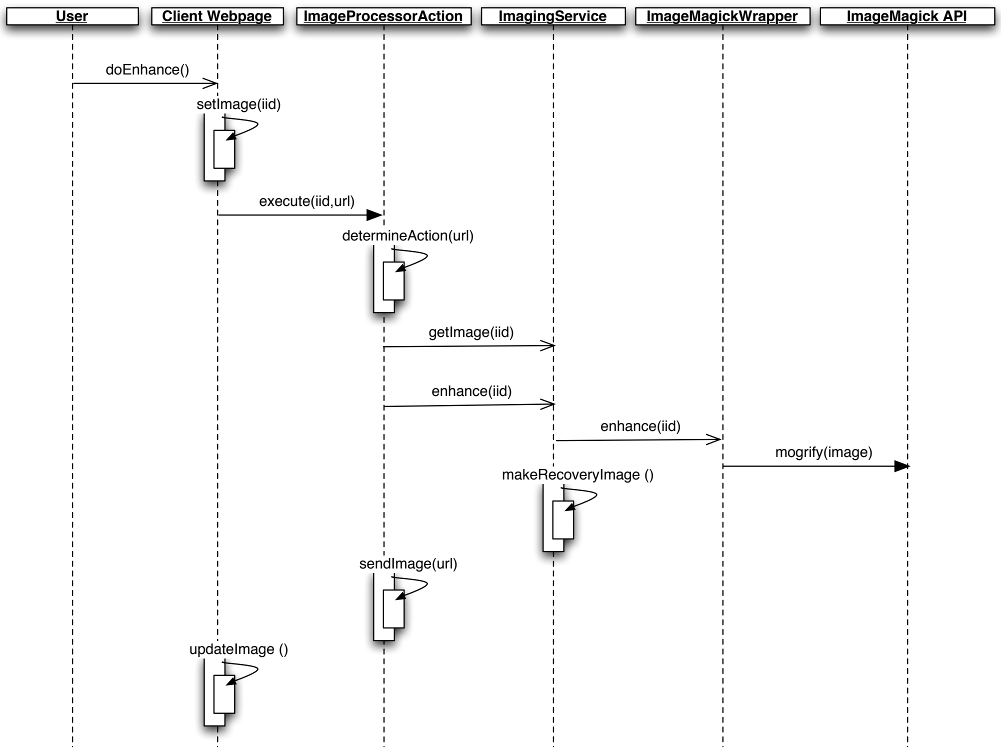


Figure 5.11: UML Sequence diagram for enhancing an image

the pixel data from the Javascript event handlers. The following sections describe the implementation of the measurement features.

5.8.3 Implementing angular measurement

The imaging Web interface includes an image layer to display the image loaded from the Scrapbook tool for analysis. This image layer comprises the image and the number of pixels in the image layer corresponds to the image being displayed. In order to measure an angle the student uses a one-click mechanism to place three cross hair images on the required area of the image (Figure 5.2 shows an example of this functionality in operation). The angle measure is calculated based on the pixel position of each the three points selected by the user. The calculation of the angle between two vectors is calculated using formula 5.1. The angle between the vectors is calculated by dividing the product of the absolute lengths of vectors u and v into the dot product of the vectors. Formula 5.4 can then be applied to the result of this calculation to express the radians in terms of degrees. A worked example of this type of calculation can be found in [Lip89, p.14].

$$\cos\theta = \frac{u.v}{\|u\| \, . \, \|v\|} \tag{5.1}$$

The implementation of the above calculations were broken down into the following steps:

1. Compute the two vectors (using the pixel cross hairs)
2. Compute the dot product of the two vectors
3. Compute the absolute length of both vectors
4. Calculate the value of the cosine of the angle between the two vectors
5. Convert degrees to radians

Javascript was used to implement these functions. The first step in the calculation is carried out in the first part of the *computeDotProduct* function shown in the code listing in Appendix F below. This part of the function extracts the the x and y coordinates of each of the two vectors from the image pixel position. The x and y coordinates of the vectors are calculated relative to the x and y position of the center cross hair, thus normalizing the vectors with respect to the center cross hair.

The second step involved computing the dot product of the two vectors. This dot product is denoted by $u.v$ in vector mathematics and the formula for calculating the dot product is shown as formula 5.2 below. This formula was used to calculate the dot product of the two vectors u and v formed by the user's placement of the three cross hairs. The second part of the Javascript function *computeDotProduct* shown in Appendix F below completes the calculation of the dot product for the two vectors.

$$u.v = x1 * x2 + y1 * y2 \tag{5.2}$$

The third step in the angular calculation involved the computation of the product of the squares of the length of the two vectors u and v. Formula 5.3 was used to calculate this and the same calculation was performed on each vector. The Javascript for this is shown at the end of the code listing in Appendix F. For ease of implementation the square of the absolute length was calculated at this point of the sequence and the rooting of the lengths was performed during the calculation of the cosine.

$$\|u\| = \sqrt{x_1^2 + y_1^2} \tag{5.3}$$

The fourth step in the calculation was to compute the value of $\cos\theta$ in radians using formula 5.1 (where θ was the angle between the two vectors). The Javascript to achieve this is shown in the code listing in Appendix F. The absolute lengths of the vectors were square rooted at this point. The final step in the calculation of the angle was to convert radians to degrees. This was seen as necessary as the users of the system would not be familiar with radians and would be more familiar with degrees. The results of the above angular calculations are packaged into an XML document and are returned via an AJAX response for display in the student data window.

$$degrees = radians \times \frac{180}{\Pi} \tag{5.4}$$

5.8.4 Implementing angular distance measurements

The measurement of the distance between two pixels in an image involved the trivial application of Pythagoras theorem. The computation of angular distance, however, required the computation of equatorial coordinates based on FITS header information. This pixel measurement must be mapped to the equatorial coordinates of the region of the sky. This was achieved using a combination of Javascript, AJAX and an API called the JFits API [Gro07]. Each FITS image is defined using header files know as HDUs. There can be several HDUs in one image, however, there is always at least one header defined in every image, this is know as the primary HDU. The primary HDU contains compulsory headers which all FITS images must contain. These headers contain metadata relating to the size and nature of information stored in the FITS file. The primary HDU may or may not have data stored which relates to the image. The primary data associated with the image is stored in the primary data array. The unit of metadata relating to the image is stored using 80 byte ASCII keywords and values. The keywords for each data record is specified using a maximum 8-byte keyword, bytes 9-10 are used to specify if a value is present and bytes 11-80 contain the actual values and any related comments. The mandatory keywords must also specify the size of the primary data array which may or may not follow, specifically the NAXIS keyword specifies the number of axes in the data array to a maximum of 999. Additionally the NAXISn keywords specify the number of data items in each of the axes, where n is the number of each consecutive axis. It is this stored data which may contain the data needed to calculate the corresponding physical coordinates of each pixel captured in the image. Each image which contains physical location data has a reference pixel along the x-axis specified using the CRPIXn keyword. For example, the *x,y* coordinate of the reference pixel could be stored using two CRPIX values, CRPIX1=100 and CRPIX2=100. The FITS headers may also contain information relating to the observation; these may include the date and time of the observation (DATE, DATE-OBS, TIME-OBS and EPOCH keyword) and the information relating to the telescope where the image was taken, for example, the TELESCOP, OBSERVER and OBJECT keywords. The captions in Figures E.1 to E.6 in Appendix E show the DATE-OBS and TIME-OBS data extracted from the FITS headers for the sample images.

