COLLABORATIVE INSTRUCTIONAL DESIGN

USING

INTERNET-BASED TOOLS AND RESOURCES

by

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ABSTRACT

Computer innovation at the post-secondary level can burden the instructor in terms of the time, expense and effort required to develop multimedia, computer-based instructional modules that keep pace with the rapid rate of research output. This study describes a successful instructor-developer multimedia collaboration that created a learning environment module for a post-secondary astronomy lab. A learning environment design model developed by Duchastel (1994) guided the team's development of the module. Internet-based tools and resources were used to help reduce development time and expense. The study investigated the requisite conditions to ensure success of the collaboration, the roles and responsibilities of the members, and the efficiency and cost-effectiveness of the collaborative development.

The study's collaboration resulted in a useful learning package consisting of a set of Web pages collectively called PLANET; (the PLAnetary *NETscape®* interface) and uses *Netscape's® Navigator™* to view the contents. This module has the attributes of a true research project. For example, the *Netscape®* interface enabled the first year astronomy students to locate and obtain images of Mars from the Internet in real time, and analyze them, in the same way as a planetary scientist. The results of the study indicate that a successful collaboration share the qualities of a friendship including similarities, trust, risk sharing, and symmetry. When these requisite conditions exist, then the time and funding limitations of developing a multimedia learning module are lessened. The study also showed that the collaborative development process is efficient when roles are established and maintained, and is an effective and inexpensive procedure for producing learning resources for post-secondary education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Chapter One

I. Introduction

Computers and Educational Technology are entering the post-secondary classroom. But for many instructors, knowing how and when to draw upon the vast array of resources is an intimidating prospect. Computer innovation at the post-secondary level can burden the instructor in terms of time and expense, and the effort required to develop multimedia, computer-based instructional modules that keep pace with the rapid rate of research output is a daunting prospect for those inexperienced with technology design. Because of the time required to develop multimedia instructional units, and the significant learning curve associated with underlying development software, multimedia instructional packages are normally developed by a team of multimedia experts rather than the individual post-secondary education teacher (Benoit, Demirjian, and Shaw, 1994). Unfortunately, limited involvement with the development process leads to minimal instructor interest in or ownership of the material. Benoit et al (1994), after spending many months developing multimedia modules for a dentistry faculty, experienced this problem first hand, noting it took a long time to inspire interest in and involvement of the faculty members. Even when readily made and easily available, the post-secondary teacher may not use the multimedia package and is unlikely to upgrade the package when new resources become available.

Is collaboration an important factor in the development and implementation of multimedia in the post-secondary classroom? According to Ripley and Hart (1989), a collaborative development effort helps to overcome instructor disinterest in multimedia packages by bringing forward a commitment to the project and, subsequently, a more ready assumption of ownership of the product. In this study, it is hypothesized that multimedia course modules can be generated

through a collaborative development process involving an instructor and a development expert, and that this process places no undue demands on the instructor.

II. Background to the Problem

Instructors are constantly in search of information for themselves and their students. The Internet represents a library of information that offers potentially easy access via an on-line computer. However, the Internet is vast and unmediated, so many resources remain underutilized. The growing popularity of the Internet is motivating developers to create a variety of access tools. Post-secondary instructors are beginning to take advantage of these Internet-based tools[1] and resources[2] to enhance instruction and learning (Crossman, 1995).

To capitalize on the rapid evolution of Web-based technology, the development of Internet-based learning environments should be quick, easy, and inexpensive. There are a growing number of models that illustrate how resources and tools can be quickly organized and developed into technology-based learning environments. An organization model, for example, may provide a series of steps to provide learner control and direct the learner towards some defined objective. Such models are valuable, especially in post-secondary education settings, where the need to keep curricular material as current as research material mandates frequent revisions of learning resources.

The Learning Environment Design (LED) model described in an article by Duchastel (1994) outlines a definitive procedure for constructing informal learning environments in a manner that is efficient while allowing for learner control. This organizational model provides a structure for the development process allowing information important from the instructor to be arranged

[1] Tools are programs used to manipulate files. i.e. create, view, transfer, or search for.

[2] Resources are files on the Internet. i.e. pictures, web pages, movies or sound.

into an effective learning environment. The LED model is applicable to a scenario in which a single post-secondary education instructor collaborating with a developer designs educational resources.

III Statement of the Problem

There is widespread interest in understanding the benefits and the limitations of computer technology as it applies to post-secondary education. A model or framework is needed in order that the benefits of technology can be realized in this setting. A significant aspect of such a development model or framework involves learning to use educational-computer technology, particularly on-line technology, in ways that are both cost effective and learning effective. Foundational to the implementation of educational technology is the development of new, technology-based learning materials. This study explores a collaborative effort to develop a multimedia learning module using Internet-based tools and resources. Duchastel's LED model is used as a design framework for the collaborative development of the learning module. The purpose of the study is to examine the attributes of a professional collaboration established to develop a multimedia learning module based on the LED model. Specifically, this study will:

- describe the collaborative process through which a multimedia module was developed,
- document and analyze the procedures through which the module was produced, and
- offer recommendations for the collaborative development of other multimedia resources for use in post-secondary education contexts.

IV. Statement of Research Questions

To evaluate the efficacy of the collaborative development of learning resources based upon the application of Duchastel's LED model, the study addresses two questions.

Question 1. What are the requisite conditions for a successful, instructor-developer, multimedia, module development collaboration? What are the roles and responsibilities of the instructor in this collaboration? What are the roles and responsibilities of the developer in this collaboration?

Question 2. Is the collaborative development of a multimedia instructional module using Internet software an efficient, effective and inexpensive procedure for producing learning resources for post-secondary education?

V. Significance of the Study

The study will be significant in the following ways:

A. The study will contribute to the efforts of post-secondary education institutions to find ways to develop resources to incorporate educational technology into teaching and learning.

B. The study's results will assist instructors to establish productive collaborative relationships with software developers.

C. The study will serve as an exemplar for faculty on how to incorporate Internet technology into post-secondary classrooms through collaboration with software developers.

D. The study will demonstrate how familiar, Internet-based resources and tools can be employed to create effective, inexpensive learning environments. Specifically, the study will show that existing, familiar software has important educational value in

1. keeping course material current with research,
2. maintaining course relevancy,
3. enhancing student motivation, and
4. facilitating instructor ownership in development of curricular resources.

VI. Limitations of the Study

A variety of conditions that impose limitations on the scope of the study are listed below:

A. The time the instructor and developer can afford to give to the collaborative process may impose a limitation on the quality of the completed module.

B. The necessity of collecting information through personal contact with those directly involved in the project via interviews, observations and document analysis limits both the number of data collecting opportunities and the volume of data that can be collected.

C. The application of Duchastel's LED model may be limited by the degree to which the instructor involved in the project shares the development experience. "*The amount of sharing depends on the collegiality of the individuals*" (Calhoun, 1993, p. 63).

D. The generalizability of the adopted collaborative design process may be limited to settings similar to those of this study, namely, astronomy labs, and in particular, solar system studies.

E. The objectivity of the researcher, who is also the developer, may be limited by the need for a successful collaborative action research study whose nature includes discussion to support and share ideas, understanding and conclusions.

Chapter Two

Literature Review

This study investigated the idea that collaboration between a single developer and a post-secondary instructor would be an effective method of creating multimedia courseware modules. The collaboration took place within the context of using a learning environment design model to develop a multimedia module. The Internet was used as a source for the post-secondary education resources and the development tools in order to minimize development time and costs. Chapter two is a review of relevant literature regarding collaboration, action research, collaborative action research, learning environment design, and multimedia applications of learning environment development.

I. Collaboration

Collaboration is a relationship in which there is active involvement of the participants in the sense that there is a vested interest in working together, maintaining common interests, and maintaining energy (Samara, 1989). For example, in Samara's (1989) study of teachers involved in action-research, he found that collaboration was the driving force for the teachers continuing to do research. Samara states that "*...with so many activities and pressures vying for the teacher's time, the temptation might be to let the research wait until later, but with the awareness that someone else is involved, there is a better chance that the research will continue*" (p. 87). The successful collaborative research team may include as few as two persons, or it may include several teachers and administrators working with staff from a university or another external agency (Calhoun, 1993).

One form of collaboration in research is a teacher and a researcher working together (Louden,1991). Such participatory research can only take place in contexts where there are well-

developed collaborative relationships between teachers and researchers, relationships, according to Louden (1991), built on mutual respect, trust, and complementary interests. The essence of a successful collaboration is that the nature of the relationship of the participants must parallel a friendship. The qualities of such a friendship, (friendship is the technical term used), are outlined in a paper by Wallace and Louden (1994). Wallace and Louden studied collaborative relationships between a single researcher and participating teachers and concluded with a list of attributes that characterized successful collaboration. A brief description of each attribute follows:

A. Similarities

According to Wallace and Louden (1994), similarities among collaborators such as common interests can be found in their traditions of teaching, and the hopes and desires in a mutual project. It is these similarities that most often bring collaborators together. According to McKernan (1996), coming together for the purposes of collaboration should be voluntary.

B. Differences

Skills and abilities that the collaborators do not have in common are shared in a successful collaboration. Wallace and Louden (1994) indicate that differences create opportunities for partners to help one another across gaps of understanding. Differences may afford a project a viewpoint or a specific look to the interface because of the unique ideas of the participants. McKernan (1996) describes how to support collaborating groups who wish to work together to achieve an improvement in their classroom learning activities. To be successful with differences, the core group must sort out their roles (McKernan, 1996) such that each individual can be understood by determining whether the contributor's input is to have a conversation or a discussion then to clarify in which type the contributor intends to engage. Discussions, such as an

examination of a topic, according to McKernan (1996), are more purposeful in intention than conversations. A conversation is the mere interchange of ideas. McKernan (1996) suggests discussions or conversations often break down because the participants are confused and at cross-purposes in their intentions.

C. Symmetry

An opportunity to work well together can be lost if obvious differences in levels of authority stand in the way of opportunities to share ideas. A balance or equality of power in a collaborative system is called symmetry (Wallace and Louden, 1994). Through mutual respect, individual professional integrity can be retained. In establishing a core group of collaborators, McKernan (1996) states that collaborative discussion will be most productive in settings where the participants know and respect one another. A shared goal and determination to reach it also indicates symmetry. Pierce (1993) discusses collaborative groups and how those groups define collaboration. Pierce (1993) states that some groups see collaboration as cooperation in working towards a shared goal.

D. Risk sharing

Wallace and Louden, (1994) suggest that a further quality of a successful collaborative relationship is a mutual preparedness to take risks and possibly fail in the presence of a partner. McKernan (1996) believes that most people are afraid of failure but insists to be professional also means committing oneself to experimentation, which entails a risk of failure.

E. Trust

An understanding of what talents or strengths the partners bring to the project helps to determine where input is required or when a weakness can be supported. Trust may empower participants to utilize their talent or strength. Wallace and Louden (1994) state that, like risk sharing, trust assumes that collaboration is a partnership in which there are no hidden agendas. Wallace and Louden (1994) state that teachers who worked best together were those who understood each other and respected each other's strengths and weaknesses.

F. Emergence

Emergence is the evolution and growth of the relationship. For example, Wallace and Louden (1994) indicate that the evolving process requires time for the partners to trust the other's talents. "*Emergence allows for the relationship and its consequent benefits to grow without being forced* (Wallace and Louden, 1994, p. 331). Wallace and Louden imply that emergence allows for the other qualities of collaboration to emerge.

G. Humility

Pierce (1993) writes that some groups in her study described collaboration in terms of using the group to work through and create new understanding, and to support individuals in the group. Pierce (1993) suggests that to support another group member requires humility and teachers who demonstrate humility in relationships are able to find the balance between professional pride and professional modesty.

H. Fair exchange

Collaborating groups successfully accomplished group tasks through shared responsibilities and equal (equitable) work (Pierce, 1993). Wallace and Louden (1994) define fair

exchange as ensuring that the rewards of the relationship are balanced by the effort involved in maintaining the relationship. Sometimes balance can be achieved by simply sharing the workload on similar tasks (Wallace and Louden, 1994). Being professional is a key factor in a successful collaboration and allows qualities similar to a friendship to emerge. A professional in a collaboration expects risk-taking, fair exchanging of tasks, and sharing of different ideas.

The factors that contribute to the success of a collaboration emerge from the nature of the relationship between professional members. In a study by Raymond, Butt and Townsend (1992), for example, paired graduate students and teachers engaged in collaborative classroom improvement projects. The only successful project involved two friends working together. Other pairings were clearly dysfunctional and characterized by phases of deflection and resistance and, at most, could only result in going through the motions of a collaborative process and solving only superficial issues. Factors leading to developing a successful collaborative relationship that came into focus for Raymond, Butt and Townsend (1992) included:

- how collaborative partners are chosen,
- how collaborative partners work together,
- the status of each of the partners,
- how research/developmental questions are formulated,
- what skills are needed,
- how to overcome fear of scrutiny and criticism,
- how to equalize the degree of risk engaged by collaborative partners, and
- how to develop mutual trust (p. 46).

These issues are related to those discovered by Wallace and Louden (1994) and referred to by McKernan (1996), and emphasize that a quality relationship is like friendship and is required for successful collaboration among professionals.

II. Action Research

Sagor (1992), in defining the meaning of action research, states that action research is research conducted on oneself. Sagor defines research as "... *any effort toward disciplined inquiry*" (Sagor, 1992, p. 9). People who want to do something to improve their own situation conduct action research. "*Action researchers look at what they themselves are or should be doing*" (Sagor, 1992, p. 7). Action researchers in education focus on three related 'stages of action':

- initiating action, such as, adopting a text,
- monitoring and adjusting action, such as , improving a current practice, and
- evaluating action, such as, preparing a final report on a completed project. (Sagor, 1992, p. 8)

Sagor states that the 'stages of action' are the basic building blocks of action research. "*Action research is all about taking action based on systematically collected data. Once you have your data, it's time to proceed with action*" (Sagor, 1992, p. 66).

McEwan et al (1997) write that action research has action at its focus. Although grounded in theory, action research is not objective observation. Action research requires researchers to "...'*get their hands dirty', to get involved, to act in ways which will most likely lead to improving a school or a classroom*" (McEwan et al, 1997, p. 31). Action research involves teachers using research methods to study classroom problems. Action research begins with "*a period of critical reflection*" (McEwan et al, 1997, p. 49), followed by project planning, implementation, and observation. The focus of action research is on the solution. For example, Isaac and Michael (1984) state that action research is designed to develop new skills or new approaches and to solve problems with direct application to the classroom or other applied setting (Isaac and Michael, 1984, p. 42). Isaac and Michael suggest that action research is empirical in

the sense that it relies on actual observations and behavioural data. In addition, action research is flexible and adaptive, allowing changes during the observation favouring responsiveness, instant experimentation and innovation. McEwan et al (1997) suggest action research be conducted in the spirit of 'collaborative inquiry' with the purpose of creating a climate of openness that encourages thoughtful practice.

III. Collaborative Action Research

Collaborative action research is a recent variation of action research, which may occur between a school system and a university and involves a team. The collaborative action research effort consists of practitioners working together to take actions within their situations to improve their practice and come to a better understanding of that practice. Action research is about making change during the process of research on oneself and collaborative action research uses the power of discussion to support and share new ideas and innovations brought about by the common agendas of the participants and the shared expertise. "*The focus in collaborative action research is on both the processes and the outcomes of a change strategy, such as a staff development program*" (Schumacher & McMillan, 1993, p. 21).

Collaborative action research seems to ground itself on the attributes of a successful collaboration. Professional discussion among team members is essential if action research is to become collaborative and lead to the development of curriculum knowledge (McKernan, 1996). Feldman (1996) examines ways teachers' knowledge about teaching grows when they are engaged collaboratively with other teachers in action research inquiry on their own practice. He writes that when action research is done in a collaborative mode, understanding and knowledge can be shared and generated in a way that embeds it in the teachers' practice (Feldman, 1996).

Some members enter a collaborative action research project with more status, expertise or authority than others, and it becomes necessary to redistribute the power to facilitate true collaboration. According to Ripley and Hart (1989), when all members have equal power, then all members have equal ownership in the project, and their commitment to the success of the project can, in fact, be that much greater. Thiessen (1989) however, says that action research groups should accept and work with their inequalities as differences, which enrich the possibilities of their projects and the collaborative nature of their interaction. Also, according to Thiessen (1989), problems can arise when the roles of the various players in the action research project are not made clear. Still, for knowledge and understanding to grow as a result of a collaborative effort, there needs to be a common culture or shared background (Feldman, 1996). One opportunity for organizing the growth of ideas of participants with similar interests is through the design and development of a multimedia learning environment.

IV. The Design of Effective Multimedia Learning Environments

The design of a multimedia learning environment can be objectivistic or constructivistic or a combination of both philosophical postures. An objectivist learning environment design presents real world content, and the learner acquires the knowledge and understanding through a highly structured and defined interface. A constructivist design presents a real world situation, and within that context, a learner derives a personal interpretation of the experience. Instructional system design, or ISD, represents an objectivistic approach to learning environment design, where control is maintained by the design and designer, and the learner is led through a series of progressively more difficult tasks. In contrast, a constructivist design of interactive multimedia instruction relinquishes much of the control of instruction to the learner.

Schwier (1995) discusses these two contrasting philosophical stances towards designing interactive multimedia learning environments. While suggesting that the application of constructivistic design principles in multimedia instruction would provide opportunities for learners to acquire strategies for learning, Schwier is careful to suggest that a designer does not need to choose one over the other, but rather, that the learning problems should dictate the balance between prescriptive solutions and learner control. Interactive multimedia learning environments, according to Schwier (1995), can present externally defined objectives (an objectivistic principle) alongside proactive learner controlled (constructivistic) learning materials. Beyond the issue of how a multimedia learning environment is designed, Schwier points out that multimedia instruction presents the learner with opportunities to use higher-order cognitive strategies, such as metacognitive procedures and mental modeling, to promote complex learning and transfer.