Equatorial coordinates are used to locate a position in the sky where an astronomical object is located. Equatorial coordinates are very similar to the longitude and latitude measurements except that they are superimposed onto the celestial sphere (the sky). The equatorial coordinates are expressed in degrees and are relative to the equator. The Right Ascension (RA), or "hour angle" is the number of degrees East of the vernal equinox (the point where the Sun is at the first moment of Spring) and the Declination is the number of degrees North or South of the celestial equator. The RA and DEC give a two dimensional coordinate of a position in the sky. This two dimensional coordinate position will correspond to a two coordinate pixel position on the FITS image. It is this mapping which can be used to compute the angular size of an object or the angular distance between two objects. The representation of these physical coordinates is complicated by the "wobble" of the Earth and the distortions that arise when mapping a two-dimensional spherical coordinate system onto a flat two-dimensional image representation. The calculation of the physical coordinates is still further complicated by the fact that there are many different celestial representations used in astronomy. Calabretta and Greisen provide a detailed description of the mappings from pixel coordinates to equatorial (celestial) coordinates [CG02]. Fortunately, the mapping of pixel coordinates to physical coordinates can be accomplished in Java using various APIs supplied by expert astronomers. During the course of this research, several Java-based

APIs were investigated and tested for use in the retrieval of this FITS information. These included the nom.tam.fits [NAS07] package, EAP [Pie07] and JFits which is written by Preben Grosbol [Gro07] of the ESO (an internationally published author on the FITS format). Each of these interfaces provide mechanisms for accessing and retrieving information from the FITS tables, however, the JFits API was found to provide an intuitive API and, therefore, was selected for use in this project.

The JFits API is combined with Javascript event handling, AJAX requests and the JDOM XML API to return the physical coordinates for the pixel selected by the user. A request to display the coordinate data is initiated by the user within the displayed image by selecting a particular pixel (currently implemented using a double-click JavaScript event handler). The client Javascript constructs a Struts-based URL with the x and y pixel location where the event occurred. This URL, which also contains a parameter with a unique image identity (as set in the database) is sent to the server using a Struts-based HTTP request (see Figure 5.7). At the server-side the x and y pixel locations and image identity are retrieved from the parameters attached to the incoming request and they are forwarded for mapping to the physical coordinates by the JFits API. The JFits API requires that pixel locations are passed as an array representation, therefore, the x and y pixel locations are stored in an array prior to being passed for mapping to physical coordinates. Once the physical coordinates have been computed by the JFits API, the server then constructs an XML representation of the physical data to return to the client using the reference to the request. The Struts request forwards the result to a JSP file to store in XML format. The client AJAX request then completes, and the XML data is read and displayed for the selected pixel coordinate. A sample sequence for the retrieval of coordinate data is shown in the UML sequence diagram in Figure 5.12.

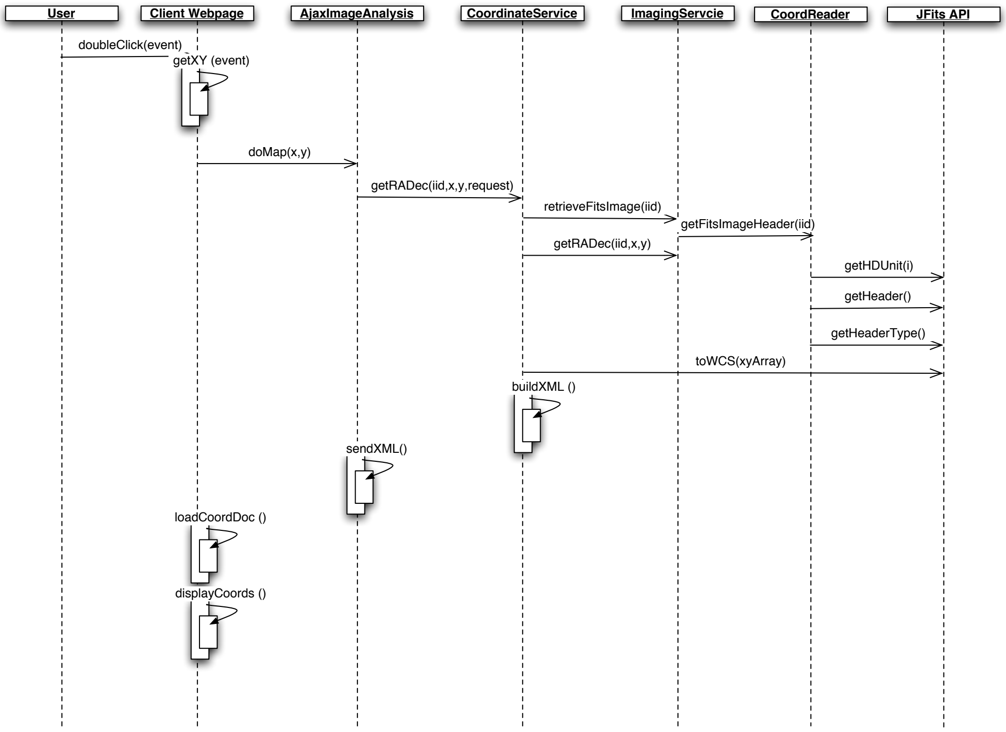


Figure 5.12: Sequence for retrieval of coordinate data

5.9 Integrating imaging into the EVE process

The imaging component is designed to be used within the context of the EVE inquiry-based process. Students using the imaging component will already have formed teams and gathered information and resources relating to the subject under investigation. The imaging component's role is invoked when a student identifies an image which requires measurement. The selected image may then be loaded directly from the Scrapbook into the imaging component's client window for analysis. The integration of the imaging component into the larger EVE process is facilitated by the Scrapbook which provides the point of entry into the imaging client window. The Scrapbook presents a list of thumbnail images associated with the current project and the subsequent user selection determines the image to be loaded into the imaging component window. The exit point from the imaging component involves the provision of a save to Scrapbook function to the user. The data gathered during the image measurement step is represented at the server side as XML and the data is displayed to the user in the client data window using AJAX. The flow chart shown in Figure 5.13 provides an overview of the process integration of the imaging component from the user's perspective.

The integration of the imaging and Scrapbook components from an implementation perspective involved the creation of several methods to service the entry and exit points from the Scrapbook to the imaging tool and visa versa (specifically the *ImagingService* and *ScrapbookService* classes). When a student adds an image to an assignment using the Scrapbook the image is stored at the EVE server and a database table entry maps the image identity with the assignment identity. The Scrapbook allows a team of students to display all of the assignment images on request using the database mapping information. It is from this list of assignment images that the student may enter the imaging component client window. On completion of the required measurements the student may save the modified image to the Scrapbook for later retrieval and the subsequent import into the final research paper. The UML sequence diagram shown in Figure 5.14 outlines the integration of the imaging component from an implementation perspective.

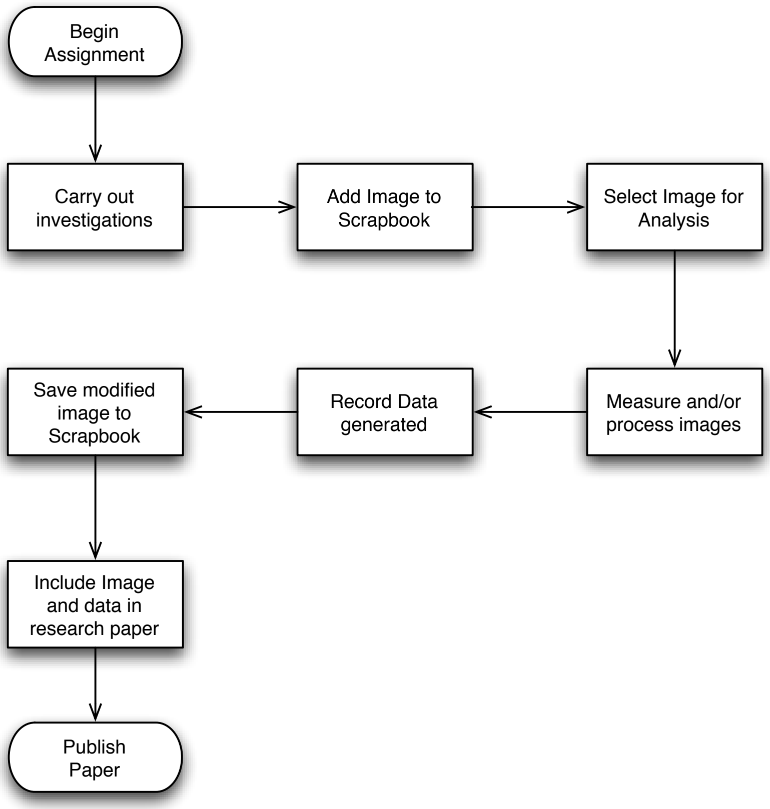


Figure 5.13: Flow chart of user interaction - process integration

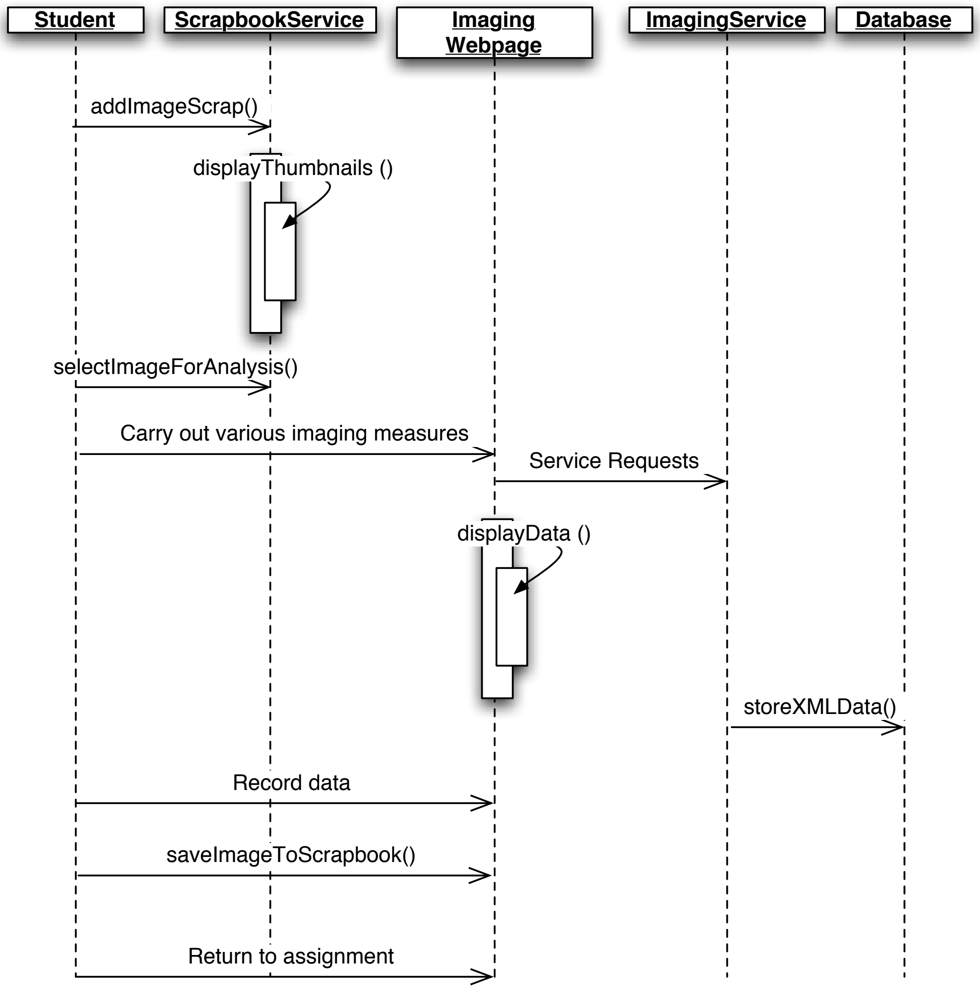


Figure 5.14: Sequence diagram for imaging process integration

5.10 Integration with an XML graphing tool

As described above, all of the data generated at the client Webpage is processed at the server in a PostgresSQL database. This includes data relating to the angles and location data which is generated during the course of an analysis task. Storing the information at the server ensures that analysis tasks can remain persistent. During the course of this research project this XML data was also used as input to a graphing component. This graphing component included a simple spreadsheet which would allow students to view and edit data stored using the imaging component. The graphing component made it possible to generate a graphical representation of the data being analyzed within the EVE Portal directly from the imaging tool [RBFK06]. This graphing component was constructed using Java Applet technology. This Java Applet complied with the Java Struts architecture, however, the Applet technology proved to be inconsistent with the general architecture of the system and did not successfully complete the integration testing phase of the project. The graphing tool successfully processed the image XML data and also produced graphs for display to the client. The graphing component certainly demonstrated a proof of concept in terms of the manipulation and automated recording of the data collected. However, the technology was not suitable for deployment to the school environment as the Applet technology placed an onus on the client architecture to run the Java JVM (this could require installation at the client which was not desirable). Further development of a purely server-side data manipulation and graphing component for EVE has been deferred for future work.

5.11 Software Extensibility

Implementing the Imaging component within the Struts Framework ensures that a well defined mechanism is in place for future modifications. The modification of the image processing actions simply involves the addition of a new client-side form buttons and the passing of the required parameters using the exiting Struts action request classes. Larger functional modifications to the component will require the implementation of new *Action* classes and the definition of a new action mappings. The Struts framework implementation also ensures that future enhancements are consistent with the other components in the EVE Portal. The imaging tool is well equipped to deal with any new requirements (for example, possible re-applications in other subject areas) which may result following future evaluations of the EVE Portal.

5.12 Conclusion

From a software engineering perspective the development of the imaging tool was an exploration of the VLE's ability to incorporate new tools within its architectural framework. As the VLE matures it is envisaged that there will be a limited number of tools required to support various data collection and analysis tasks which are at the core of the scientific inquiry-based process. The development of the EVE imaging tool has provided important feedback to the development team regarding the integration process. It is envisaged that future use of the imaging tool to support other subjects and tasks using images will require only minor modifications and enhancements to the existing implementation and that the use of images within the inquiry process will remain central to the inquiry activities using the portal as outlined in Raeside et al., [RBWK08].

The imaging tool described in this paper has been developed following extensive user-centered testing and with direct feedback from teachers and students. The addition of this imaging component enables students using the EVE Portal to take full advantage of the dynamism available from the Internet and enhances greatly the depth of inquiry-based activities and experimentation possible using the Portal. The next phase of testing of the VLE will produce a new set of student research papers. It is hypothesized that this imaging component will better support the completion of image related data collection activities and that the participating students will analyze these raw data and subsequently include them in their research papers. The level of raw data collected and level of analysis achieved will be measured through further detailed content analyses of the student output and comparisons will be drawn with the previous evaluations content analyses.

Chapter 6

Conclusion and Future Work

6.1 Contribution

This thesis makes several contributions to the fields of e-Learning and educational technology. Firstly the formative evaluation phase of this project has provided empirical evidence that an amalgamation of software tools can support an inquiry-based scientific process with schoolchildren and teachers as the target population. These initial trials were responsible for driving the software innovation presented in this thesis and involved over 150 schoolchildren and their teachers which produced more than 50 team research reports. These reports which were produced by the schoolchildren were independently assessed by 14 schoolteachers and the results of this survey provide empirical evidence that the software was capable of supporting an inquiry process within a constructivist paradigm. The formative evaluations provide a well documented case study and present a research approach for driving innovation in this area. The methodologies applied during the formative evaluations are of interest to researchers endeavouring to develop software for use in schools. The combination of the teacher meetings and discussion forums, test trials, survey-based assessments and post-trial analyzes applied in this study have implications for those who are researching constructivist learning at pre-tertiary level using ICT.