Mayer and Sims, (1994), state that multimedia learning is considered beneficial in aiding the learner to make referential connections. Referential connections are structure mappings between two representations of the same system. "*Multimedia learning occurs when students use information presented in two or more formats - such as a visually presented animation and verbally presented narration - to construct knowledge*" (Mayer and Sims, 1994, p. 389). Schwier, in the book 'Instructional Technology: Past, Present and Future', states that "*a constructivist might argue that learners construct multiple - and equally valuable - realities from their unique interactions with multimedia*" (Schwier, 1995, p. 120). In the study by Mayer and Sims (1994), students learn about the workings of a tire pump through a 30-second animation accompanied by a 30-second narration. One group experienced the animation and narration concurrently while another two groups experienced the animation and narration successively (in reverse order to each other). A fourth group, the control group, received no instruction about the

workings of a tire pump. Students who received the concurrent presentation of the animation and narration—i.e. a multimedia presentation—performed significantly better on the post treatment problem-solving test than the students who experienced the successive presentations, or no instruction. Students who received the successive presentations performed no differently than the control group on the problem-solving test. Mayer and Sims concluded that the lack of difference between the successive and control groups indicated that the separated visual and verbal instruction provided to successive students was quite ineffective (Mayer and Sims, 1994, p. 396). The findings of Mayer and Sims show that there is a transfer to problem-solving or structural understanding when connections by means of simultaneous verbal and visual representations, (multimedia), are made by the student. Furthermore, this study delineates the value of instructional materials that maximize the learner's chances of building connections between words and pictures (Mayer and Sims, 1994). This study indicates that students are better able to build referential connections when verbal and visual materials are presented contiguously than when they are presented separately and that multimedia learning is more beneficial than single media learning.

While multimedia instructional *materials* can present material in a way that promotes learning, the *design* of the multimedia learning environment can, in itself, affect the quality of that learning. Mayer and Sims establish that "*there are unfortunate examples of a lack of coordination between animation and narration that can be found in educational multimedia products currently in use*" (Mayer and Sims, 1994, p. 400). Such problems could hinder student learning and could be eliminated through the application of effective design principles. For example, an environment with too little structure can leave a learner without the tools to be successful. On the other hand, a too rigid environment may over or under prescribe instructional sequences. A well designed multimedia learning environment will incorporate ideas which

empower the learner by providing a balance between prescribed objectivist activity and learner controlled, constructivist activity.

As an example of a learning environment not using effective design principles, the following set of screen captures, (Figures 1-5), show a learning environment module currently in use. This module has been selected as an example of a poorly designed and uncoordinated module to illustrate why Internet-based resources need to be designed using a *more* constructivistic model than was employed in the design of this module. Figure 1 shows the initial page of the Internet-based module on Relativity taught in Physics 105 at Syracuse University. Note that the course's first page does not offer a whole map of where to go and how to return. The learner must "discover" the essential navigation features of the site. Figure 2 shows the second page of the module. A learner arriving at this page directly from a Web search has no way to connect to the home page of the module. On page two, the learner is presented with two types of options: at the top of the page are direct links to only a few specific course components whereas at the bottom of the page are the links to broader categories. Choosing the 'assignments' link near the bottom of the page in Figure 2 allows the user to access the assignments page (Figure 3) which provides links to all the course assignments. For example, the page shown in Figure 3 allows a user to link to the assignment cited in Figure 2 taking the user to Figure 4. None of the assignment pages provide links back to the pages shown in Figures 1, 2 and 3. Thus, the learning environment in Figures 1-5 provides no learner control and lacks the ingredients of an effective learning design such as a map for easy navigation.

The module design just described relies on the user to draw upon the linear recording capabilities of the Web Browser to navigate among the various screens of the module. However, Web Browser navigation capabilities are limited and may not be familiar to the user. Moreover, this navigation information is lost each time the browser is shut down. Another design problem

with this module is that Figure 3 acts like a stand alone classroom handout and, although it is part of a series of pages that supplement the course's material, there is no indication given to the student of this screen's function. In addition, since the preceding pages offer opportunities to skip the screen shown in Figure 3, by choosing the direct link to the assignments via the screen shown in Figure 2 for example, this page may well be redundant. The screen shown in Figure 4 is material designed by the course instructor and only uses the Web to display information. Not one of the screens in this module makes use of remote or external Internet resources. Figure 5 shows the module to which the user was directed to go via a direct link at the top of Figure 2. At the site of 'The Light Cone' (Figure 5) there is no direction of how to return to Figure 2; this page is treated as a 'stand-alone' Web page although it is actually part of a larger unit. A map or set of links available on each page would have enhanced user navigation around this module or at least given the user some more control.

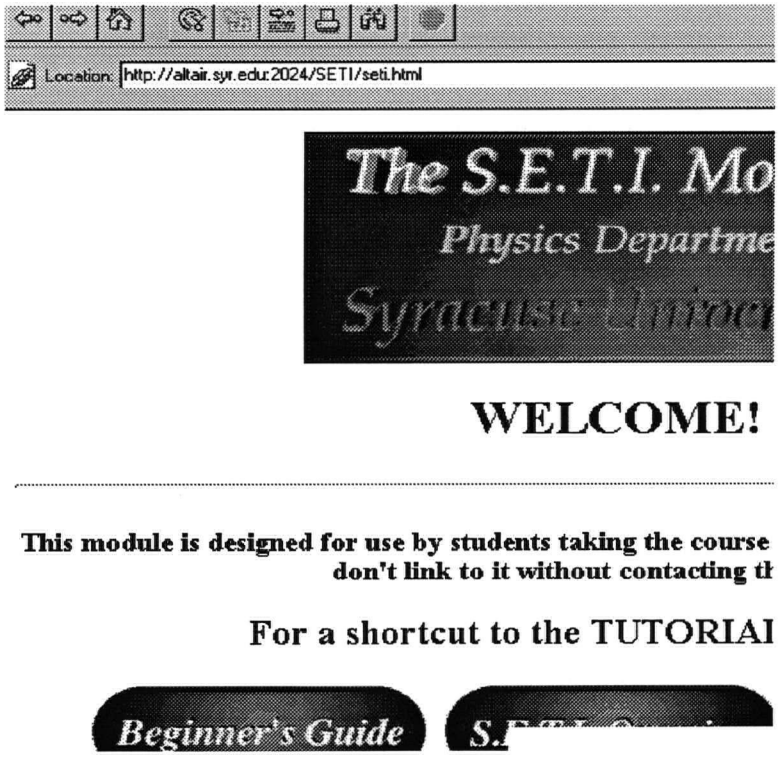


Figure 1

An example of a learning environment not using effective design principles. This figure shows the initial page of the Internet-based module on Relativity taught in Physics 105 at Syracuse University.

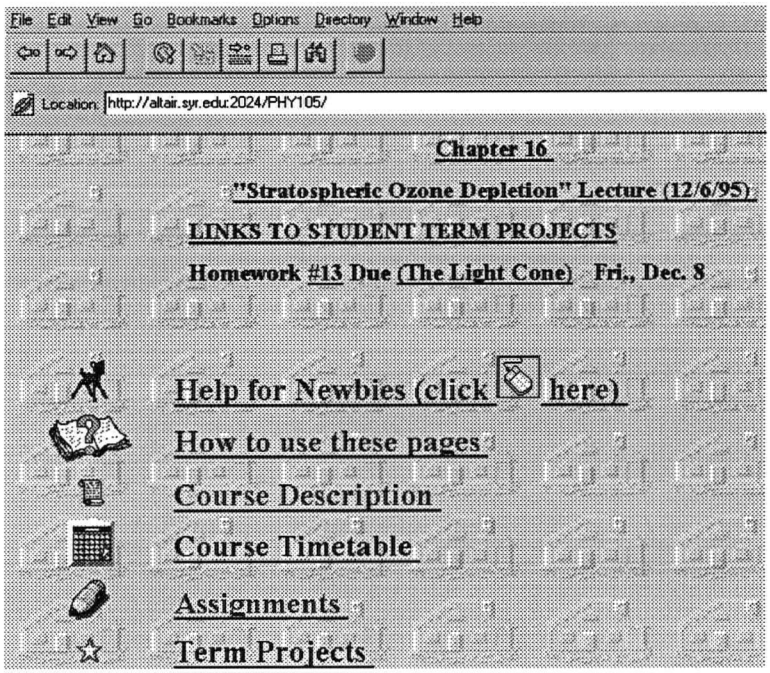


Figure 2

This figure displays a menu of links, which are only available on this page. The 'term projects' hotlink at the top of the page is the same as the hotlink at the bottom.

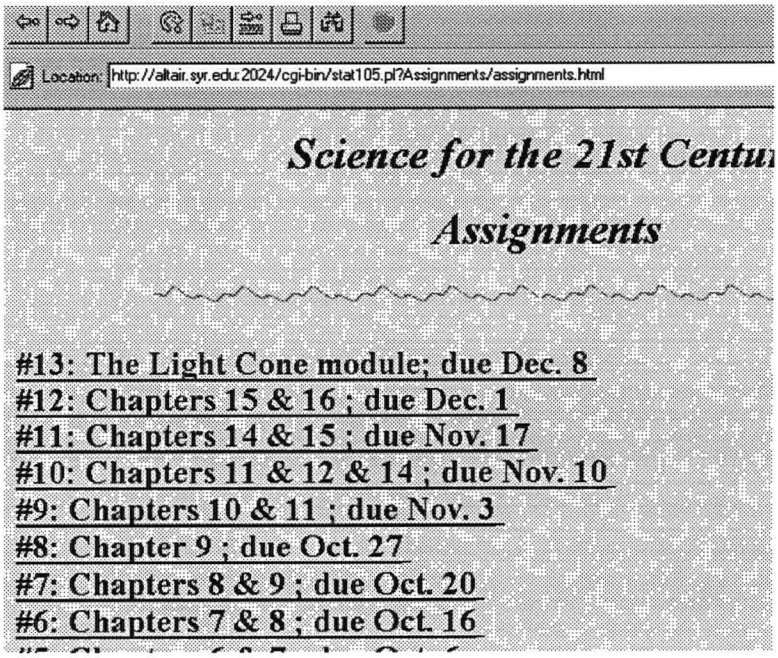
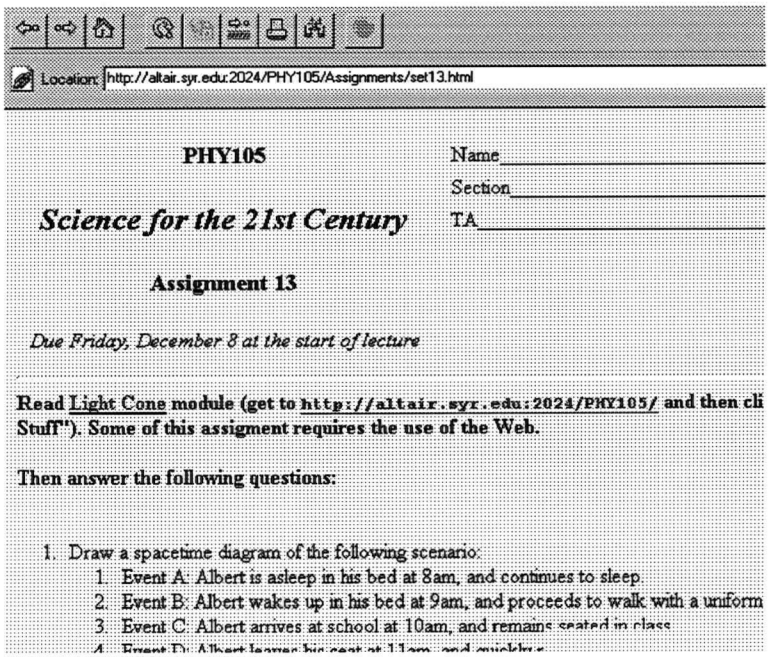


Figure 3

This page of the relativity module displays a list of the course assignments. Choosing 'assignments' in Figure 2 accesses this page.



Location: http://altair.syr.edu:2024/PHY105/Assignments/set13.html

PHY105

Name_____

Section_____

Science for the 21st Century

TA_____

Assignment 13

Due Friday, December 8 at the start of lecture

Read Light Cone module (get to `http://altair.syr.edu:2024/PHY105/` and then cli Stuff"). Some of this assigment requires the use of the Web.

Then answer the following questions:

1. Draw a spacetime diagram of the following scenario:
    1. Event A: Albert is asleep in his bed at 8am, and continues to sleep.
    2. Event B: Albert wakes up in his bed at 9am, and proceeds to walk with a uniform
    3. Event C: Albert arrives at school at 10am, and remains seated in class
    4. Event D: Albert leaves his seat at 11am, and quickly r

Figure 4

This figure shows the Relativity module's 'The Light Cone' assignment sheet. There is no hotlink to return to the previous page (Figure 3), the menu of items in Figure 2 or the main page in Figure1.

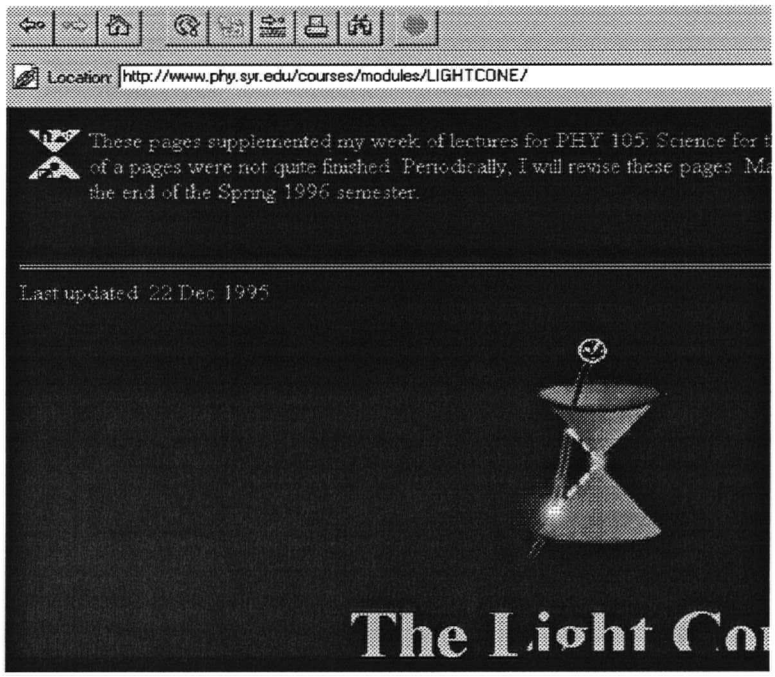


Figure 5
This figure shows the activity to which the user was directed in Figure 2 and Figure 3. There is no return link to any of the previous figures.

The next five figures (Figures 6-10) show an example of a well-designed series of coordinated Web pages. These pages serve as an exemplar of the constructivist approach to interactive multimedia instructional design. These five figures contain a definite structure and predefined objectives to help the user make appropriate choices and to avoid confusion. These five figures are not an educational site *per se*, but the site could be used as a template for a learning environment. Note that, unlike Figures 1-5, in Figures 6 through 10, the *Location* indicator never changes. The menu on the left margin shows all the components of this particular Web site and may be considered to be a map of the site. Like the *Location* indicator, this menu also never changes as the user navigates around the site. This unchanging effect is possible when 'frames' are embedded into a web page. The horizontal menu bar at the top of the Web page indicates the sub-topics available under each item selected on the vertical menu bar. A Web site

designed in this manner removes the sense of disorientation and confusion that often results when surfing the Internet. A well designed Web page promotes focused users who will not stray from the designated topic but will still have some control to choose their own paths. Well designed Web pages also have an initial screen that provides an index to the entire site, is available at all times, and allows the user to return to any location should an erroneous selection be made or if the module asks them to do so.

The screen shown in Figure 6 illustrates the site before a selection is made. The vertical menu (left margin of the page) remains intact at all times. In Figure 7, 'Space' on the vertical menu has been selected. The sub-topics for 'Space' are shown on the horizontal bar (at the top of the screen). The horizontal menu begins with the word of the item selected on the vertical menu and is followed by the sub-topics. Figure 8 shows the result of selecting the Sub-Topic: Earth, on the horizontal menu. Clicking on the Sub-Topic: Earth actually takes the user to a new site (cf. Figure 8) out on the World Wide Web but the only indication of this new site is the change in the "contents" frame within the Web page. The remote site is confined to the "contents" frame, a frame to the right of the vertical menu and below the horizontal menu. The horizontal and vertical menus from the home site remain and the information in the Web Browser *Location* indicator does not change. It is possible for an advanced user to find the address of this new site. The novice user does not need to know the address and therefore will not lose sight of the vertical menu.

The location of the page the student accesses by selecting a specific topic from the horizontal menu is insignificant with respect to a lesson or direction the module is leading. The sub-menu 'Space' remains intact until another item is chosen from the vertical menu on the left. In Figure 9, a link on the Earth page was chosen. This Earth page is located somewhere else on the Internet, and the link within the Earth page changes only within the frame containing the Earth

page itself. In Figure 10, 'Search Tools' was selected from the top of the vertical menu on the left showing the available search engines and the result of a query made on Martian Volcanoes in the frame below.

The elements of this coordinated Web site that make it user controllable while structured and defined, result from applying the principles of both constructivistic and objectivistic design philosophies. Adding the appropriate design features from each philosophy is an essential element of Learning Environment Design research.