The evolution of the EVE Portal from a VLE to a collaborative VLE makes a contribution to the fields of e-Learning and educational technology and is of interest to interaction design specialists. The encapsulation of the team allocation and team-based writing has presented an innovative method for supporting constructivist, inquiry-based learning within schools. Additionally, none of the existing environments within the literature have placed such a central focus on the role of writing in constructivist learning at this educational level and few provide the means within the software to define projects, teams, and to complete a collaborative writing process within an integrated Web-based environment. The development of this open-ended Web-based virtual learning environment which codifies the emphasis on team-based writing tasks, support for team-based investigations and team allocation within the context of constructionist paradigm represents a novel approach to supporting e-Learning and authentic science in the classroom. Moreover, the EVE Portal provides one possible exemplar for supporting e-Science in the classroom. The requirements elicitation and development of the EVE image analysis tool presents many of the difficulties that are associated with the creation of software tools to support constructivist learning using ICT. Many of the issues reported on during the development of the imaging tool are of interest to others attempting to achieve authentic science learning using Web-based software and will serve to guide the design of similar Web-based technologies. The addition of the imaging component to the EVE Portal increases the depth of experimentation and data acquisition now possible using the VLE. Finally the imaging tool, when combined with a collaborative writing project, provides an innovative way for teachers to capitalize on the time spent analyzing images by producing tangible team-based output from Web-based inquiry activities.

6.2 Conclusion

The development of the EVE Portal began by observing groups of schoolchildren using an amalgamation of software components and with the hypothesis that it would be possible to support these inquiry-based activities using a completely Web-based software solution. The results of the formative evaluations have provided empirical evidence to support this hypothesis. The results include the observational data gathered during testing and the survey-based assessment of the output from the students by 14 independent professional schoolteachers. Analysis of the survey results showed that the teachers unanimously held the opinion that the reports contained evidence of learning of the subject matter, were generally above the average expectation for the age group of the children, and that the children collectively demonstrated an understanding of the topic presented in the laboratory sessions through their writing. All of the teachers agreed there was at least 'some' evidence of data analysis contained in the reports they had assessed. The layout and appearance of the reports was rated very highly by the teachers, in all, there was a 92% consensus that the reports looked 'good'. These results were consistent with our qualitative evidence that the Paper Writing Component was very successful in achieving a high standard of presentation among the participating children. Approximately 66% of teachers believed that reports of a similar high quality appearance could not be produced by their pupils in the same time period using standard word processing tools. All of the teachers agreed there was at least 'some' evidence of a logical/scientific approach contained in the reports, these opinions were further broken down into 38% believed there was 'some' evidence and 62% believed that there was 'lots' of evidence of scientific process in the reports. This result reinforces our contention that schoolchildren are able to successfully engage in an inquiry-based scientific process using the early VLE. Finally, when the teachers were asked to grade each report on a 5-point Likert scale, the teachers responded with overwhelmingly positive results: 43% of the reports were rated 'very good', 42% 'good', 14% were rated 'average', and only one report was rated as 'poor'. This survey-based assessment provided the research team with the impedous to continue to persue the building of a constructivist inquiry-based VLE and has lead to the further development of the writing supports and data collection and analysis support as summarized in this thesis.

In addition to the formative evaluations providing evidence to support the hypothesis that the VLE can support inquiry-based learning the evaluations also provided a mechanism for critical analysis of the success of each component of the VLE based on observation, direct feedback and content analyses. The post-trial analyses of the successes and/or shortfalls of the current VLE drove the innovation which lead to the development of the CWE discussed in Chapter 4 and the EVE image analysis tool described in Chapter 5 above. The initial trials of the CWE have already been completed and have provided sufficient evidence that collaboration has been successfully encapsulated within the writing process. 15 students (aged 15-16 years) took part in this trial and they were issued with pre- and post-trial questionnaires. The pre-trial questionnaires established that the profiles of the students participating were not exceptional, and that their experience with similar software was limited, thus adding weight to the conclusion that the CWE was successfully adopted. The students reported that they enjoyed the experience of using the CWE to produce a team-based research paper. None of the students considered the experience of using the CWE to be less enjoyable than writing by hand and a majority rated it as being much more enjoyable. Fourteen of the fifteen students reported that they were pleased with the final paper produced by their group. Use of the commenting context to comment on other sections was reported to be the second most common activity, suggesting that the students were indeed collaborating actively to some degree during the production of their papers (76% reported use of the commenting context to comment on others work). Although these initial trials have produced very positive results, it is acknowledged that further studies must continue to explore the extent of this success in comparison to similar open-ended writing tools currently being used in school. The EVE Portal, incorporating the CWE and the image analysis tool certainly represents an incremental shift in the development of the VLE.

Innovation is essential if ICT is to be successfully incorporated into the school environment, much of the literature suggests that innovation in this area is difficult to achieve given the lack of enculturation of ICT at pre-tertiary level. This project has enabled some of the required innovation to take place in a relatively short period of time. During the course of this project schoolchildren and their teachers have been at the center of this innovation and it was the observational data gathered and subsequent analyses that primarily drove the innovation in the development of the VLE. The EVE project has now reached a point where it is possible to deploy projects to the school environment, however, there are a number of qualitative and quantitative based studies which should be performed to further investigate the effectiveness of the VLE both from the educational objectives perspective and the human-computer interaction perspective. Many of these outstanding questions and possible future directions are summarized in the section that follows.

6.3 Future Work

The formative evaluations have created the conditions necessary for the innovation of this project to take place. The latest version of the VLE has successfully incorporated team allocation, collaborative writing, team management and image data collection. It was essential that the EVE Portal reached this point and following this study a more summative approach should be applied to future testing of the VLE. These further studies should address the hypothesis that the EVE Portal enables students to collaborate and that this engagement leads to deep learning. The effectiveness of the CWE can be researched by conducting a comparative study between it and other open-ended writing environments such as word processors. This comparative study would involve the collection of both qualitative and quantitative data and would compare experimental groups with control groups. The role of the imaging data can be examined through a comparative study between the output produced by students in previous evaluations and those produced in sessions using the new imaging component. These trials will focus on the success or failure of the data collection within the inquiry-based process, and will investigate the effectiveness of the data collection and data analysis within EVE. Additionally the imaging tool may have further generic applications, for instance, in Geography studies image-related data collection plays a central role. This further research will be of interest to e-Learning researchers and interaction design specialists.

The question of the role that scaffolding can play in supporting students with learning difficulties while engaging in an EVE project should also be explored through a similar user-centered study. The scaffolding can encompass the support of the writing task and may include prompting and writing templates. This would require close cooperative research with special needs teachers.

Currently the EVE software operates on a gender-neutral basis, this was sufficient for a study which focused purely of the collaborative aspects of science inquiry but would not be sufficient to explore any potential gender issues or apparent differences either in terms of output or participation. Future versions of the software should endeavour to model the gender of the participants so that hypotheses relating to any apparent differences between the interactions of males versus females can be examined in detail. This simple modification to the software would make it possible to carry out gender-based analysis similar to that being carried by a number of educational technology researchers [Mum01, VvEHK03, Hug04, CC03][GBL93, p.95–100].

The EVE Portal has scope to expand beyond its current application. For example, the EVE Portal can support writing tasks that are not science related given that writing is a ubiquitous activity within schools. It is hypothesized that the EVE Portal can be included into existing curricular activities and inquiry-based investigations which already take place in the school environment. The EVE Portal provides an excellent medium for recording the progress of students as they progress through writing assignments, whatever the subject. Adapting the EVE Portal to other subjects will explore the hypothesis that there is a generic tool capable of supporting inquiry-based learning through ICT which may have the wide appeal necessary to make the desired impact at pre-tertiary level.

There is much scope to explore the effectiveness of the EVE Portal in terms of its interactivity and usability. The EVE Portal should be evaluated based on sound HCI techniques, for example, an evaluation could be carried out using the proposed criteria as put forward by Squires and Preece [SP99] which would include, as Squires and Preece suggest, a full heuristic evaluation involving the usability heuristics as published by recognized experts such as Nielsen [Nie92]. This usability study would make a solid contribution to the combined fields of interactivity and educational technology, specifically in the area of supporting collaboration using ICT and would serve to minimize any possible usability issues which may be effecting the students' experiences using the VLE.

The EVE Portal could certainly be expanded to include the use of mobile devices such as mobile phones or PDAs as part of field studies. The data and/or images captured during a field study can be uploaded for later inclusion in the final research papers. It is envisaged that existing school trips and field study days could employ mobile devices to record images and data, that data can be uploaded directly to the EVE Portal database for inclusion in a subsequent collaborative writing task to summarize the learning outcomes of an excursion. This study would provide an opportunity to explore the combination of traditional fieldwork with ICT and would explore the hypothesis that ICT can enhance the educational goals of learning which takes place outside of the classroom.

The EVE Portal produces content that has been created by groups of students, however, the level of data gathered in the study was limited by the length of the writing assignments. It is envisaged that this research should be expanded so that the writing assignments and the degree and depth of writing and data collection is greatly increased. This extended collaboration should involve a more specialized detailed study such as those conducted by researchers whose works centers on collaboration using technology, for example, O'Donnell et al. [OHSE06, HS06], Erkens et al. [ERJ+05, EPJK02], Neale et al. Neale2004, Olson et al. [OO03] and Neuwirth et al. [NKCM90]. A study such as this would better address the hypothesis that the EVE CWE (and the Portal as a whole) students using EVE are required to communicate, coordinate, cooperate, collaborate and compromise to produce their document. Finally the EVE Portal presents an excellent opportunity for schools that are not co-located to collaborate in a writing assignment. Interactions between students in the same virtual team but not co-located would limit communications taking place outside of the interface and produce very complete and interesting data. This type of study would contribute to the advancement of ICT use at pre-tertiary level and would explore the limitations and possibilities of team-based inquiry learning via the Internet.

Appendix A

Sample student research paper

An investigation into the planetary nebula NGC246.

Abstract

In the following paper we discussed the planetary nebula NGC246 and nebulae in general and of how we viewed them from the 14" telescope at Mount Wilson.

Key words:
Nebula NGC246, NUIM Science Camp, Planetary nebula

1 Introduction

NGC246 is a planetary nebula. It's common name is the Pizza Nebula. A planetary nebula is the last stage in a small stars life - it is dying. The magnitude of NGC246 is 8.5. It's apparent size is 4.6 x 4.1 arc min. It's real size is 1.73 x 1.52 light years across. The R.A. co-ordinates of NGC246 are 00h 47m 0.0s (2000.0) and it's dec. is -11 53' 00" (2000.0). NGC 246 is 1500 light years away from Earth.

2 Observation

When we observed the planetary nebula NGC246 on the internet we saw the nebula under many different wavelengths, including x-rays, gamma rays, radio waves and visible light. We saw that under the long wavelenghts such as radio waves and infra-red rays, the image came out very cloudy and difficult to interpret. The opposite happens for the short wavelengths such as x-rays and gamma rays, the image came out quite clear and the areas of high heat intensity were very clear.

3 Conclusion

What we learned throughout the day was that all stars are created in nebulae and small stars die gradually in planetary nebulae. However, large stars die in huge explosions called supernovas. A supernova occurs when a star at the end of it's life collapses in on itself and the extremely dense core is all that remains. We now know that these dense cores are called neutron stars. a spoonful of a neutron star would have a mass on earth of 10,000,000 tons.

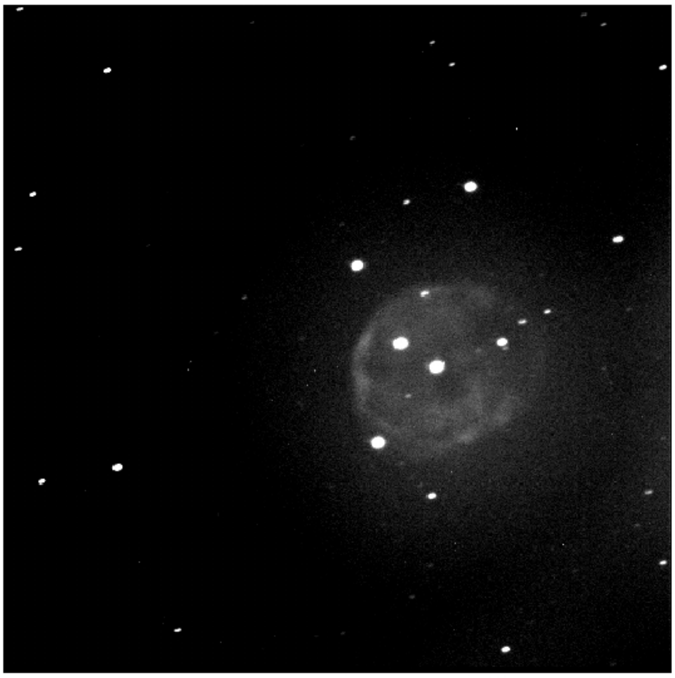


Fig. 1. Our image of NGC246 from Mount Wilson

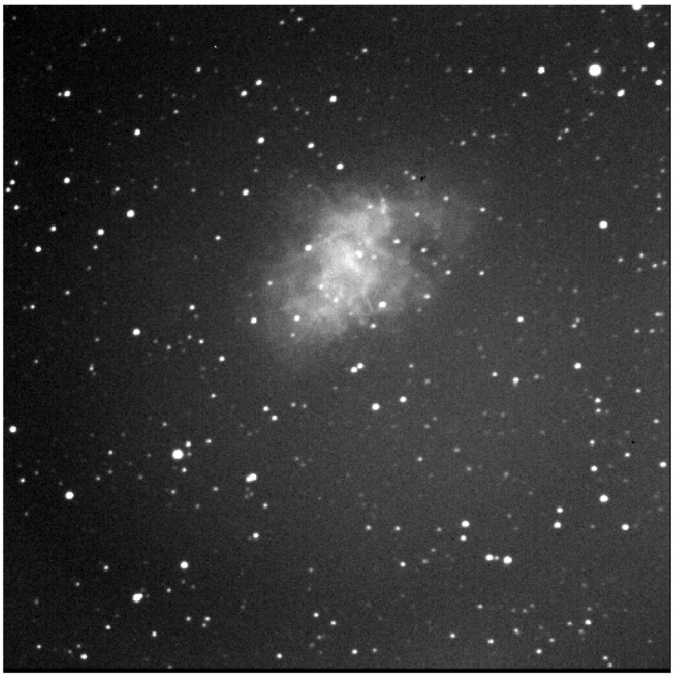


Fig. 2. M1, a remnant of a supernova from Mount Wilson

Appendix B

Data collected from teacher assessments

Table B.1: Data table of 'yes/no' responses (Question 1, Question 4, Question 7 and Question 8).

Question	Yes	No
Q1. Do the reports appear to be written by students of the given age group?	80%	20%
Q4. Do you feel that the students could have produced similar reports using a standard word processor?	33%	66%
Q7. Do the students demonstrate evidence of understanding of the topics?	100%	0%
Q8. Do the reports show evidence that the students had a positive learning experience	100%	0%

Table B.2: Q2. How much evidence of independent research is evident from the reports?

None	10%
Some	40%
A lot	50%

Table B.3: Q3. How would you rate the appearance and layout of the reports?

Average	7%
Good	57%
Very Good	36%

Table B.4: Q5. How much evidence of a logical/scientific approach is present in the reports?

Some	62%
Lots	38%

Table B.5: Q6. How much data analysis do the students include in their reports?