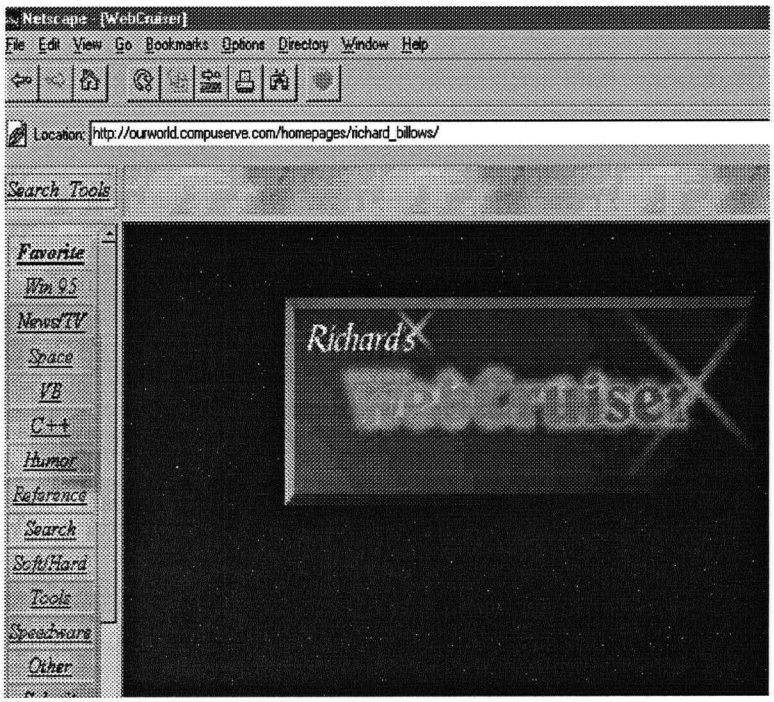


Figure 6

The initial page of a coordinated Web site. Note the menu on the left margin (vertical menu) is the map for the whole site.

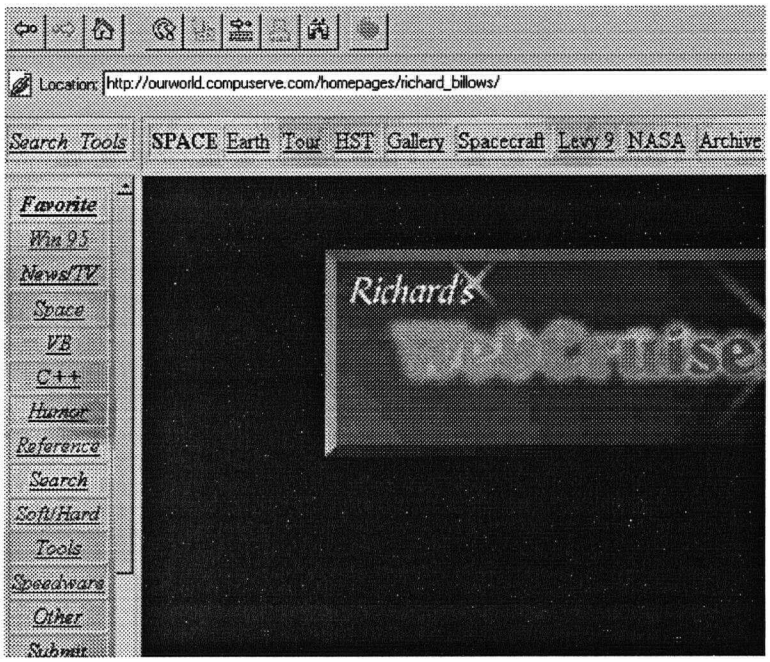


Figure 7

This figure displays the horizontal menu at the top of the page. The horizontal menu changes according to the selection made in the vertical menu.

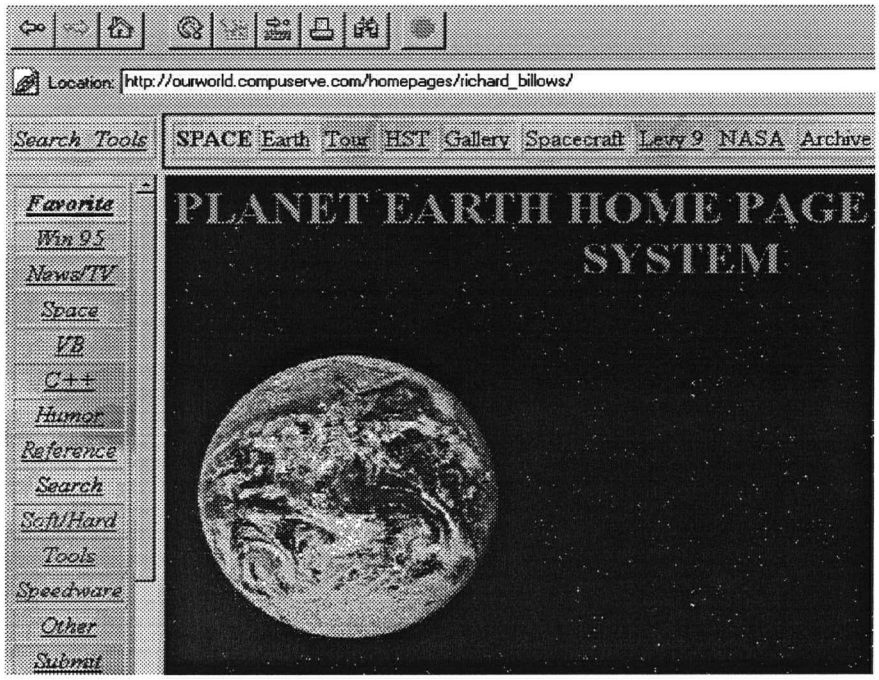


Figure 8

The link 'Earth' was chosen in the horizontal menu. The location bar above the horizontal menu has not changed but the 'Main Area' of the page has reflected the selection. The Earth page resides at http://www.tidusa.com/PEHP2000/Planet_Earth/solar.html.

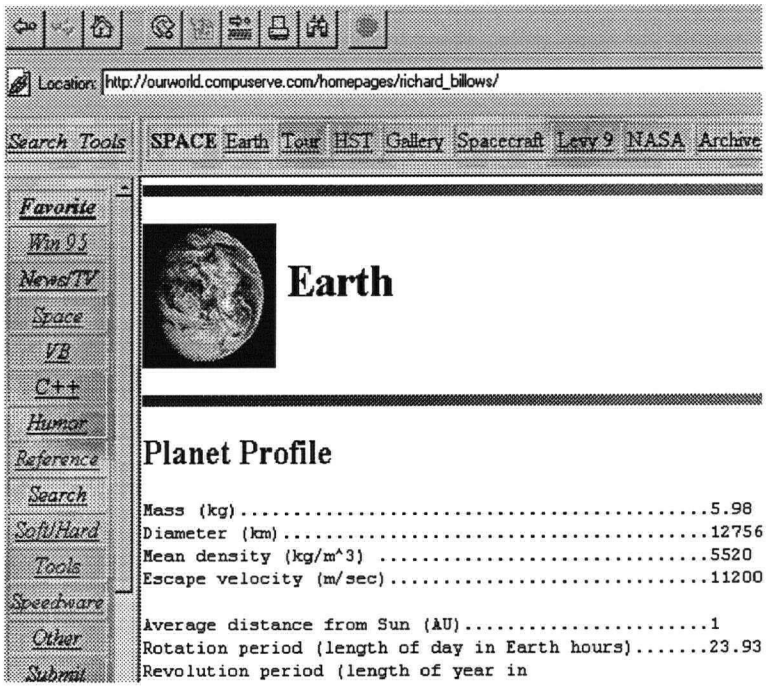


Figure 9

This Figure shows the page that is accessed from the chosen link in Figure 8. The link on the earth page resides at http://www.tidusa.com/PEHP2000/Planet_Earth/pehp-pcn_map.htm.

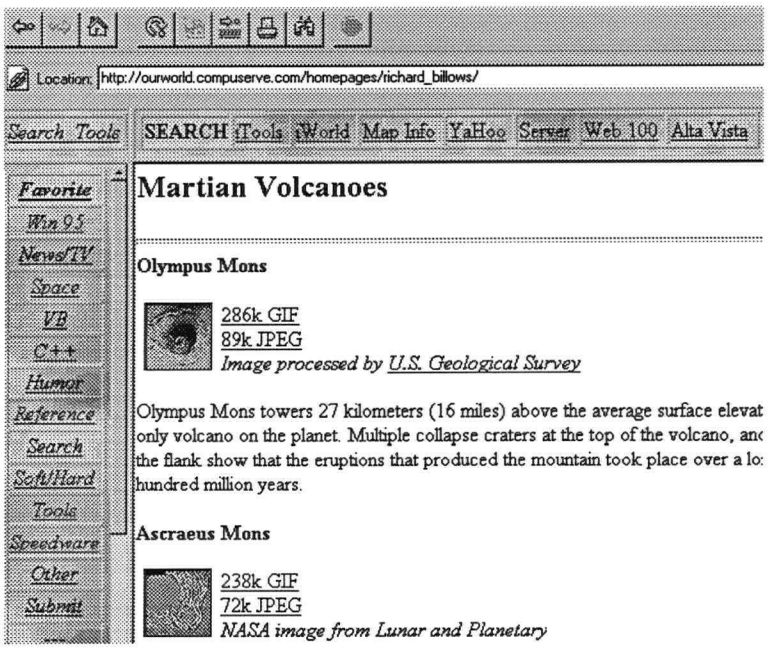


Figure 10

This figure shows a page found using a search engine. Search-Tools was selected from the top of the vertical menu, updating the horizontal menu with a selection of search engines while leaving the horizontal menu and location indicator unchanged.

V. Learning Environment Design

In an article in which learning, learning environments and learning environment design (LED) are described, Duchastel (1994) outlines a definitive procedure for constructing informal learning environments in a manner that is both efficient and allows for learner control. This model is not inherently restricted to a technology based learning environment; it applies to all instructional designs. According to Duchastel, with an appropriately designed learning environment, learners will become engaged in the subject matter and become their own best judge of learning. As previously mentioned, a constructivistic notion of learning environment design incorporates opportunities for learner control. The LED model is particularly appropriate to this approach because it combines the elements of the traditional objectivistic approach with its provision of formal structure with the element of learner control found in the constructivistic approach (Appendix IV).

In Duchastel's LED model for the design of learning environments, content is integrated with strategy. While being designed separately from each other, content and strategy merge, in the finished design, into a unified learning environment. According to the model, the design of an effective learning environment can be accomplished by following two series of steps; one series of steps for determining and structuring content, and another for selecting and integrating the strategies to be used. Strategy steps include selecting the media that will be used and organizing the presentation process. An advantage of the LED step protocol lies in explicitly focusing attention of the designer on each facet, in turn, in such a way that each is unbundled and considered in detail. Duchastel's LED content and strategy steps are summarized below using his words (Duchastel, 1994, p. 229).

Content Steps:		Strategy Steps:	
C1.	*Scope the content*	*S1.*	*Scope the learning context*
C2.	*Establish a content structure*	*S2.*	*Establish media and process*
C3.	*Create content information*	*S3.*	*Establish learning paths*
C4.	*Create a content map*	*S4.*	*Create a support structure*
C5.	*Validate the content*	*S5.*	*Validate the strategy*

Table 1

The Content and Strategy Steps of Duchastel's Learning Environment Design Model

Step (C1) deals with the knowledge to be covered by the learning material. '*Scope the content*' refers to the area or range of material covered by the topic. Step (C2) fits the elements of knowledge from step (C1) together. Step (C3) is the creation of the information in whatever format is necessary, such as a picture or a movie. Step (C4) is the development of a map of the content for easy browsing. The notion of access by browsing is very important to the content of the subject matter. Ease of access reflects how the material is organized for perusal. The result must not lead to confusion. An example of map use is shown in Figure 6. Figure 6 lists the contents of the Web site in a column on the left-hand site of the page and acts as the site's map. Step (C5) is a validation of the content via a review by a content expert. Generally, the teacher would review the proposed material for accuracy and for the appropriateness of the knowledge level for the intended user prior to the implementation of the strategy steps.

The first strategy step (S1) is to identify the physical environment including who the user is, what equipment is available and what resources are available. '*Scope the learning context*' refers to viewing the situation or location within which the learning environment will be employed. This step largely determines how the material is presented. For example, what

software is the equipment capable of running? The boundaries of the learning environment may well limit the type of material to be presented. Establishing the media in step (S2) involves choosing the type of media for a particular idea. This step also involves decisions *"regarding the cognitive and physical interfaces via which the learner is to interact with the information"* (Duchastel, 1994, p. 230). The learning paths in step (S3) take into account the level at which the users enter the interface or the type of information they wish to gather. Hypermedia lends itself to linking relevant information but alternative paths must be thought through in advance, or at least, the user should be offered an opportunity to take an alternative path. The fourth step (S4) is the "guidance structure" that particularly tunes the designed environment to the requirements of learning. *"Support may be added in different ways, such as learning objectives, embedded questions, tasks and problems, self-assessment items, competitive features, embedded help features and so on"* (Duchastel, 1994, p.231). Step (S5) is the Validation step. A formative evaluation in step (S5) determines if the strategy elements of the design have prospects for success. Procedures included in this step are intended to deal with any emerging difficulties. Although the list is ordered, Duchastel insists that the design process need not follow any set order but must ensure each element is considered at some time in the process.

VI. Multimedia Applications of Duchastel's LED Model

An Internet-based learning environment based on Duchastel's LED model provides a structure for using Internet resources. To produce such an environment, however, requires the use of Internet-based software that includes a vast and expanding array of tools and resources that can be utilized for different purposes. Internet-based material is readily accessible, requiring only simple multimedia tools such as a picture viewer or sound player to transform it into material that

may be accessed in an educational environment such as a classroom. Such multimedia tools can be gathered together to create a multimedia module.

Internet-based software is starting to be used successfully in education, not only to organize the specific resources available on the Internet but also to facilitate communication using software designed for use on the Internet. Ontario's University of Waterloo has integrated an HTML editor into a technical writing course: http://itrc.uwaterloo.ca/~engl210e/. Each writing assignment takes the student further into HTML until, by the end of the course, some students are implementing full multimedia displays. An interesting aspect of the design of this course is that the professors use the same tool as the students to mark assignments, and to provide comments and support to the students on a one-to-one basis. According to Deveau (1996), "*this concept (of on-line instruction) is only the beginning of an important new trend in education*" (Deveau, 1996, p.30).

Packages such as *Macromedia Director*™, *Authorware Professional*™, *HyperCard*™, *Supercard*™, *or Toolbook*™ may be considered as curriculum development tools. Benoit et al (1994) considered these various software packages when they attempted to promote technology-based learning in Dentistry. Because of its speed and ability to create special effects, the research team chose *Macromedia Director*™ to develop a multimedia, computer based instructional module for dentistry students. A high level of funding enabled the researchers to assemble a diversified team of 10 individuals and provide them with up-to-date equipment and software. This team generated six multimedia, computer-based instructional modules on clinical and anatomical topics in dentistry in <u>one year</u>. These modules were created as courseware for first year medical and dental students and as continuing education tools for health professionals. The research team suggests that the level of effort and funding they placed in the project could only be justified if usage of interactive multimedia courseware becomes a standard teaching and learning

strategy. "*That time frame (to when the effort and funding can be justified) will depend mostly on how many experts will come forward and invest themselves to produce new subject-matter for development of more titles*" (Benoit et al, 1994, p. 211).

Instructors' lack of familiarity with multimedia technologies inhibits their adoption in most post-secondary education contexts. For example, in a study of technology use by Spotts and Bowman (1995), fewer than half of the faculty surveyed predicted they would use technology in the coming year. Faculty unawareness of technologies was cited as a major reason for this result. Spotts and Bowman (1995) also discovered basic educational computer usage paralleled the earlier use of the VCR. VCRs did not get fully recognized as a viable tool in the classroom until they became common in the home (Spotts and Bowman, 1995, p. 63).

The collaborative development of multimedia learning modules may be facilitated by the use of tools with which faculty are already familiar. *Netscape*® is an excellent example of a familiar technology. *Netscape*® is commonly used as a browsing tool and is utilized in that capacity by many faculty. In addition, *Netscape*® may be used for e-mail, for accessing information posted in news-groups, or to write a Web page using HTML. Sweany et al (1996), for example, used *Netscape*® as in instructional tool in a study testing the availability of cognitive tools in a hypermedia environment against achievement. The instruction, developed by a physics content expert, was delivered via the Web to the subjects using *Netscape*®. The physics content expert describes his use of *Netscape*® in a quote that parallels the effective design principles displayed in Figures 6-10. The expert states:

> *"Netscape® Navigator™ has various features that lent itself well to the instructional module. Netscape® Navigator™ allowed the dividing of the Web page into areas called frames. Two frames were created: the Tools frame and the Content Frame. The tools frame ran along the left margin from the top of the page to the bottom of*

the page containing various tools. The content frame filled the remainder of the screen with the actual instruction (Sweany et al, 1996, p.5)".

When designing a multimedia module to enhance learning, it is necessary to take into account educational outcomes, the available resources and tools, and the users. In the book, 'Instructional Technology - Past, Present and Future' Anglin (1995) describes post-secondary education instructors using the Internet to communicate. Within their courses, professors e-mail responses to students' inquiries and communicate with colleagues. On-line courses are popular, but they are primarily used to post and transfer information. There is a need to organize the already readily available information on the Internet as course material. Getting information that is really useful, according to Crossman (1995), requires much more work than creating your own pages using information not derived from the Internet. Crossman (1995) suggests that the key to successfully using the Internet be in the development of navigation skills, a skill that a developer of Internet-based learning environments would possess.