Some	70%
Lots	30%

Table B.6: Q9. Rate each paper in the booklet from 'very poor' to 'very good', this table contains results table for papers 1-25

Paper	Min	Max	Average
1	5	5	5
2	4	5	4.5
3	5	5	5
4	4	5	4.67
5	4	4	4
6	5	5	5
7	4	4	4
8	2	4	3
9	5	5	5
10	3	5	4
11	5	5	5
12	5	5	5
13	5	5	5
14	4	5	4.33
15	5	5	5
16	3	3	3
17	4	5	4.5
18	4	4	4
19	3	4	3.33
20	4	4	4
21	3	3	3
22	4	4	4
23	4	4	4
24	3	3	3
25	4	4	4

Table B.7: Q9. Rate each paper in the booklet from 'very poor' to 'very good', this table contains results table for papers 26–37

Paper	Min	Max	Average
26	4	5	4.5
27	4	5	4.5
28	4	5	4.33
29	5	5	5
30	4	4	4
31	4	5	4.5
32	5	5	5
33	5	5	5
34	5	5	5
35	5	5	5
36	5	5	5
37	4	4	4

Table B.8: Q9. Summary table for rate each paper question, shows results for all papers assessed

Paper	Min	Max	Average
All	2	5	4.36

Table B.9: Q10. To what degree do these reports compare with your expectations of students in these age groups?

Above Average	100%

Appendix C

Data from pre-trial questionnaire

Table C.1: Response table for Male/Female

Male	38.5%
Female	61.5%

Table C.2: Table of Likert responses on software familiarity

Question	Not Familiar	Familiar	Very Familiar
Word Processor	15.4%	15.4%	61.5%
Speadsheets	23.1%	38.5%	30.8%
Presentations	23.1%	38.5%	30.8%
Web search	0%	0%	100.0%

Table C.3: Table of Yes/No responses

Question	Yes	No
Computer at home		
Do you have access to computers at home	100%	0%
Do you play games on the computer?	61.5%	38.5%
Do you access the Internet?	100.0%	0%
Do you use computer for school work?	84.6%	15.4%
Do you use e-mail?	76.9%	23.1%
Do you enter chat rooms?	23.1%	76.9%
Do you download music?	53.8%	46.2%
Do you use the computer for other?	100%	0%
Computer in school		
Do you use a computer in class?	100%	0%
Do you use computers for other subjects?	76.9%	23.1%
Have you done ECDL?	23.1%	76.9%
Do you get teacher demonstrations in school?	30.8%	69.2%
Collaboration with others		
Do you play team games?	100%	0%
Do you do debates?	76.9%	23.1%
Are you part of youth group?	23.1%	76.9%
Do play multi-player gaming?	7.7%	92.3%
Do you play team games?	53.8%	46.2%
Astronomy		
Have you studied Astronomy before	53.8%	46.2%

Table C.4: Table of Likert responses on likability of subjects

Question	Dislike a lot	Dislike	Neutral	Like	Like a lot
Science	7.7%	23.1%	15.4%	46.2%	7.7%
Math	15.4%	23.1%	38.5%	15.4%	7.7%
English		7.7%	38.5%	23.1%	30.7%

Table C.5: Likert responses on working with others

Question	Rarely	Quite often	Frequently
How often do you work in the classroom with others?	46.2%	15.4%	38.5%

Table C.6: Likert responses on helpfulness of other students

Question	Unhelpful	Quite helpful	Very helpful
How would you rate the helpfulness of classmates?		53.8%	46.2%

Table C.7: Likert responses on enjoyment working with others

Question	Dislike	Like	Like a lot
How would you rate your enjoyment of working with others?		30.8%	69.2%

Table C.8: Open question on previous study of astronomy

Topic	(%)
Venus	23.1
Sunspots	15.4
Other	15.4
None	46.2

Appendix D

Data from post-trial questionnaire

Table D.1: Table of responses to Yes/No questions

Question	Yes	No
Did you comment on others work using the CWE?	66.7%	33.3%
Did you share scraps with others in your group?	40.0%	60.0%
Did you call for mentor assistance?	80.0%	20.0%
Were you pleased with the final paper?	93.3%	6.7%

Table D.2: Handwriting and collaborative writing using EVE

Question	No difference	More Enjoyable	Much More Enjoyable)
How would you rate enjoyment of team writing compared to team writing by hand?	6.7%	20.0%	73.3%

Appendix E

Sample angular position experiment

Background:

In 1514 Nicholas Copernicus proposed a model of the world that put the Sun at the center with the planets orbiting it. This was contrary to the accepted Aristotelian/Ptolemaic view at the time that the Earth was at the center of the universe. In 1609 Galileo used a telescope to observe planet Jupiter. The planet was observed to have several 'stars' (which were in fact some of the moons of Jupiter) moving in a regular pattern around it. This cast serious doubt on the idea that everything orbited the Earth. This evidence was published by Galileo to support the Copernican theory and began to change the way people viewed the world. The following experiment gives students the opportunity to see first-hand the type of observations and observational data that Galileo would have collected to support Copernicus's theory.

Aim:

The aim of this experiment is to carry out Galileo-like observations by observing the movement of moons around a planet (for example Saturn). Sample images of Saturn and its moons are provided in Figures E.1 to E.6 below.

Method:

1. Select the first image of Saturn supplied (it may need to be adjusted to see the planet and moons).

2. Choose any of the moons (small star-like dots) which surrounds the planet (the large dot) and measure the angle of the moon relative to the approximate center of the planet.

3. Record the angular data and the date and time when this image was taken at the telescope.

4. Repeat this experiment for the remaining images, each time selecting the same moon(s).

5. Using the writing tool summarize the data gathered and the conclusion drawn from the observations.

Data:

The data gathered will be angular data relative to time.

Expected outcome:

The students should be able to show that the selected moon(s) appeared to move relative to the planet. The students should include the angular position data gathered to support their conclusions in their research paper.

Possible Variations:

1. The students can repeat this experiment following more than one moon or more than one planet.

2. The students could attempt the calculate the period of the moon's orbit around Saturn and identify the moon using existing data, e.g., Titan's orbital period is approximately 284 hours. Plotting the period would involve the combination of length measures and angular measures over time.

Sample Images:

The images below show Saturn and several star-like objects surrounding it, these are in fact some of Saturn's moons. The time related data can be supplied with the images or extracted from the FITS header TIME-OBS and DATE-OBS fields.

Figure E.1: Image 1. Header data: DATE-OBS= '2001-01-09' TIME-OBS= '19:33:21'

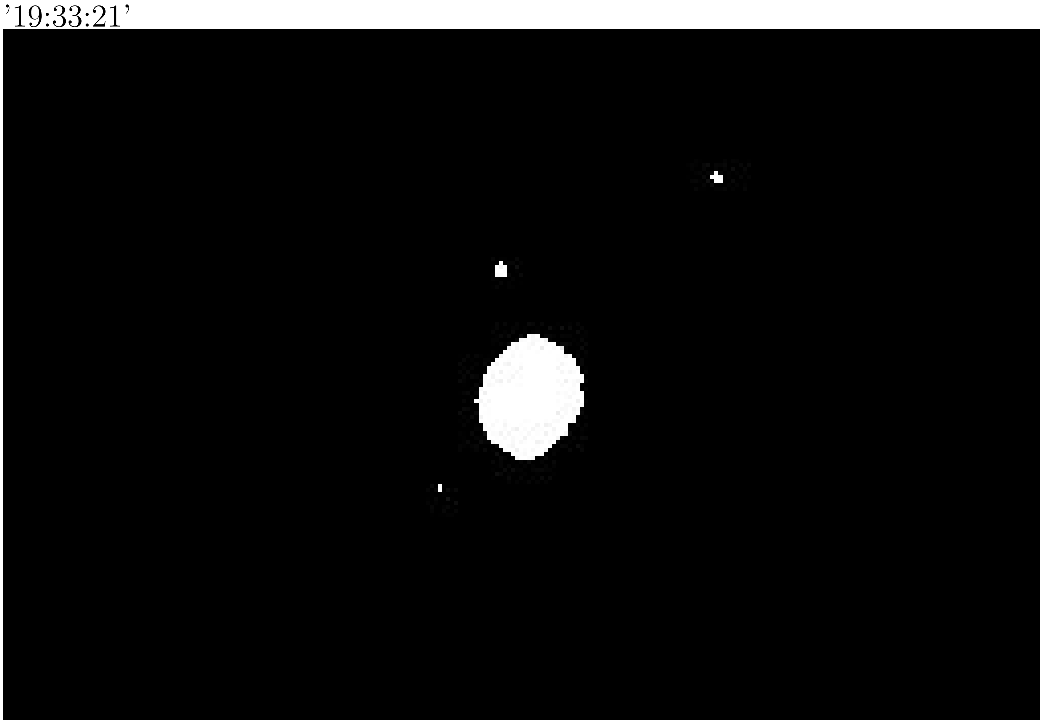


Figure E.2: Image 2. Header data: DATE-OBS= '2001-01-09' TIME-OBS= '22:04:29'