VII. Conclusion

This review of the literature suggests that collaboration among individuals can be successful when the effort resembles that of a friendship. The need for collaborative development teams is suggested by learning environment development models. Participation on such teams can increase an instructor's ownership of, and commitment to use, multimedia learning resources. The use of learning environment design models to develop instructional resources helps developers to address issues such as learner control, and to reduce the required development time and effort. Recent technology has made the Internet an inviting learning environment with a vast array of tools and resources that can be appropriate for the classroom. These ideas, when considered together indicate that it may be useful to construct a collaborative model for the

development of multimedia learning environments. No studies of collaboration to generate Web-based learning modules exist and the research described herein was undertaken to fill that gap.

Chapter Three

Design and Methodology

I. Introduction

This study investigated an instructor-developer collaborative development of a multimedia module for use in a post-secondary science classroom course in introduction Astronomy 101. The purpose of the study was to examine the nature of collaboration between the instructor and the developer, and the backgrounds, roles and responsibilities of the two collaborating professionals. The research was conducted during the course of the development and implementation of a multimedia module titled PLANET. A UBC Astronomy professor, Dr. Jaymie Matthews, the instructor, and a computer science teacher/graduate student, Doug Bilesky, the developer, collaboratively developed the module. The module was created using Internet-based tools and resources, and presented to students as a laboratory activity in Astronomy 101 during the fall of 1996. The following two research questions were posited for the study.

Question 1. What are the requisite conditions for a successful, instructor-developer multimedia module development collaboration? What are the roles and responsibilities of the instructor in this collaboration? What are the roles and responsibilities of the developer in this collaboration?

Question 2. Is the collaborative development of a multimedia instructional module using Internet software an efficient, effective and inexpensive procedure for producing learning resources for post-secondary education?

The first research question was addressed during the module development process through an analysis of video recordings of instructor/developer meetings, researcher-developer journal entries, and e-mail communications between instructor and developer. The second research question was addressed through a questionnaire e-mailed to the instructor and by reflecting upon the development process itself.

To investigate the research questions, a qualitative research design was used. A qualitative methodology was adopted because *"qualitative methods are particularly oriented toward exploration..."* (Patton, 1990, p. 44) and *"qualitative research is concerned with understanding the social phenomenon from the participants' perspective."* (Schumacher & McMillan, 1993, p. 373). The research design in this study included a range of data-collecting instruments and procedures including: video recording, e-mail exchanges and journalizing by the researcher. The collected data was subjected to systematic sorts, analyses and codings using the constant comparative method (Conrad, 1982, p. 280). The constant comparative method prescribes that the researcher begin by collecting a wide range of pertinent data, then to continually and systematically sort, analyze and code the data to abstract its underlying concepts and properties, and to determine the relationships that exist. The researcher develops theory through the data, eliminating some concepts and hypotheses as they are refuted (Conrad, 1982). Theory that emerges from the data subsequently controls how further data is collected. The data collected in this study was inspected for signs of a successful collaborative process using the guidelines of Wallace and Louden (1994), (cf. Chapter 2) as a framework.

II. Post-Secondary Context of the Study

This study involved the collaborative development of multimedia instructional materials for the topic of Planetary Surfaces in UBC's Astronomy 101 course. The Astronomy 101 course includes general principles of the celestial sphere, laws of motion and light, optics, telescopes, and current knowledge of the Sun and Solar System. The roughly 170 students who annually enroll in Astronomy 101 at UBC are undergraduates but not necessarily Astronomy Majors. At the start of the study, the Astronomy 101 laboratory facilities included networked PC computers that were mainly '486' and Pentium processor based models. The computers used a DOS-Windows 3.x environment.

The subject of Planetary Surfaces was chosen for the study since it is a major component of the lecture portion of Astronomy 101 but had no corresponding lab component. At the time this study began, the materials available for a lab on this topic, such as maps of planet surfaces, were deemed to be outdated and expensive to replace in quantity. The module was developed to support the lecture part of the course with practical applications and was scheduled for the six lab sections of the course over a one-week period near the end of October, 1996. The module was assigned as a one-day, three-hour laboratory session and all six sections, each with 20 to 30 students, were to complete the module in one week.

A collaborative process was used to design and develop the Planetary Surfaces module based upon the instructor's pedagogical goals for the course. The data for this study, of the collaborative design process, was collected over a three month period, August to October, 1996, in the UBC office of the instructor, in the home-office of the developer, and in the student laboratory in the Astronomy building at the University of British Columbia. Initially, face-to-face discussions between the instructor and developer were scheduled to gather information on the instructor's 'wish list' about content and interface design of the proposed module. These

discussions took place at the University of British Columbia in the office of the instructor. Gradually the locus of the module development shifted to the developer's office and e-mail exchanges replaced face-to-face discussions.

III. Instructor

The instructor in the collaborative process was Dr. Jaymie Matthews, an Assistant Professor in the Physics and Astronomy Department at the University of British Columbia. For the last five years, Matthews has tried to incorporate innovative technologies into his teaching of Astronomy. Matthews felt that technology would enhance his courses by motivating and keeping the students' interest in the subject as well as maintaining his own interest. Matthews' early implementation of technology was documented and analyzed by Ajayi (1995). At the time of Ajayi's study, Matthews was dealing with issues regarding convenience, technical knowledge, software, and time.

Ajayi (1995), found that the issue of convenience was a particularly impeding factor to Matthews' early implementation of technology. For example, the setup and breakdown (assembly and disassembly) of equipment before and after class, especially in a classroom that was not geographically convenient, caused Matthews to seek alternative technology such as a light weight CD-ROM instead of a cumbersome and heavy laser disk player. The use of a laptop in a darkened lecture theater was another impeding factor. However, after altering his normal teaching methods and adapting to the physical demands of the technology, Matthews found the issue of convenience dwindled to insignificance. The issue of technical knowledge also diminished as Matthews' experience with classroom use of technology increased. However, the two issues of software selection and lack of time proved to be more difficult to address than the issues of convenience and technical knowledge. The instructor admitted that it was not the use of the hardware

technology, i.e. the panel and laptop, that took any real additional time to prepare for his classes, but "*the additional time now is going to look for new software and trying to keep in mind as you prepare the course, "Where can I use the technology?""*(Ajayi, p. 61). Most of the available astronomy software was not suitable for Matthews' specific course objectives.

Adjusting commercially available software to meet specific instructional objectives can be difficult and time consuming. Matthews' solution to this problem was to have software custom made. Specifically, Matthews had a tutorial package on Galactic Morphology specially developed for his Astronomy 101 course. This approach permitted Matthews to have software that matched his specific course objectives rather than spending the time attempting to modify existing software himself. From his initial exploration with multimedia technology, the instructor realized he preferred to work with customized software (Ajayi, 1996, p. 58). According to Ajayi (1996), working collaboratively with a software developer on the development of the galaxy morphology package reduced the impeding factor of time associated with implementing new technology by saving the instructor the time that was needed to decide on the appropriate software for use in the class and modify the software to fit the classroom needs.

Matthews regularly uses resources from the Internet for research. The nature of modern astronomical observation requires Matthews to be aware of the technology necessary to observe, record and analyze data in his research and some of this information is available on the Internet. For example, Matthews has a need to search the Internet for information on a specific telescope and review its instruction manual before engaging in an observation session. Space Observations take place on a regular basis and the information gathered is readily available on the Internet. Matthews wanted to introduce his students to this "real world" of the subject by integrating Internet technology into his classroom practice.

IV. Researcher-Developer

The researcher-developer in this collaboration was the author, Doug Bilesky, a high school teacher of Computer Science. Before starting this project, I had worked with computers, designed software, and procured and exhibited resources on the Internet. For three years, I had been endeavoring to bring recent technology and Internet access into my classroom. I felt that technology would enhance my courses by allowing the students to experience a wonderful tool for discovery and learning. In the process of adding technology to my classroom, I discovered the vast resources of the Internet and the tools available to take advantage of them. The resources of the Internet can be found in Web pages (cf. Appendix II), with News Groups, on e-mail lists or at File Transfer Protocol (FTP) sites. I have drawn upon all of these Internet resource repositories to support my computer studies curriculum and to assist my colleagues in other curricular areas. The recent surge in the Internet's popularity has been accompanied by a surge in development of tools used to create or exploit Internet resources (cf. Appendix III). I discovered that the tools I employed to gather information are sometimes more interesting to use than the data itself. I enjoyed examining new software tools and developing Web pages. When the project started I felt I had only scratched the surface of a plethora of tools that are available but I felt that I worked well with those I knew.

Before this project, I had developed some small software packages for UBC's Computer-Based Science Education 412 course. The course instructor, Dr. Janice Woodrow, who already had an academic connection with the Astronomy department, created a liaison for an exchange of technology ideas with members of that department and I was introduced to Matthews. I, too, had an interest in astronomy, and had enrolled in astronomy elective courses during my Geophysics undergraduate degree. My first working experience with Matthews was to develop the Galaxy Morphology module in 1995. This multimedia module was first developed in a Macintosh

environment using *HyperCard*™, and then again in a Windows environment using *Toolbook*™ as the software development tool as the Astronomy department used Windows-based computers. The Galaxy Morphology module was limited to the information I had typed into it and to the information it controlled on a laser disk. The interactivity of the module was severely limited by my programming skills at the time.

When I became interested in the pursuit of a Master's degree in Education, my skill in educational software development combined with my interest and connection with the Astronomy department made research involving the two faculties appealing and feasible. I knew from my earlier experience that I enjoyed working with Matthews. The idea of using the Internet spawned from discussing with Matthews his requirements for a Planetary Surfaces module, and how the Internet had in place many of the ideas, information and development tools that seemed useful. At the start of the project, Matthews' wish list for the Planetary Surfaces module contained some interesting special effects, such as a rotating, clickable, animation of Mars and data analysis ideas that were beyond my programming capabilities. The Internet contained some of these tools and resources on sites that were available to the public. The resources available on the Internet coupled with the tools for integrating them, made the Internet appear to be a more flexible medium for development than the authoring software I had used previously. In addition, the Internet resources and development tools seemed to be updated more easily than either *HyperCard*™ or *Toolbook*™ based resources. Matthews and I collaboratively decided to explore how the Internet's tools and resources could be an avenue for quickly developing a multimedia learning environment.

V. The Site

The module described in this study was made specifically for and tested in the laboratory section of the Astronomy 101 course, Introductory Astronomy I, taught in the Astronomy Building at the University of British Columbia. The Planetary Surfaces module was designed to fit into the Astronomy 101 laboratory section, specifically addressing 'Recent Observations of the Solar System' which is a component of the lecture section. The Astronomy 101 laboratory was equipped with 18 networked computers. Eight of the machines were Pentium 75's containing 850 Mb hard drives while the other machines were mainly 486's with hard drives ranging from 80 Mb to 420 Mb. Most machines were equipped with 8 MB of RAM and SVGA quality graphics. The network was connected to the Internet.

VI. Development Procedures

The study used the framework of the LED (Learning Environment Design) model of Duchastel (1994) as a guide for the collaborative development of the Planetary Surfaces multimedia module. This development model was selected to organize the development process and address the issue of learner control. The LED model allows the developer to examine each element of the design process in order to create an effective learning environment. The LED model provided the instructor and the developer a focused starting point for discussion. Duchastel's LED design was used as a framework but not a prescription for the content of meetings. Over a three-month period, meetings, focused by the elements of the LED model, were held to examine each element in the design of the module including its content. The meetings were not always specifically aligned with an element of the LED model nor did they linearly follow the LED model from beginning to end. Rather, discussions held during the meetings

shifted from one aspect to another. These discussions led to the development new ideas that ultimately led to the production of the finished module.

VII. Data Collection Procedures

The collaborative meetings between developer and instructor were video taped and analyzed using the constant comparative method. The video recordings were examined for examples of references to the LED and connections to the elements of successful collaborations. Field notes made by the researcher when work was done on the module itself, and e-mail correspondence, also formed part of the study data. When examining the data, attention was directed to instances where:

- resources and tools were used and rejected,
- patterns for appropriate content and style occurred,
- signs of a successful collaborative relationship matched elements suggested by Wallace and Louden, (1994) and
- elements in the development process matched those suggested in the LED.

Field notes were made when specific issues were collaboratively agreed upon to avoid the need for transcribing the video before implementing the ideas. After August, 1996, when other commitments made extended, face-to-face meetings difficult, shorter meetings were held in the evening, after work. Field notes, e-mail and bookmarked results of Internet navigations helped to guide decisions when a direct collaborative discussion was not possible. The majority of correspondence occurred through e-mail. Specifically, e-mail correspondence was used to:

- pose a question easily and efficiently,
- exchange and discuss new ideas,
- correct thoughts from a previous meeting or e-mailed response,

- ensure an understanding by carefully wording responses, and
- set up a face-to-face meeting.

Internet search engines such as *Yahoo, Excite* and *InfoSeek* were used extensively to locate solutions to 'wish-list' ideas. Solutions to Web page development problems (as experienced by the developer) were often posted by knowledgeable people on the Internet at appropriate News-groups or on e-mail lists. Solutions were either posted in response to the developer's questions, or were found among ideas posted by others. The telephone was only used when it was well known that the instructor was available.

After the module was implemented in the laboratory, the instructor was e-mailed a question asking for his perspectives about the success of the method of development. The question posed to the instructor was research question #2.

Question 2. Is the collaborative development of a multimedia instructional module using Internet software an efficient, effective and inexpensive procedure for producing learning resources for post-secondary education?

VIII. Summary

The purpose of the study was to examine the nature of the collaborative process, and the backgrounds, roles and responsibilities of an instructor and developer involved in co-constructing a multimedia science module. The research was conducted during the course of development and implementation of a multimedia module entitled, PLANET. The module was collaboratively developed by a university instructor and a developer with Internet-based tools and resources using, as a guide, a learning environment design (LED) developed by Duchastel, (1994). The first research question was addressed during the module development process primarily through an analysis of video and e-mail communications between instructor and developer. The second

research question was addressed through the response from a post implementation question given to the instructor and reflection from the developer. A discussion of the analysis of the data is given in Chapter 4.

Chapter Four

Results and Analysis

The study examined the characteristics of a collaboration between two professionals involved in the production of a multimedia module for use in post-secondary education. The backgrounds, roles and responsibilities of the collaborating instructor and developer are documented. In this chapter, the data from this study are presented and discussed. Duchastel's model of Learning Environment Design (LED) was used as a guide for the study. Duchastel's model offers a generalized process for creating a learning environment in all areas of teaching including those that involve technology. In this chapter, a monthly timeline of the development process is presented first. Second, a description of results specifically related to the module is presented. Third, issues that focus on the roles and responsibilities of the instructor and developer are addressed. Fourth, results relating to the collaborative aspects of instructional design are presented. And finally, the effectiveness of the module is examined.

I. Timeline of Project

This section is a chronicle of the module's development and a description of what was accomplished by the collaborators. The development process extended over three months. The module had to be ready for use in the third week of October and this deadline drove the development timeline.

A. August, 1996

The first month of study, August, 1996, was used to ensure that the basic pedagogical needs of the proposed lab were incorporated into the module so that a written student 'activity

guide' could be published for the students. Three two-hour, face-to-face August meetings were held. The developer in the project scheduled the meetings with the instructor and video taped the proceedings. The videos were used to clarify notes and to provide data on the collaboration. The instructor was vocal and communicated his views and ideas clearly during these meetings helping to make the development process efficient. Typically, a meeting was initiated by selecting an element of Duchastel's design to focus the conversation into a discussion about the module. However, the collaborative discussions were open to discussing any element of Duchastel's design steps.

In the first of the August meetings, an instructor 'wish list' was created. This list included content and motivational effects. The Internet was chosen as the development medium at this time because:

- many of the items in the instructor's 'wish list' were beyond the developer's initial programming ability, such as clickable surface maps on a rotating globe of Mars,
- many of these 'wish list' items were already extant on the Internet, such as planetary data and pictures,
- solutions to specific problems such as static, zoomable, surface maps were available on the Internet,
- it was deemed that drawing from the Internet was the fastest and easiest development method that matched the skills and experiences of the developer with the needs of the instructor, and
- the instructor and developer were already reasonably proficient at using the Internet.

The first meeting was also used to establish the content of the PLANET module and a direction for development that encompassed the developer's needs, the instructor's needs, and the LED. One of the developer's needs included time to search the Internet for the resources and

tools for implementing the instructor's ideas. An understanding was also established that e-mail would eventually become the prevalent form of communication and that the work on the project would always be on a part-time basis when full-time teaching began in September, 1996.

After the first August meeting, a preliminary Web page design was sketched out on paper by the developer. This design included the structure for a map of the content for easy browsing (Duchastel's content step, C4). This map addressed Matthews' concern that the students might wander from the site if they were unsure of the direction the module was taking them or get confused if the contents of the module were not readily available.

The second face-to-face meeting between the developer and the instructor took place in mid August. This meeting focused on establishing appropriate terminology for the main menu to avoid user confusion, generating appropriate links for the sub-menu, and ensuring that the module was adequately supported by the Activity Guide. The topics of discussion during this second meeting mapped onto several aspects of Duchastel's learning environment design (LED) including creating content information (C3) and establishing media and process (S3). The discussion also led to the addition of new sub-topics, such as adding an astronomy Picture-Of-The-Day link, (C1), deemed to be important because interesting and relevant resources were located on the Internet, (C3). While looking for resources to fit the instructor's established content and 'wish-list', new resources were discovered and added by the developer.

The focus of the third August meeting was selected to ensure that the basic elements of the module under development conformed to the introduction to the Planetary Surfaces Activity Guide that Matthews had prepared for the Astronomy 101 lab manual, (S1). (cf. Appendix X) The Activity Guide's specific instructions for the use of the PLANET module were added as an addendum to the lab manual in October. One of the module's designated functions was to provide access to the most detailed images of the surfaces of terrestrial planets currently available

on the Internet for this activity. The Activity Guide was designed to have the students apply the same basic principles in the laboratory activity that are applied by planetary scientists to interpret the terrain depicted in these images, and to reconstruct some of the planet's history based upon this interpretation (cf. Appendix X). In addition, the module was designed to include relevant animation sequences, numerical data and pictures about recent excursions into the Solar System. The third meeting also included a discussion of potential changes to the module such as adding a new link to a sub-topic item like Mars' volcanoes.

B. September, 1996

During September, the second month of development, four small informal meetings between the instructor and developer took place. These shorter, one-hour meetings, were held mainly to permit the developer to show the instructor the significant changes made to the design and content of the module and to clarify a variety of visual representations of specific content items, such as pictures of the Moon. The instructor either validated the items the developer placed into the module, or offered suggestions or sites to find potential alternate content. At the beginning of September, the instructor began writing the specific lab instructions for the Planetary Surfaces' Activity Guide. By the end of September, the developer had discerned a consistent pattern to the instructor's content requirements and style of presentation. Most of the detailed work on the module during this time period was done in the home-office of the developer using the LED model as a guide.

Also during September, the equipment (computers) in the Astronomy 101 laboratory was upgraded to the minimum standard required to run the module. Although the upgrade itself was the responsibility of the instructor, the developer specified the requisite hardware necessary to run the module. The module was developed in a *Windows 95* ™ environment using *Netscape*® 3.0 to

display it. Appendix I shows the state of the equipment after the upgrade which allowed the machines to run *Windows 95 ™* and *Netscape®* 3.0.

C. October, 1996

In the third month, October, the module was installed on each of the computers in the Astronomy 101 laboratory. Here, the module was tested to ensure that it was compatible with the available hardware and examined for possible user difficulties. Some minor revisions and adjustments were done to the module on the student machines rather than at the developer's home office to save time between development and implementation. Also during the third month, the instructor completed the Planetary Surfaces Activity Guide which included instructions keyed to the PLANET module. The module on each of the laboratory machines was ready for implementation and classroom usage within a day of the deadline date (October 22, 1996).

II. The module

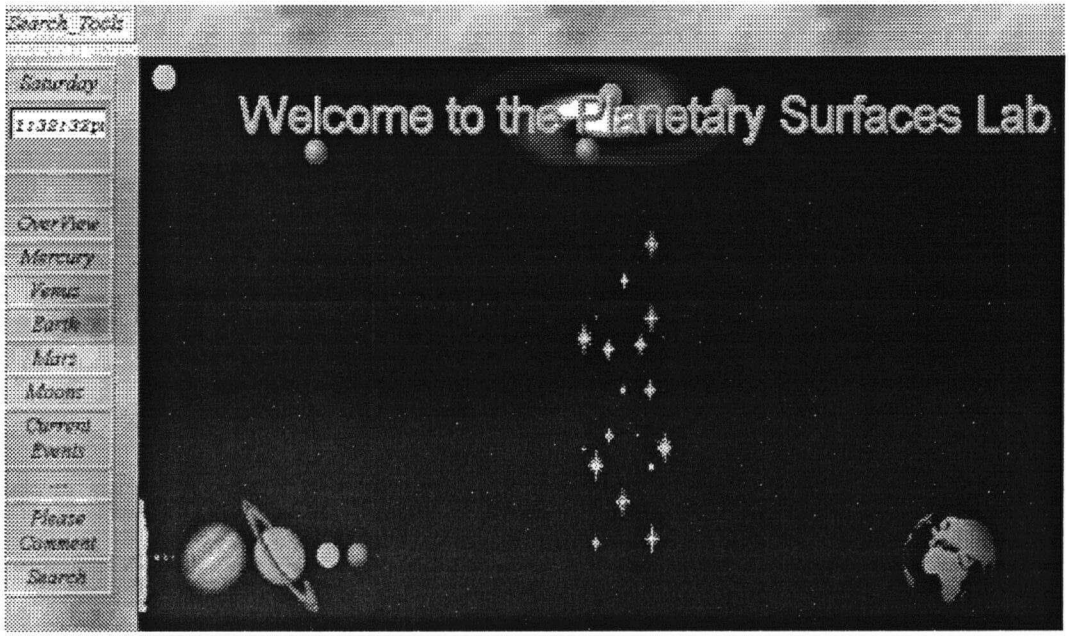


Figure 11

The initial page of the Planetary Surfaces module. The Internet address (URL) is http://www.astro.ubc.ca/test/planets.html.

The collaborative development process examined in this study produced a fully functional, post-secondary education, Internet-based multimedia module called "PLANET" (cf. Figure 11) which has since been successfully implemented in UBC's Astronomy 101 course for three consecutive years. The module was designed to present material in a manner that allows the students to discover answers to the Activity Guide's questions by accessing a variety of sources. This module filled a gap in the Astronomy 101 laboratory section where, because materials were out of date and no longer exciting to the students, a lab activity on planetary surfaces did not exist prior to 1996. The module was developed using an HTML development tool (*HomeSite®)* and is accessed by the students using the *Netscape®* browser, *Navigator™.* The HTML development tool called *Hotdog®* was also considered but quickly rejected because it ran too slowly on the

developer's computer. The developer also used *Microsoft's*® text editor, *Notepad*®, and Netscape's® HTML development tool, *Composer* ™ for quick, simple editing.

The PLANET module is a multimedia conduit to Internet-based resources for the students to learn about planetary surfaces. The interface includes motivational features such as clocks, animated images, and some humour. Specific images and text are hyper-linked to aid the student in the search for items of interest on pages that may be either local or on the World Wide Web. Figure 12 is an example of a page the students were required to use. This page contains a clickable image-map of Mars that is used for selecting areas of interest. To arrive at this page, a student would select 'Maps', a sub-topic of Mars, then select the '...Mars Multi-Scale Map' link. Figures 15, 16 and 17 are examples of how the basic structure of the interface never changes. When a hyper-link is chosen, the vertical and horizontal menus remain in place while the remainder of the screen is updated (cf. Figure 16). The effect of the unchanging menus is to help the students remain on task within the topic of Planetary Surfaces by providing menu items with relevant links, and to reduce confusion which can result if students were to stray from the designated topic.

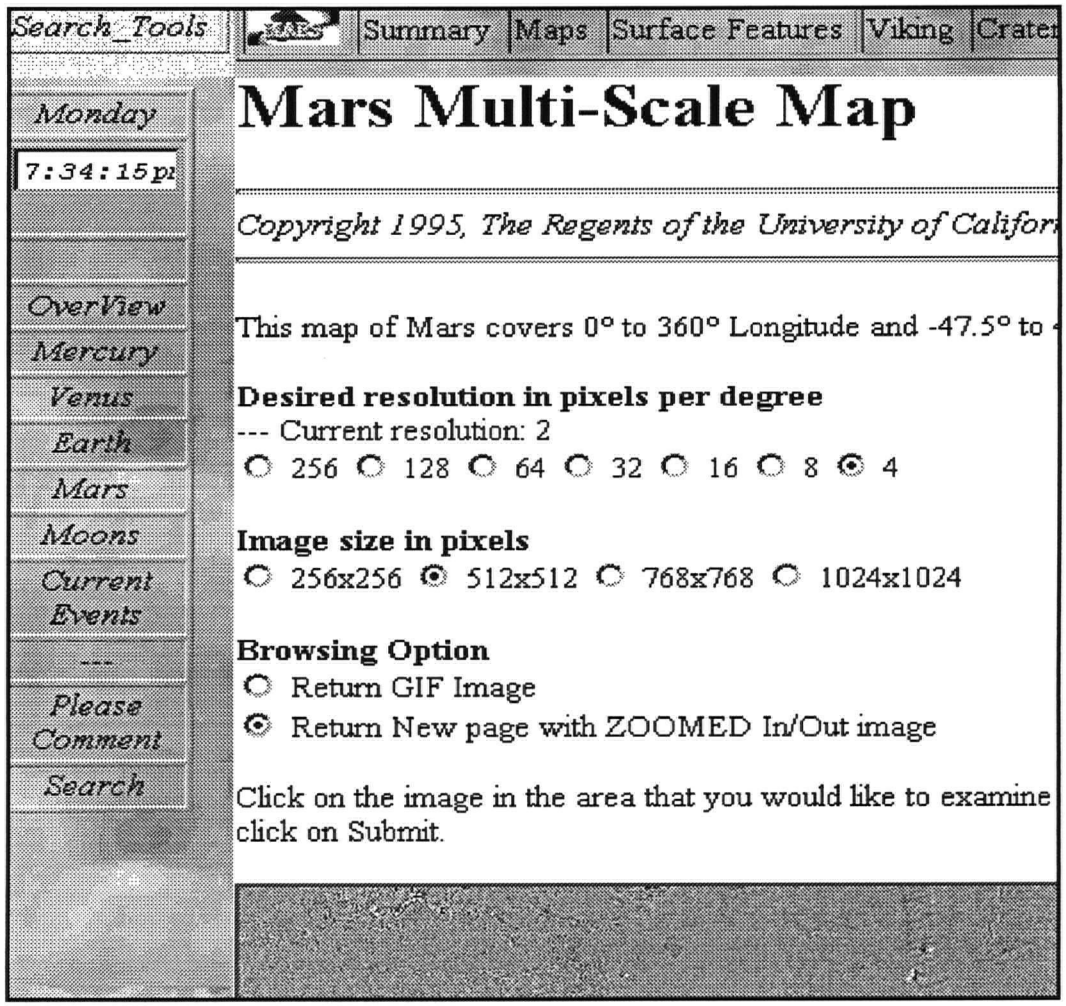


Figure 12

Clickable Surface Map of Mars

By using Internet-based resources for the development of the PLANET module, three objectives were achieved:

- First, the subject of the lab, Planetary Surfaces, required that current scientific material be used. Up-to-date information such as daily weather reports from Mars can best be readily accessed via the Internet. NASA regularly posts recent information, pictures and data to the Internet at sites such as http://www.jpl.nasa.gov/galileo/ as a free public service. It is necessary to use Internet tools, such as *Netscape*® to access this

information. Only an Internet based laboratory can give students ready and easy access to this data for their laboratory activity.

- Second, tools to access resources on the Internet are appearing and improving daily. These tools are often made available at no charge to educational institutions. For a developer, each successive upgrade is also often free for an evaluation period. As a result, use of Internet-based multimedia resources is relatively inexpensive because of ease in development and access to tools and resources. A goal of the module developed in this study was to determine if these tools could easily integrate a variety of useful resources at an acceptable cost.
- Third, the use of the most recent technology is motivating to the instructor and students. According to the instructor, "*anything that allows you to try to teach something in a different way keeps it interesting for you*"(Matthews quoted in Ajayi, 1996, p. 64). Matthews was motivated to use new technology and this allowed him to teach in a different way. "*I think students would like to have the impression that they are coming to a place where they are seeing some of the latest techniques in studying current Science and so be able to use current technology*". (Matthews quoted in Ajayi, 1996, p. 68) A role of the module was to access the latest in technology and motivate all those who came in contact with it.

III. Interpretation of Roles

Each member of the team primarily assumed the roles for which they were best qualified. The instructor's role was that of the content expert. Matthews ultimately decided what content the module would display. The developer's role in this study was that of the module producer. The developer was solely responsible for building the Web pages. The developer also introduced

Duchastel's steps into the discussions. The instructor's and developer's roles occasionally overlapped when either participant had a valid suggestion. The two collaborators also shared many of the tasks, such as locating resources, and discussed issues relating to each other's role.

Duchastel's learning environment design (LED) model was used by the researcher-developer to focus the ideas generated during the collaborative meetings in an effort to create an exciting, effective, student centered learning module. This section describes the individual and overlapping roles of the participants in the development process. These roles are discussed using the framework of the LED model.

A. Duchastel's Content Steps in the Collaborative Process

1. C1: Scope the content

Matthews' role in the collaboration process was that of the content expert. Although a major user of computer technology, Matthews never attempted to assume the role of writing the module's Web pages. From the very start of the project, he accepted the developer as the software development expert in the relationship. In part, his open acceptance of the developer's role was based upon prior experience working with the developer on designing customized software, and in part, on his restriction of time. Matthews' contribution to the software module focused mainly on content and pedagogical issues. His concerns about content details helped to ensure that the module contained all the information necessary to support the core content of the lab activity while allowing room for the students to explore. For example, Matthews stated, "*put priority on the inner planets, low priority on the moons and have some fun things that are current*" (August 9, 1996, Meeting on Content Usage). Matthews also wanted the students to be able to go beyond the lab and to explore more than just the basic facts required by the core

element of the laboratory *"The students can do the bare-bones assignment that they are expected to. Then there are all these other places they can explore if they finish early or bonus questions if they have time or the inclination to work on it"* (August 9, 1996, Meeting on Content Usage). The pedagogical decision to purposefully include general information about the solar system ensured that many different lab activities could be written for the module. The developer began the project with a different vision for the development process, *"my [the developer's] interpretation [of the module] was to create a fairly proprietary set of pages"* (Developer's Field Notes, August 9, 1996). After discussion, Matthews made it clear that the module would contain general information about the planets and not pages of questions like the developer had assumed. *"We began to construct a page that would be accessed with an instructional handout"* (Developer's Field Notes, August 9, 1996). Although the developer suggested that room be left to expand the module by adding features of the galaxy and universe at a later date, the instructor decided that this module would stand alone as a tool for accessing information only on the planets of this Solar System (Discussion Session, August 19, 1996).

The developer's role in scoping the content focused mainly on finding and displaying content related information. The developer searched for Internet-based information according to the instructor's desired content and included this information in the module for the instructor to review and validate. For example, *"[I am] surfing through different sites looking for items agreed upon. 'Welcome to the Planets' has good general statistical information and can be used for consistency"* (Developers Notes, July 29, 1996). The discussion of scope and the display of content in advance of Internet searching allowed for efficient use of development time. Joint searches were also an efficient procedure. The developer noted, *"we will get together on Monday or Tuesday to surf the Internet for good sites"* (Developer's Field Notes, August 21, 1996). Sharing the role of searching for resources, and doing so together, resulted in immediate decisions

being made as to the appropriateness of the material and the accumulation of a collection of useful information such as source code and images that could quickly and efficiently be added to the module.

2. C2: Establish a content structure

Matthews, having an expert understanding of the content, suggested how the elements of knowledge should be linked together to provide a structure for the module's content. The collaborative team chose the titles and their subsequent hotlinks to avoid a confusing content structure and to make an intuitive and appealing interface. For example, the developer selected the heading 'Space' to link items recently found in the news. The titles of the vertical and horizontal menus were altered by Matthews to best represent what resources the developer was able to locate. The instructor envisioned such headings as 'What's Hot', 'Cutting Edge' and 'What's New'. The order in which the titles were set is also relevant. For example, "*we decided an order representing the order of the planets would be expected in the vertical menu*" (Developer's Field Notes, August 17, 1996). The order on the horizontal sub-menu represents a level of increasing importance (in terms of potential for usage by the students during the laboratory session) from right to left. The developer built templates of pages to help establish a consistent content structure. By establishing a template, the developer could copy the design of a page and reuse it, thereby making the Web-page building process more efficient.

3. C3: Create content information

The Internet was the sole source of resources to supply content for the PLANET module. Duchastel's 'Create Content Information' step was accomplished by the instructor's selection of appropriate Web pages provided mainly, but not exclusively, by the developer. These Web pages

were located by utilizing search engines or simply by following links made available by the instructor. The instructor's role was to chose from these sites familiar ones, ones for variety, or ones that addressed specific pedagogical objectives. The creation of information pages in the format required by the instructor, such as a picture or a movie, was the responsibility of the developer. When appropriate sites could not be located, pages were specifically created to contain information selected personally by the instructor. For example, Matthews downloaded some images of specific areas of Mars and had the developer build a Web page to include them. "*...I've saved gif images of some of the Martian surface frames I'm going to have the students use. They're in c:\user\astr101 and have names like mars_viking1.cgi*" (e-mail, Instructor to Developer, October, 17, 1996). The developer's role also included the responsibility for positioning the data into the module.

4. C4: Create a content map

Step C4, of the LED model, entails a focus on the students' ease of access to information. Some of Matthews' concerns about how content should be displayed ensured, at a minimum, that the design of the interface would make the intent of the activity clear to the student. He felt that a confusing interface would hinder the student from completing the necessary course work (Developer's Field Notes, August 17, 1996). To address this concern, the developer established an interface structure map for the display of content. The details of this map are shown in Figure 13. The *list* area (vertical menu) contained the topics of the module. The *head* area (horizontal menu) displayed the module's sub-topics when a topic was chosen in the *list*. The *tail* area (main area) displayed data. The *clear* area was used to access search engines. The *E-mail* area contained the developer's e-mail address. All the pages in the module used this map structure. An example of a complete page is shown in figure 12.