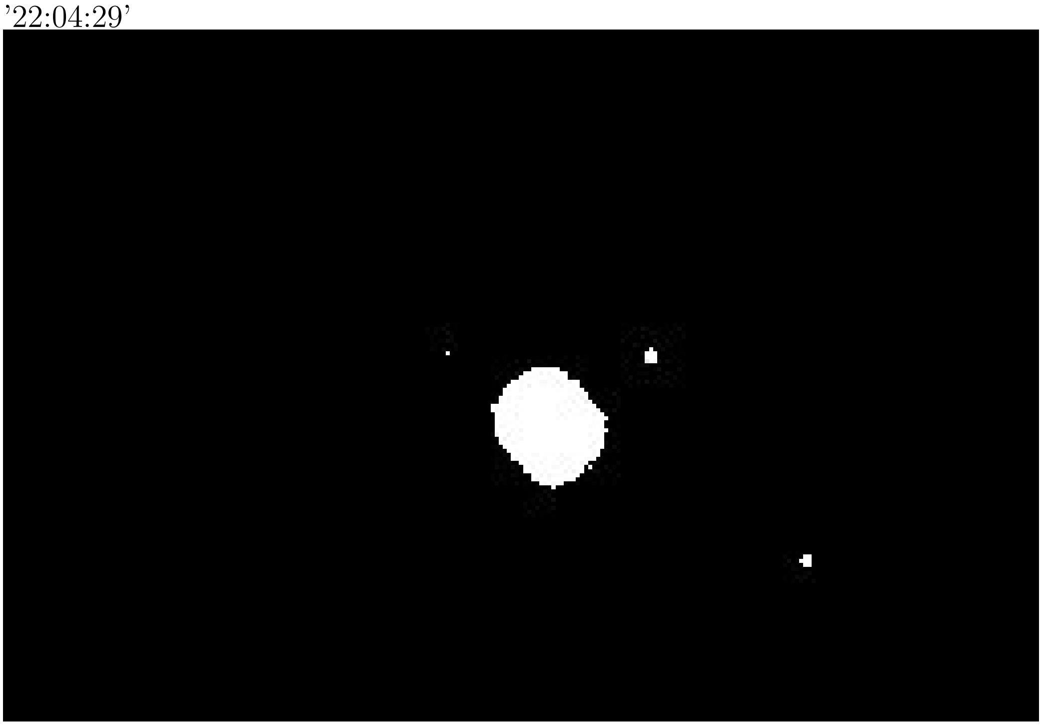


Figure E.3: Image 3. Header data: DATE-OBS= '2001-01-09' TIME-OBS= '23:05:33'

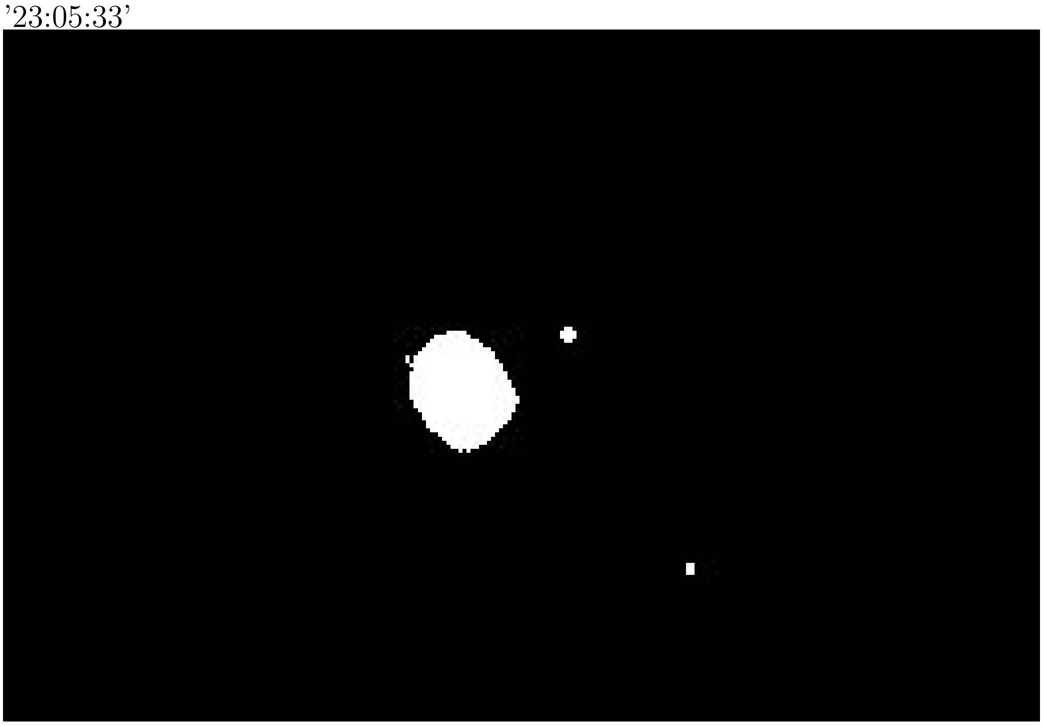


Figure E.4: Image 4. Header data: DATE-OBS= '2001-01-10' TIME-OBS= '20:04:18'

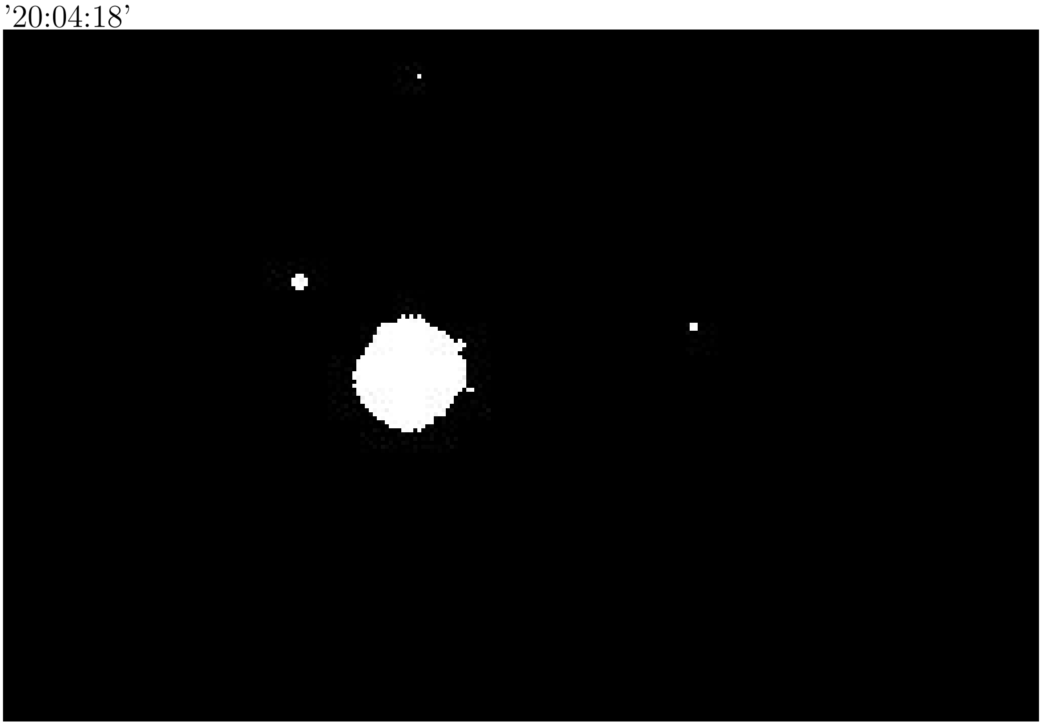


Figure E.5: Image 5. Header data: DATE-OBS= '2001-01-10' TIME-OBS= '21:33:08'