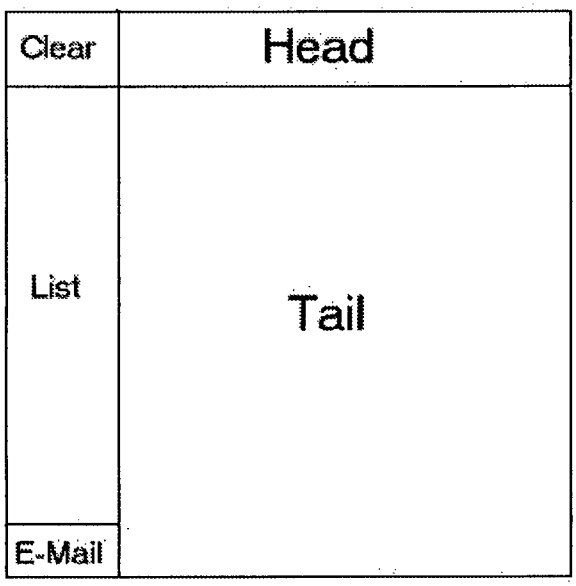


Figure 13

Initial Structure Map

5. C5: Validate the content

The instructor, in the role as the content expert, took the responsibility of validating the content for accuracy. This activity mapped onto Duchastel's step C5. Matthews validated content by assessing the pages for accuracy of information and for relevancy to his pedagogical goals during each of the one-hour short discussion sessions held in September and October. He also ensured the pages had relevant links.

Matthews' sense of humour encouraged the developer to add extra, nonessential and/or motivational content related items to some of the module's pages. For example, Figure 14 displays a page about Mars' surface from the module. This page contains features that, to some observers, resemble man-made objects (pyramids, carved faces...). The extraterrestrial/alien references on this Internet site suggested the addition of content related humour to the page in the form of animated 'spacecraft' and 'alien' heads. These features are easily edited if an instructor decided that the details of the content are obscured by their presence. Matthews, however,

validated these features for appropriateness in the PLANET module, an implementation of step C5 of the LED model.

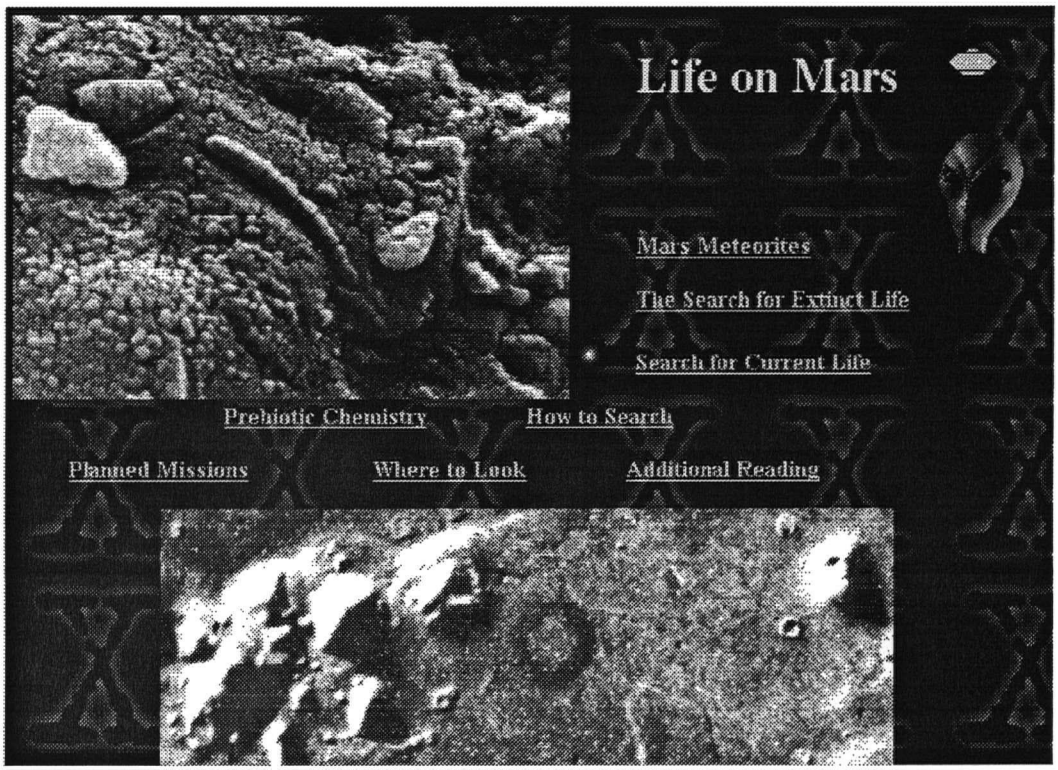


Figure 14

Content related humour

B. Duchastel's Strategy Steps in the Collaborative Process

Duchastel's Strategy steps were intended to guide the collaborative team through the process of presenting the content. The strategy steps were part of the development process as a whole and were referred to throughout the development. The strategy steps were used to remind the collaborative team that the tools, the physical environment, and the intended users needed to be taken into account when selecting content.

1. S1: Scope the learning context

Duchastel's first strategy step (S1) is to identify the physical environment including who the user is, what equipment is available to support the learning environment, and what resources are available. This strategy step proved to be critical to the successful development of the module. The primary users of the PLANET module are the Astronomy 101 students. However, other students with access to the same computers could also use the module. In 1997, the module was available to the general public via the Internet. As the discussion between the content expert and the developer progressed, it became clear that the existing Astronomy 101 lab facilities were inadequate to support the content needs of the instructor. To achieve these needs, the developer had to develop in *Windows 95®*, which could use a Java, JavaScript and Image-map enabled version of *Netscape®*. *"To run the Internet for the purpose of this module, the lab requires Windows95™ because of the 32-bit processing environment. The proposed module uses an environment that cannot be run on the [existing] Windows 3.11™ or lesser operating systems"* (E-mail Exchange, Developer to Instructor, August 15, 1996). For example, links to pages such as the USGS Flagstaff Field Center on the 'Browse the Solar System' page at http://wwwflag.wr.usgs.gov/USGSFlag/Space/wall/wall.html which has a clickable map leading to images and information on every planet, requires the use of an image-map capable, 32 bit browser. The instructor assumed the responsibility of ensuring that the Astronomy 101 lab could support the use of the PLANET module and took the necessary steps to ensure that the lab computers were upgraded to *Windows 95™* and equipped with a 32 bit version of *Netscape®*. In some cases, the RAM and hard drives of the student computers were also upgraded. Appendix I displays details of the lab's computers after modification. Matthews discussed the problem of the computers in an e-mail communication writing, *"Fortunately, the Earth & Ocean Science people*

want to upgrade the PC lab for their own Web-weaving ambitions, so we should be able to pool our resources" (E-mail Exchange, Instructor to Developer, August 16, 1996). With these laboratory upgrades in place, it became possible for the developer to fulfill all the instructor's requirements for the module.

The developer's role of creating content information required Internet-based tools including programs such as *Eudora ™* for e-mail, *HomeSite ™* for Web page development, *HyperSnap ™* for image capture and *Paint Shop Pro ™* for image manipulation. The developer added the 'demo version' of these programs to the laboratory network for efficient onsite development of the module once the upgrade was in place. Duchastel's strategy step, S1, was referred to each time new resources were discovered to remind the collaborative team that the content requirements of the instructor had implications for the physical environment.

2. S2: Establish media and process

Duchastel's Step, S2, was primarily the responsibility of the developer. It was the developer's task to locate and utilize suitable media to fulfill the instructors needs. The instructor's role in Duchastel's strategy step, S2 was to choose the specific resources such as pictures and data. The selection of the images was largely determined by the content and the selection of the Web sites presented to the instructor by the developer. For example, for the 'Face on Mars' feature, several animated movies were located by the developer. Matthews chose the most appropriate movies and disregarded those movie files that confused the issue. The developer's role also included choosing the tool that best displayed the resource. The instructor, who was familiar with technology, offered suggestions. "*By the way, have you encountered a program called NetTube? Apparently, it's very good for running mpeg, QuickTime and more*"

(E-mail Exchange, Instructor to Developer, September, 1996), but it was the developer's role to decide what worked best in the choice of media and process.

3. S3: Establish learning paths

Hypermedia lends itself to linking relevant information and affords an opportunity to create alternative paths to learning. Learning paths in the module were established by both the instructor and the developer. The design of the module's Web pages took into account the fact that the Internet had a great deal of information to offer and that much of this information should be linked to the module. It was the instructor's role to determine which links should be included in the module and ensure these links take into account the students and the type of information they needed in order to learn the content. Matthews suggested that, while some students may take a path through an instructor supplied link to access information to answer a specific question, another student may wish to search the Internet for information (Discussion Meeting, August 17, 1996). The latter situation, anticipated by the instructor, resulted in the addition of links to Internet-based search engines via the *Search Tools* feature, thus establishing alternative learning paths.

The specific items in the instructor's 'wish list'[3] were used by the developer to create learning paths. For example, a linked 'wish list' item, *Current Events,* was linked to the Mars Pathfinder mission site at http://mpfwww.jpl.nasa.gov/ as a sub-topic under the horizontal menu. In the establishment of learning paths by the developer, a common occurrence was to link various sub-topics to the same page in an attempt to assist students in understanding that one learning path could bestow many answers. For example, a hyperlink was established to the 'Welcome to

[3] The 'wish list' was a collection of ideas the instructor envisioned should be included in the module. Some of the 'wish list' items included simple statistical data on each planet.

the Planets' Web site at http://pds.jpl.nasa.gov/planets/welcome/ for each of the planets named in the sub-topics menu of *OverView*.

The following scenario illustrates the collaboration between developer and instructor when establishing the learning paths for students. In an early version of the module design, the developer programmed the horizontal sub-topic menu to change when a student chose a topic from the vertical menu bar on the left of the screen's main frame, (cf. Figure 15). The 'Main Area' of the screen, however, remained unchanged creating an opportunity for the student to miss the simple menu change in the horizontal menu. For example, Figure 16 shows the result of selecting Mars on the vertical menu from the original module screen. A comparison of Figures 15 and 16 indicates that the only change resulting from the selection is a change in the horizontal menu. To avoid possible confusion, Matthews decided to have each selection on the vertical menu change both the 'Main Area' <u>and</u> the horizontal menu. For example, a picture of Mars was selected to accompany the selection of Mars on the vertical menu (cf. Figure 17). Adding this feature was not a simple procedure and required incorporating JavaScript into the finished module to achieve the desired operation. This example illustrates the importance and strengths of the collaborative development process—while the developer may have chosen to incorporate the simpler solution as an expedient to finishing the software development quickly and cost effectively, the instructor could see and communicate a clear need why it was worthwhile to spend the time to incorporate the more sophisticated operation.

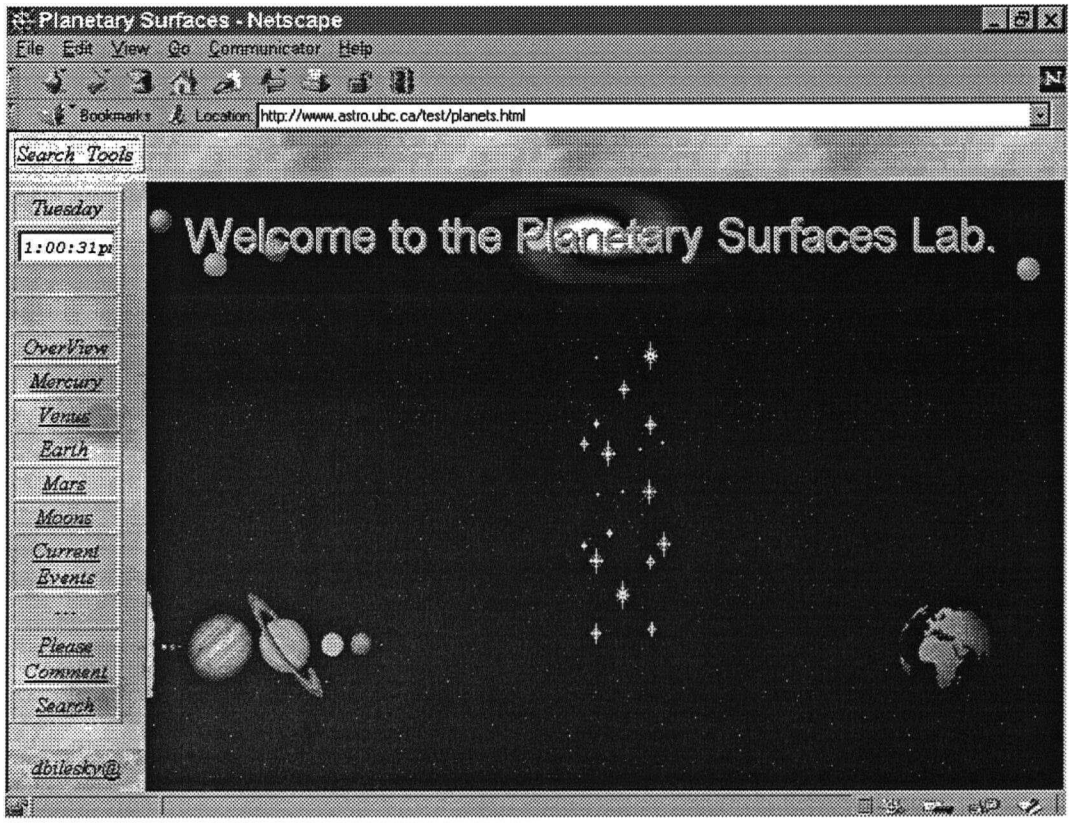


Figure 15.

The welcome page to the Planetary Surfaces module before any links are chosen.

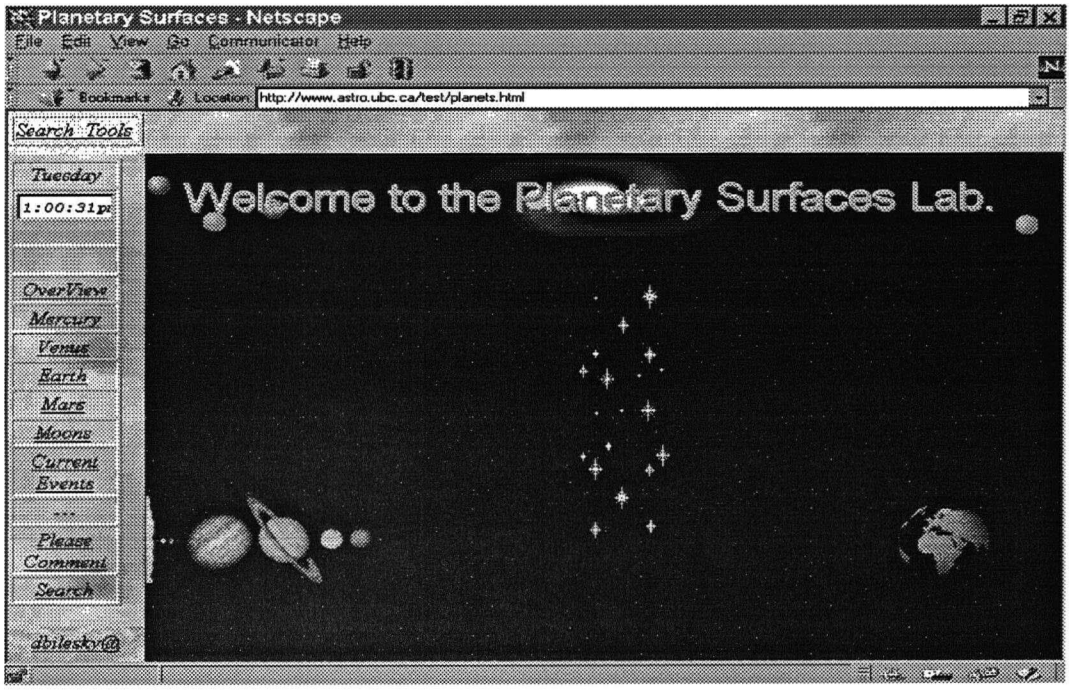


Figure 16.

Mars, on the left menu, has now been chosen. A horizontal 'Mars' menu appears above the welcome image but the main area appears unchanged. This page is too similar to Figure 15 and may confuse the user.

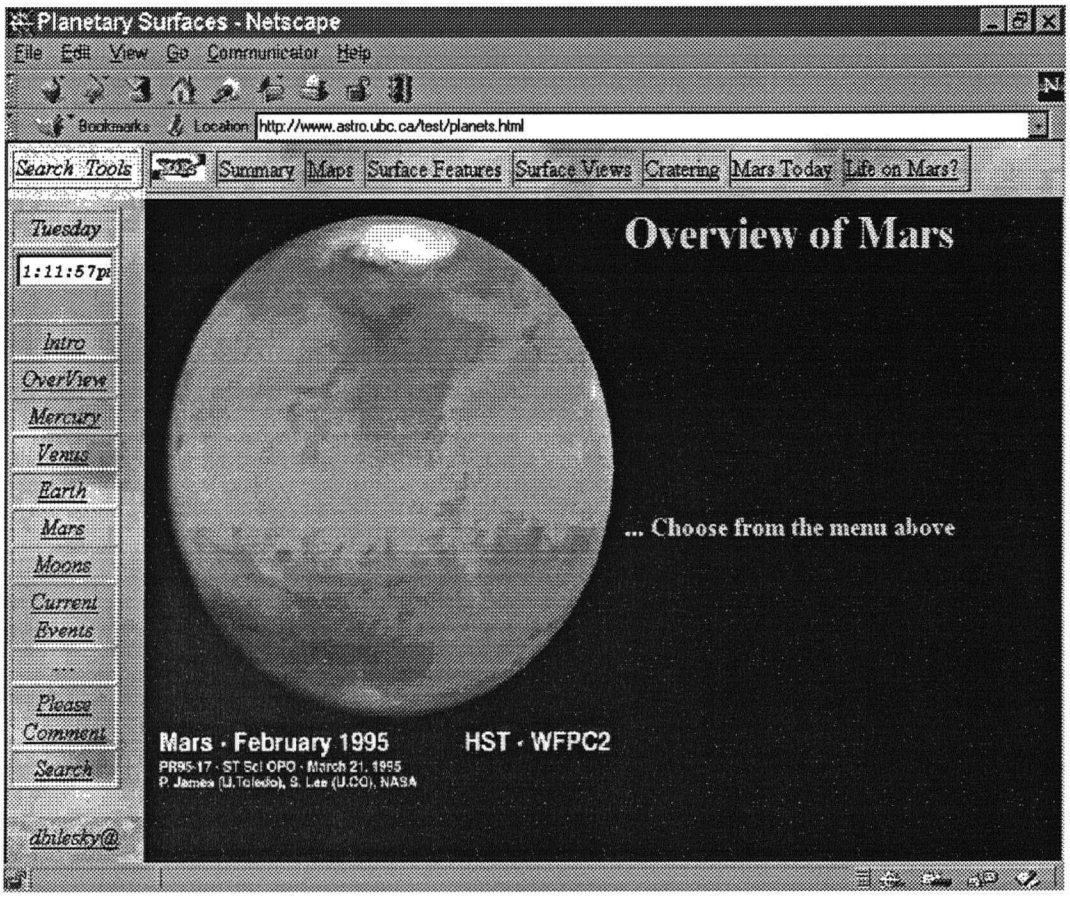


Figure 17

In the Revised Version of the module, the image of Mars accompanies the selection of the sub-menu of Mars on the horizontal menu.