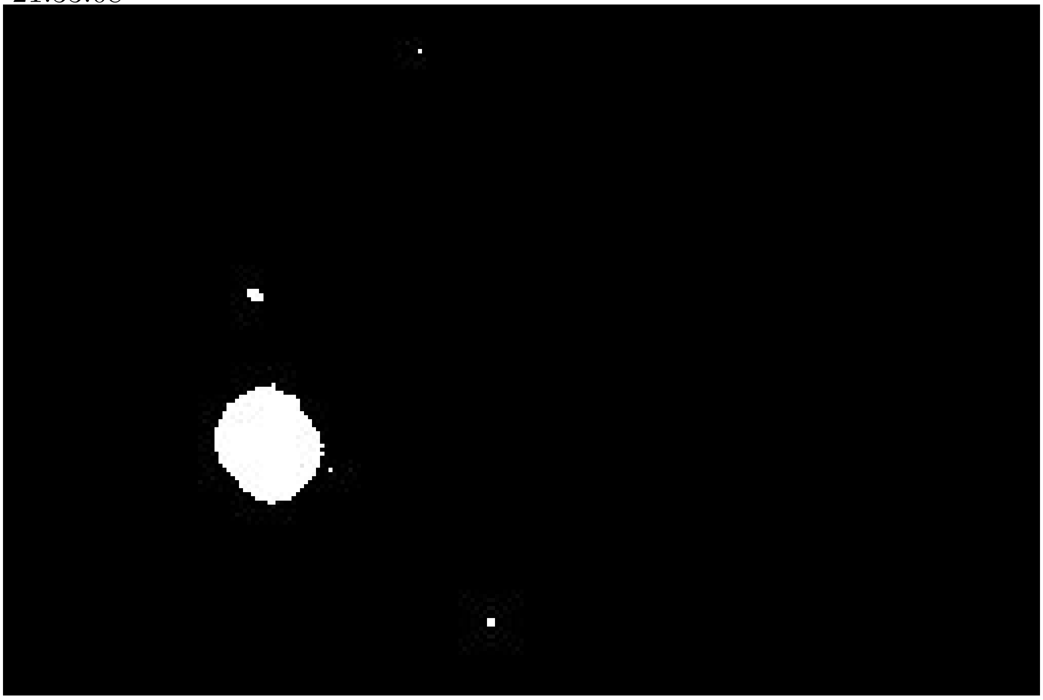
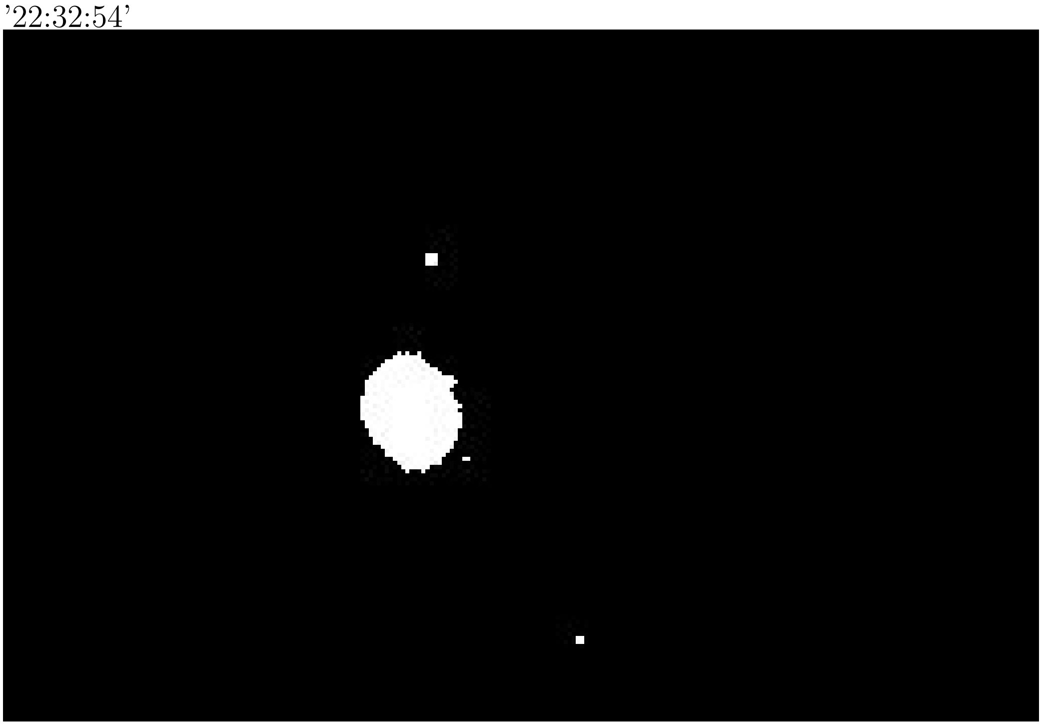


Figure E.6: Image 6. Header data: DATE-OBS= '2001-01-10' TIME-OBS= '22:32:54'



Appendix F

Imaging Tool Code Listing

```
//FUNCTION TO RETRIEVE VECTORS AND CALCULATE DOT PRODUCT

function computeDotProduct() {
 //Computes the cross product of two vectors A <x1,y1> and B <x2,y2>
 //AB is hard coded to vector1endPt X, vector1endPt Y, and, vectorCenterPt X,
 //vectorCenterPt Y
 //BC is hard coded to vectorCenterPt X, vectorCenterPt Y, and, vector2endPt X,
 //vector2endPt Y


 //Get vectors between points
 //vector 1
 var x1 = vector1endPt.getCenterX() - vectorCenterPt.getCenterX();
 var y1 = vector1endPt.getCenterY() - vectorCenterPt.getCenterY();

 //vector 2
 var x2 = vector2endPt.getCenterX() - vectorCenterPt.getCenterX();;
 var y2 = vector2endPt.getCenterY() - vectorCenterPt.getCenterY();

 var dotProduct = x1 * x2 + y1 * y2;

 var vector1AbsLengthSqrd = Math.pow(x1,2) + Math.pow(y1,2);
 var vector2AbsLengthSqrd = Math.pow(x2,2) + Math.pow(y2,2);

 computeAngle(dotProduct,vector1AbsLengthSqrd,vector2AbsLengthSqrd);
}
```

Figure F.1: Javascript code extract for calculation of angle between vectors

```
//FUNCTION TO COMPLETE ANGLE CALCULATION

function computeAngle(dotProduct,uLengthSqrd,vLengthSqrd) {
 //take dot product and calculate Cos Theta, where cos theta is the angle between the two
 //vectors
 //Cos theta is calculated by the dot product over the product of the abs lengths of vectors
 //u and v
 var infoDisplay = document.getElementById('crossHairPositions');
 var dataView = document.getElementById('dataWindowContent');
 var cosTheta;

 cosTheta = Math.acos(dotProduct / (Math.sqrt(uLengthSqrd)*Math.sqrt(vLengthSqrd)));

  //Convert the radians to degress
  var cosThetaAngle = cosTheta * (180/Math.PI);
  currentAngle = Math.round(cosThetaAngle);
  writeToDataWindow(cosThetaAngle);

  return cosTheta;
}
```

Figure F.2: Javascript code extract for calculation of angle between vectors

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