4. S4: Create a support structure

The instructor decided that the module needed to be supported by an Activity Guide to ensure the students met his desired educational goals (Developer's Field Notes, August 9, 1996). The chapter in the lab manual, entitled "Exploring a Planet's Surface", was developed in two forms. The first form was online (cf. Figure 18), designed because Matthews thought it was appropriate for it to be included as part of the module. The second form was a hardcopy version included as a part of the Astronomy 101-laboratory manual. The development of the planetary surfaces section of the manual proceeded concurrently with the development of the module and

was essentially the responsibility of Matthews, *"If things do not work well some of it will be on my shoulders. I [must] write and run an understandable lab that satisfies the pedagogical goals"* (Discussion Session, August 19, 1996). However, the developer was responsible for converting the Activity Guide into the online, HTML document.

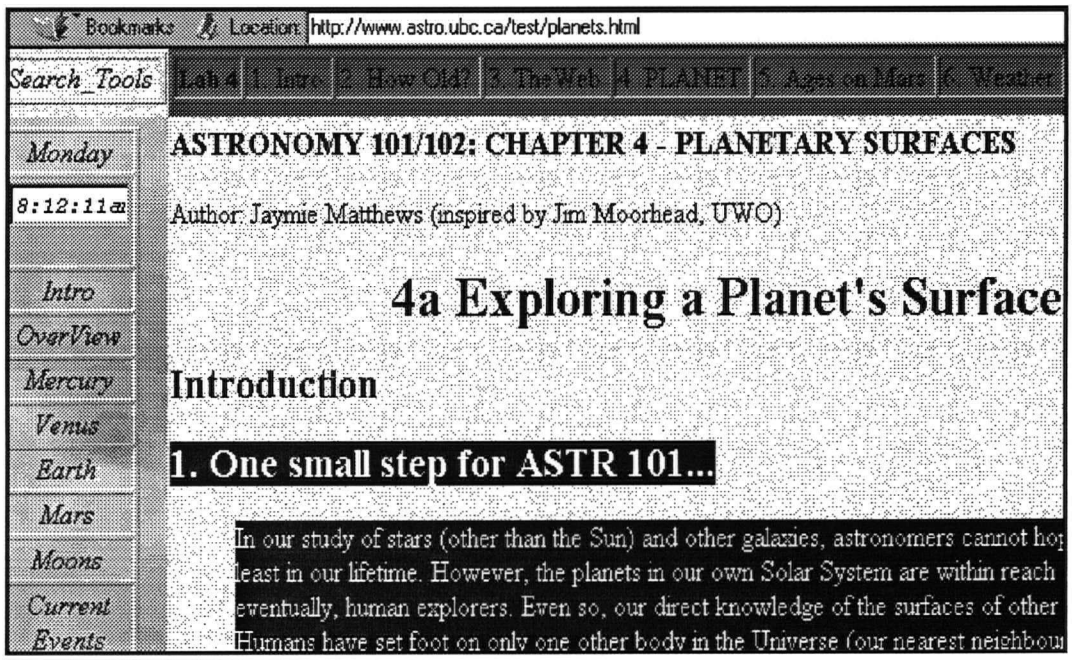


Figure 18

The figure shows the online Activity Guide which is available at: http://www.astro.ubc.ca/test/planets.html

5. S5: Validate the strategy

The strategy validation step was used as a guide by the collaborative team to test the module in order to determine if the strategy elements of the design led to a successful implementation of the module. The instructor's role was to test for emerging difficulties including verifying links to pages which contained further links that might have been broken, erroneous, or that demanded an unavailable tool. However, the module contained

many links to remote sites. Matthews could not validate all possible links on the Internet nor could he hope to hide distracting Web pages.

> *"I like the open-ended nature of the labs but the danger is the students can get distracted from the project they are supposed to be doing and they start looking at other stuff before they get going on the lab and they run out of time to actually do the lab"* (Discussion Session, August 9,1996).

The developer's role in the strategy validation step was to solve any difficulties that were discovered. For example, a link discovered by the instructor (One-Hour Meeting, October 18, 1996), led to a remote site that activated a movie. The developer's role was to find and install a movie player that would play this movie.

The validation process helped to ensure that the students' focus was on the content of the module rather than guessing on how the program worked. The instructor stated, *"if they explore they can find out lots more things then they are asked for in the project. I like to have that here as well so long as we avoid a button that does not do anything nor go anywhere. They must see or do something related to the topic"* (Discussion Session, August 19, 1996).

Pursuant to step S5, Matthews systematically evaluated the design of the module to identify possible implementation difficulties. For example, he tested the various search engines that the students could access so that he was familiar with the types of inquiry responses these engines produced on a range of topics. This testing for emerging difficulties ensured that the instructor was prepared to suggest a more appropriate search engine during the module's implementation. For example, the instructor may suggest that students use 'Yahoo' instead of 'InfoSeek' should the search engine 'InfoSeek' produce erroneous or confusing inquiry responses. In another instance, Matthews realized the need for locally stored images and data in case the Internet link should fail or become unmanageably slow during student use (E-mail,

Instructor to Developer, October, 17, 1996). Again, it was the developer's role to solve this potential problem by importing and storing essential images and data.

The interface design process created a self-contained module in which all resources had the appearance of residing on the local site. However, since the module actually accessed resources on the Web, it was possible that a knowledgeable user would realize that Web-based resources were being used, and exit from the program and engage in "unstructured Web exploration" - an activity which Matthews preferred to discourage. Nevertheless, through discussion, Matthews conceded:

> *"I do not want to make it so sexy that they get drawn away to other things but we cannot spoon feed them too much either because they are adults and they know they have a certain amount of time to accomplish it and if they squander their time it is their own fault"* (Discussion Session, August 9,1996).

To deal with this issue, the design of the module helped to confine the students to the Planetary Surfaces subject area. When the students activated remote links and retrieved information from a remote site, the downloaded pages were confined to the 'Main Area', a "smaller than screen size" frame in the module leaving the horizontal and vertical menus visible. This interface feature was included by the developer to satisfy Matthews' concerns regarding the distractions inherent in open-ended web exercises.

IV. Collaboration

A successful collaboration is defined as a relationship similar to that of a friendship. According to Wallace and Louden (1994, p. 332) *"qualities such as trust, risk sharing, humility and fair exchange can be found in any relationship between close friends"*. These qualities are also some of the characteristics of a successful collaborative relationship. Wallace and Louden

(1994) identify eight attributes that characterize a successful collaboration: similarities, differences, symmetry, risk sharing, trust, fair exchange, humility and emergence. Data from video tapes of discussions between the developer and the instructor, personal developer notes, and e-mail correspondence between developer and instructor were examined for evidence of these attributes and the establishment of a successful collaborative relationship between the instructor and the developer.

A. Similarities

The developer's field notes indicate examples of similarity between the developer and the instructor with regards to issues pertaining to the design process. For example, the developer noted that the instructor and the developer were similar in their low tolerance for 'In Construction' (Under Construction) pages. Web-page developers frequently place notes on Web pages indicating that the page is not complete or that it is still 'under construction'. In the developer's field notes, the developer wrote, " *Jaymie and I agree that 'In Construction' pages are not good*". This comment indicates a collaborative agreement made after an exchange of ideas in the August 9 discussion. In another conversation, which also illustrates the similarity of ideas on using links in the project, the instructor suggested that, "*the map should be clickable such that 'Mariner' images pop up*". The developer agreed (cf. Figure 17) and suggested, " *[I will] tailor the package so they [the students] expect things to happen. For example, the mouse turns into a hand [when on a link]*". As the 'package' got 'tailored' the instructor suggested that the developer should, "*pick out the best images to hot link*". The developer agreed, "*high resolution and more detailed the better*". The instructor continued with suggestions, "*plus, put in links to existing sites and avoid links to nothing*" (Developer's Notes, August 15, 1996). These examples show that the instructor and the developer were similar in their low tolerance of "In

Construction' (Under Construction) pages and in their views on how and when links should be established

B. Differences

Differences in the skills and abilities of the team members are shared in a successful collaboration. The developer intended to share his development skills with the instructor. In a discussion meeting (August 9, 1996), the developer suggested the instructor might like to learn how the package was made in the event that the instructor may wish to develop another in the future on his own. " ... *at the end [of this study] you are supposed to be competent at this*". The instructor replied, "*Yes, [laughs twice], we'll see*", and continues, "*I like to think of this as a black box and I am just a consumer*". The developer conceded the point and offered, "*we are doing a collaborative study, if we adhere to that perspective then you do not have to know all that much about it [the module] was made*". The instructor replies, "*I like this setup*", referring to the instructor-developer relationship in the development of the module (Discussion Meeting, August 9, 1996). This conversation illustrates that differences existed between the developer and the instructor, and indicates the willingness of the instructor to accept and draw upon the skills of the developer in producing the module. Trust is also displayed in this exchange as the instructor acknowledges the developer's ability to implement an idea.

C. Symmetry

Symmetry indicates a balance of power. Disagreements expressed in some e-mail exchanges, (cf. Appendix VII) could be interpreted as an event where the instructor insists that the developer's choice was inferior and that the developer does not understand when an idea is too confusing. For example, on one occasion the instructor told the developer

that "*having the various maps pop up immediately will be too confusing*". However, the willingness to communicate disagreements can signify equality of power and mutual respect among two collaborating professionals. In another instance, the instructor, again, communicates a disagreement with the developer's original choice and wrote, "*For Mercury, the Moon and Mars, could you change your 'Craters' button to 'Cratering'?*" (E-mail Exchange, Instructor to Developer, September 10, 1996). A balance of power allows the partners to alter their decisions without adversely affecting on the development process or the collaborative relationship.

D. Trust

An example of trust is illustrated in the e-mail exchange in Appendix VII. The instructor wrote that, *"the link to 'Mars Today' should go to the introductory home page for that site which explains what the student will see on the next page"*. The instructor trusts that the developer understands the meaning of the implied instructions. As another example, Matthews trusted that the developer would have the module complete in time for the scheduled lab while the developer trusted that Matthews would have the Activity Guide ready. Lack of trust may contribute to an unsuccessful study.

E. Risk Sharing

The development of the module involved risk-taking for both members of the collaborative team. The collaborators also shared the risk in terms of their level of commitment afforded to the project. The instructor incorporated the module into the Astronomy 101 course and in doing so, risked providing a sound laboratory session for the students. In a discussion session, on August 19, 1996 the instructor stated that most of the responsibility was his should

'things' not work well. The instructor wrote understandable labs that satisfied his pedagogical goals (Discussion Session, August 19, 1996). Therefore, he risked implementing a substandard lab because the lab was collaboratively developed. The developer was conducting a study for a graduate degree. The developer risked the possibility that the instructor might have decided not to go forward with the module because of time constraints or because of his concern for his students' learning. The collaborative team thus shared the risk associated with module development; although their personal stakes were different, the risk was evident nevertheless.

F. Humility

The change in the content of the instructor-developer discussions provides evidence for the quality of humility in the collaboration. For example, at the beginning of the project, the developer was prone to affirming that the instructor's 'wish list' would be accomplished. However, later in the study, as humility emerged, the developer began to suggest that some items were too difficult for his skills and that these items may be found on the Internet. An example of a 'wish list' item that proved to be impossible to integrate was the rotating globe of Mars. The globe was intended to give the students the ability to generate surface maps of various locations on Mars. This access to various locations on Mars would give the instructor the freedom to assign different areas to different students and to give the students a greater sense of ownership in the data. Where, at the beginning of the project, the developer offered to create the rotating globe, he later confessed that this 'wish list' item was beyond his skills and suggested that a static version, available on the Internet, be used instead.

G. Fair exchange

Fair exchange is a characteristic seen in successful collaborative relationships and refers to the act of sharing the workload on similar tasks. In one example, (cf. Appendix V), the instructor refers to writing the Activity Guide that accompanies the module, "*I submitted the camera-ready copy of the Astronomy 101/102 lab manual to the printers this morning*". Part of the instructor's role was to write and run an understandable lab, but the instructor was depending on the developer to create overlays and locate images that mesh with the content of the Activity Guide. "*Once I see the actual images we can access and we decide how to approach the overlays with transparent GIFs, then I can work out detailed exercises...*"(Appendix V). The success of the lab session depended on this fair exchange of work and the collaborative effort needed to work with content resources.

V. Effectiveness of the Module

The development of the PLANET module may serve as an example of an easy and cost-effective way of developing a multimedia learning environment. One of the main concerns of the study was to demonstrate that a product could be quickly developed and readily duplicated at a reasonable cost. Thus, the developer was not prepared to spend an unlimited amount of time developing the features—particularly given the evolving nature of the topic and the possibility of yearly revisions (cf. Appendix VIII). The cost inherent in the development of this module was in terms of the developer's time and the instructor's time. An e-mail exchange from the instructor in response to an inquiry from the developer on the instructor's impression of the effectiveness of the module in terms of time is included in Appendix VIII. The instructor writes, "*My experience with this lab module convinced me that it was worth the time and effort to incorporate Internet resources into my course*" (Appendix VIII). The instructor also commented on the module's effectiveness in terms of money. The instructor writes, "*As for cost... well, we did this on essentially zero budget, other than the cost of the PC upgrades (which were not exclusively for this project) and our own time (valuable but free, in this case). So I think it was pretty cost-effective*" (Appendix VIII).

The developer in a collaborative situation similar to the one examined in this study would also not necessarily be paid for development time—the module would be essentially developed in the developer's "spare time". Thus, the use of readily available resources and tools is mandatory. Currently, one of the best sources of readily available resources is the Internet. Using resources produced and mounted on Web pages by "experts in the field" is clearly a time efficient method of producing educational products. The Internet incorporates e-mail lists, as well as News Groups

and Web sites. All of these locations contain information that can be easily accessed and incorporated into personal resources. All three information sources were accessed in the development of the Planetary Surfaces module. The developer felt the limitations of time and money can be offset because Internet-based resources for specific projects can be efficiently located by a variety of means:

- Firstly, a question could be posted to a News group or e-mail list on a topic of interest and a response will normally follow.
- Secondly, an existing topic, called a 'thread', can be tracked and parts of this discussion saved when it is relevant to the developer's needs.
- Thirdly, a Web site may be referenced by an e-mail list or News group, through a search engine, or on a related Web site. Upon discovery of interesting material in these Web sites, their pages can be saved and viewed off line.

The development time invested by the instructor was approximately 70 to 80 hours (with a large proportion of the time spent on creating the Activity Guide) (E-mail Exchange, Instructor to Developer, July 25, 1998). The development time invested by the developer was approximately 200 hours (Developer's Field Notes, August through October, 1996). The data suggested that 30 to 40 hours of the instructor's time were in collaboration with the developer.

Effectiveness of the module may also be a characteristic of the individual instructor's willingness to promote the development model and resulting module to colleagues. Matthews actively promoted the module's uses and framework through presentations such as one given at the Canadian Astronomical Society (cf. Figure 19). Dissemination and use of this module was aimed at increasing the use of instructional technology in post-secondary education and demonstrating that a project of this nature is achievable.

CANADIAN ASTRONOMICAL SOCIETY

28th Annual Meeting

June 14 - 18, 1997

Planetscapes via Netscape

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We have developed a special Netscape interface, dubbed ***PLANET***, which enables first-year astronomy students to perform lab-style measurements on images and data of the terrestrial planets. For example, students measure crater densities and observe superposition of features on various parts of the Martian surface to estimate relative ages. The menu-driven framework is easily adaptable to a variety of Web-based astronomy applications, without a great deal of expertise beyond basic HTML script.

Figure 19

Matthews discussed the concept of the PLANET module and offered practical suggestions towards its implementation at the 28th meeting of the Canadian Astronomical Society. These suggestions are included in Chapter 5.

Matthews commented on the module as a learning resource (cf. Appendix IX), in response to an inquiry by the developer regarding the module's implementation in the Astronomy 101 lab. Matthews writes that, "*the Astronomy 101/102 lab is intended to help students learn at several levels including:*

- *personal experience of abstract astronomical concepts introduced in lectures,*
- *honing general technology skills,*
- *stimulating independent thought,*
- *improving information search and retrieval skills, and*
- *creating additional interest in and excitement about science.*" (Appendix IX)

He concluded that, "*the Netscape®-based software interface and the associated Planetary Surfaces lab project appear to have succeeded in all five goals*" (Appendix IX).

VI. Summary

This study documented and examined the backgrounds, roles, and proceedings of a collaborative relationship that was undertaken to add technology to a post-secondary education classroom. The instructor was the content expert. His role included recommending resources to be implemented into the module, verifying resources, and writing the corresponding student Activity Guide. The developer located Internet-based resources and built the Web pages. Duchastel's Learning Environment Design (LED) was used as a development and discussion guide. A deadline drove the module through a three-month timeline. The basic pedagogical needs of the instructor were the first items to be incorporated into the module to facilitate preparation and publication of the Activity Guide. The 'wish-list' items of the instructor were added when suitable resources were located on the Internet. The data collected during the development process provides evidence that all of the LED steps were applied and that the attributes associated with a successful collaboration were present.

In chapter 5, the reason for documenting such a learning environment development process is discussed in regards to the research questions. In addition, suggestions for further research, and recommendations for conducting a similar successful collaboration are included.

Chapter Five

Findings, Conclusions and Further Research

This chapter begins with a brief overview of the study. In the second section, the findings of the study are discussed. The third section offers suggestions for further research. In the fourth section, the study's conclusions are presented in the form of recommendations for conducting a successful collaboration for the purpose of implementing Internet technology into a post-secondary education classroom.

I. Overview of the Study

This study examined the attributes of a professional collaboration established to develop a multimedia learning module within the context of post-secondary education. The module development was based upon the application of Duchastel's Learning Environment Design (LED) model. The study addressed two questions:

Question 1. What are the requisite conditions for a successful, instructor-developer multimedia module development collaboration? What are the roles and responsibilities of the instructor in this collaboration? What are the roles and responsibilities of the developer in this collaboration?

Question 2. Is the collaborative development of multimedia instructional materials using Internet software an efficient, effective and inexpensive procedure for producing learning resources for post-secondary education?

To explore these issues, a collaborative, multimedia development partnership between a post-secondary education instructor and a developer was established. This team undertook the

development of an Internet-based, multimedia module on the topic of Planetary Surfaces designed to be used as the basis of a student lab in the Astronomy 101 course at the University of British Columbia. The choice of the topic for the module, Planetary Surfaces, was selected by the instructor on the basis of an identified need in the laboratory section of his course. The instructor recognized that suitable materials to address this need were available on the Internet. Both the instructor and the developer were familiar with Internet technology prior to the start of the study. Duchastel's LED model (Duchastel, 1994), provided the working framework for the development of the PLANET module. This study examined the process whereby the multimedia module was collaboratively developed, identified the requisite conditions for the success of this process, and defined the roles and responsibilities of the instructor and developer. The study also examined the efficacy of the development process in terms of the applicability of the resulting product.

The goals of the study were to:

- establish procedures that capitalize on the abilities of participants in a collaborative relationship in order to minimize time and funding requirements of creating a successful multimedia learning module.
- demonstrate how to incorporate technology into post-secondary education classrooms in a relatively simple and cost-effective manner through a process of collaborative resource development.

In order to examine the efficacy of the collaborative relationship, the study applied a qualitative research design and used the constant comparative method to sort and analyze data collected via video tape recordings of meetings, journal entries, and e-mail communications. The author was a participant-observer involved in this collaborative action research project which produced a multimedia module over a 3-month period.

II. Discussion of Findings Related to Research Question #1

A. The Requisite Conditions

The success of the collaborative relationship established in this study resulted from the planning, organization, and development of the multimedia Internet-based module, 'PLANET'. This relationship was characterized by a number of the aspects of a successful relationship identified by Wallace and Louden (1994) including similarities, differences, symmetry, risk sharing, trust, humility and fair exchange of the workload. Although all these elements were present during the module's development process, risk sharing may be the leading attribute that brought the module to completion. Both partners in the collaborative team had a personal stake in the project and, although the level of risk for each person was quite different, neither could afford not to complete the development process without consequences. The instructor had committed time in his course for the module, while the developer was dependent on the data from the completed project for his graduate degree. The element of risk sharing helped the participants to remain committed to the project's completion.

The aspects of a successful relationship, when combined with the steps taken in the Learning Environment Design (LED) model, formed the requisite conditions for a successful multimedia development process. Duchastel predicted that the LED model could help form a learning environment that is an inviting environment for learning. In this study, Duchastel's LED model helped focus the development sessions by establishing the essential steps of developing the content of a learning module, and by providing a strategy for ensuring that the module's content addressed the needs of the target learning audience. In addition, the application of Duchastel's LED model provided a structure that allowed for the steps in the design of the module to be separately examined, affording a better chance of effectively achieving the pedagogical goals of

the instructor through careful and systematic examination of the module's content and implementation strategy during development.

Within the context of this study, the instructor and developer assumed roles that complemented their talents. The acceptance of roles served as an example of trust and fair exchange. The instructor was not required to learn the skills required for software development nor the criteria that the developer used to choose and use the various tools in the module. The instructor chose not to engage in Web-page development because of the restriction of time. Similarly, the developer left all the pedagogical decisions to the instructor. The assumption of roles was necessary to efficiently develop the module given the short developmental period. In a less successful situation, the instructor may have found it necessary to leave the instructor's role, which was mainly content validation, and assume the developer's role of Web-page design particularly if he lacked confidence in the quality of the developer's work. Such a role departure would have been costly in terms of time.

B. The Instructor's Role

In his role as the instructor, Matthews provided input into the LED design from personal teaching experience by validating the content and the implementation strategy for accuracy. The analysis of the study's data indicates that, although the researcher/developer was also a teacher, the pedagogical issues were left to be solved by the course instructor. The individual steps of the LED model provided some pedagogical direction. The LED verification process helped to focus the instructor's attention on essential design elements from the instructor's special expertise of content expert. It was a mark of the success of this collaboration that, given the instructor's experience with technology, the instructor restricted his role to pedagogy.

The instructor was also responsible for providing a suitable lab environment and for writing the Activity Guide. Many of the other laboratory assignments in the Astronomy 101 course were completed using computers. Matthews' responsibility was to upgrade an already existing computer environment to incorporate Internet technology—a procedure that required only minor changes.

C. The Developer's Role

The role of the developer was maintained by the researcher throughout the study. The developer contributed to the module development by establishing what equipment and tools were necessary, by determining the availability of applicable resources, and by implementing the content requirements of the instructor by creating the PLANET module's Web pages. The developer had a level of computer programming skills, (such as understanding the elements of the source code), which allowed the contents of the instructor's wish list to be efficiently implemented. The developer was not required to learn the content of the instructor's course nor the pedagogy applied in the teaching of this content.

The Internet was collaboratively established as the medium through which the module was to be developed, and the developer was trusted to choose the most efficient tools to create the module. Since the Internet is a popular environment, tools and resources related to Planetary Surfaces were found to be readily available. As an example of fair exchange of the workload, the developer spent the majority of the time constructing the module based on the notes derived from the collaborative discussion sessions for which the instructor prepared content. The establishment of a successful collaboration permitted the developer to remain in his preferred role throughout the development process.

III. Discussion of Findings Related to Research Question #2

The PLANET module was collaboratively designed to produce a learning resource for post-secondary education. In spite of limitations such as time and money the module development appeared to be effective, efficient and inexpensive.

A. Effective

The effectiveness of the development process is illustrated by the fact that the collaboration resulted in a useful learning package. In an e-mail response (cf. Appendix IX) to a question about the purpose of the Astronomy 101 lab experience posed by the developer, Matthews stated that the Astronomy 101 lab was intended to help students learn at five different levels and, in the eyes of the instructor, the module, PLANET, satisfied these five lab functions very successfully. Students performed well in their lab reports and were able to perform the tasks set for them at the time. All the students were able to use *Netscape*® as an information search tool at the minimum required level. This result is particularly significant since many students had had no prior *Netscape*® experience. According to the observations of Matthews, many students demonstrated quite innovative thinking in tackling some of the problems from the Activity Guide. Further, some Astronomy 101 students continued to use the PLANET module as a study tool during the rest of the term. Although, according to Matthews, (Appendix IX), it may have been possible to achieve some of the lab goals without *Netscape*® such as with a 'traditional' multimedia module that does not access current data, this procedure would not have imparted the same sense of immediacy among the students. An 'off-line' lab would have had more of the sense of a textbook assignment rather than a true research project. The *Netscape*® interface enabled the students to locate and obtain images of planets in real time, and analyze them, in the same way as a planetary scientist.

B. Efficient

Two people developed the PLANET module in just three months on a part-time basis using readily available resources and tools. That the collaborative development process was efficient was acknowledged by both the instructor and the developer, both of whom felt that expenditure of time and effort was reasonable given the result. In the year following the development of the module, Matthews suggested that the software only needed modest updating and did not put undue demands on his time to make ready for student use. Efficiency may also be addressed in terms of the module's usefulness. For example, Matthews noted that the PLANET module was an efficient interface as a study tool for the students during the rest of the term.

C. Inexpensive

Both the developer and instructor agreed that the time and effort of the collaborative team was valuable but free and so not a burden in terms of expense. In addition, the module was created on essentially 'zero budget' with the exception of the laboratory upgrades to the computers and even this expense was shared among several projects. All of the tools and resources incorporated into the module were downloaded, without cost, from the Internet. The existence of elements of a successful collaboration, such as trust and fair exchange, allowed the developer and instructor to remain in their respective areas of expertise and helped to minimize the costs of time required for the module's development.

IV. Recommendations for conducting successful collaborations for the purpose of implementing technology

The following are recommendations, arising from this study, for conducting successful collaborations for the purpose of developing technology enhanced instructional environments.

A. Take time to develop a sound friendship

The aspects of a successful collaboration require time to emerge. In order to aim towards a successful collaboration, take time to develop a sound friendship-based relationship before beginning the development process. Before this study began, the participants shared a history of having experienced the skills of the other. As the developer, I had designed software for the instructor on previous occasions and so was familiar with the instructor's demeanor. The instructor was relaxed, open-minded and willing to share the workload. These qualities, engendered a good, collaborative working relationship. The results of this study support Wallace and Louden's (1994) claim that a successful collaboration includes the qualities of a friendship such as trust and humility, and these cannot be forced.

B. Define Roles Clearly

When roles are clearly defined, then the elements of a successful collaboration make room for the collaborators to fully utilize their talents. For example, Matthews trusted my talent in the area of Web-page design. Matthews chose to not develop Web pages, not only because of the restriction of time, but because he believed I was capable of creating a Web page that successfully realized the pedagogical needs of the module. Since I enjoy designing and creating Web pages I

was happiest and most efficient when I was able to work within this role. Without the knowledge and expertise of Matthews, I would have been inefficient at validating the content or the implementation strategy. Choosing roles and adhering to the chosen role is an efficient method of respecting the limitations of time and funding. In addition, identifying and maintaining roles helps the elements of a successful collaboration to emerge. When there is an opportunity to show differences and experience the expertise of the team members, other elements paralleling a friendship such as trust and humility can emerge.

C. Ensure that all participants are equally committed to the success of the project

When the study was first proposed, there was no hesitation by the participants to share ideas and commit time. If the potential participants in a proposed project were concerned about their ability to commit themselves to the other, they may wish to stop immediately or to start on small projects to first build the necessary relationship and commitment. One of the aspects of a successful collaboration is risk taking and, although each participant's stake in the project may be different, risk taking may also lead to commitment and the success of the project.

D. Draw Upon The Internet

Use the Internet as a source of tools and resources. In this study, the instructor, Matthews, used the Internet regularly for academic pursuits and was aware of the Internet-based resources available to his discipline. The developer was aware of the tools used to develop Internet Web sites, such as the Web page development program *HomeSite* ™, as well as where to find these tools and how to use them. Thus, when it was proposed that the Internet be used as the

base for tools and resources, both participants readily saw the potential for this approach and understood the implications. The decision to use the Internet was based on the fact that:

1. the Internet is a vast and growing data-bank of information
2. the Internet is an excellent source of up-to-date classroom material especially for the Astronomy 101 lab
3. Internet-based resources can be easily updated and distributed, and
4. students expect to use recent technology in their post-secondary education classroom.

Some of the immediate limitations of basing the module on Internet tools and resources were that:

1. the existing hardware may be inadequate or
2. some ideas may not be possible to implement because the resource cannot be located or is not available, or the tools may not be stable enough for development. For example, a tool may be very new and can be expected to experience problems.

It is recommended that participants be aware of the potential and the limitations of developing with the Internet. For example, an individual who wishes to develop using the Internet may wish to spend time using the Internet to truly appreciate the tools and resources and to understand some of the pitfalls such as inaccurate data or erroneous pages. Nevertheless, the Internet should be considered as a means of adding technology to the classroom.

E. Follow an Established Design Process

Follow the procedures of an instruction design process. Duchastel's LED model explicitly distinguishes between the content and strategy facets of design in order to highlight the importance of both. The LED model facilitated the definition and regulation of the roles of instructor and developer by delineating steps with both pedagogical and developmental concerns.

As a result of using this model, the module development was efficient and the resulting product effective–two major goals of this project.

V. Practical Advice to Other Development Teams

Certain elements in the module's development and implementation have been reflected upon and are presented here as practical advice:

- Have a permanent on-screen menus. Such menus are particularly useful to help the novice user navigate.
- Create templates of pages for efficient development and consistent design.
- Proofread the sites directly linked by the module to ensure scientific accuracy.
- Look for students who are off task, especially navigating experts who will find a way to exit the boundaries of the module.
- Include open-ended challenges for the more capable student.
- Confirm that all sites exist from year to year and that the contents of the sites have not been changed.
- Have essential images cached in case the Internet connection is unavailable or too slow.

These elements are noted as practical because they reflect an instructor's perspective of having observed their impact on the target users and the developer's perspective of the development process together with his experience with the unreliable nature of information placed on Web sites and Internet connections.

VI. Recommendations for further Research

The study focused on the process of the development of a multimedia learning environment. Examining the process was necessary because of the uncertainty of how the collaborative relationship would affect the development of the module. The development of the module was also affected by the skills that the participants brought to the study and the limitations presented to them in terms of time and funding. Data was collected from collaborative sessions between the instructor and the developer, and e-mail communications relating to the development of the module. The results of the study establish that much of the success of the development of the PLANET module was due to the quality of the collaboration. In addition, establishing roles was important to the efficiency of the process. The efficient development was aided by following an explicit design, (in this case Duchastel's LED), for the creation of the learning resources. The success of the developed module was inferred, in part, from the immediate responses of the students during their use of the module and from the resulting thoughts of the instructor after the module had been used by the Astronomy 101 students to complete the lab on Planetary Surfaces.

Some specific suggestions for future research on developing a multimedia learning module within the context of post-secondary education are listed below:

1. The study focused on the needs, desires, expertise and skills of a specific instructor and developer in a collaborative development process. Further research is needed to demonstrate that the collaborative process can be successfully generalized to other instructor/developer pairs.
2. Further research is also required to demonstrate that the success of this study was not proprietary to the teaching of Astronomy, nor to the topic of planetary surfaces.

3. A related area that needs investigation is that of the students' reactions to the given interface design and the changes that a student or a group of students might like to have implemented. For example, a study could develop several modules serving the same purpose but focusing on differences in learning styles. The resulting data may be used to develop a model for a learning environment that may better serve different learning styles.

VII. Conclusions

The study demonstrated the possibility and feasibility of establishing a successful instructor-developer multimedia development collaboration. A successful collaborative relationship allows the participants to trust the skills of the other participant and to share the workload. The development process is efficient when clearly defined roles are established and maintained—when each participant contributes mainly from within their own area of expertise but understands some aspects of the other participant's domain. Remaining within a certain role or area of expertise is accomplished by collaborating in the manner of a friendship. The development process is further assisted when a structure provided by a learning environment design model is applied to the process. When these requisite conditions exist, then the limitations of time and funding of developing a multimedia learning module are lessened.

The process of the development of this module is an example of a promising development style for producing curricular material. Whereas software-based resources are not flexible, the PLANET module is easily modified through a developer/instructor relationship similar to the one that created it. The module is the product of a collaborative relationship between a developer and

an instructor where the module's effectiveness, in terms of meeting the pedagogical goals, was forefront in the design. The developer's role of locating resources and the instructor's role of validating the content and strategy paid close attention to the needs of the environment and the students. Where the developer is in a position to make a choice among alternatives, the instructor's view helps to make the decision fit the pedagogical goals. Where the instructor makes a choice, the developer can help make the idea a reality or offer alternatives based on the developmental goals of the project such as time and funding. As this study demonstrates, it is possible to collaboratively develop effective multimedia resources on a cost and time efficient basis provided that clearly defined guidelines are followed. The process studied in this work may serve as a model for accelerating the implementation of technology enhanced instruction in post-secondary education.

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Appendix I

The state of the under-grad lab after upgrading.

Under-grad Lab PC's Hardware Info. UBC Geoph. & Astr. Rm360

#	PC Name	Process.	Math Co.	Ram	H.D	Monitor
1	Amalthea	486DX66	Yes	4MB	170MB.	SVGA Int.
2	Ananke	P75	Yes	8MB	850 MB.	SVGA Int.
3	Callisto	P75	Yes	8MB	850 MB.	SVGA Int.
4	Carme	P75	Yes	8MB	850 MB.	SVGA Int.
5	Elara	P75	Yes	8MB	850 MB.	SVGA Int.
6	Europa	P75	Yes	4MB	50 MB.	SVGA Int.
7	Ganymede	386SX16	Yes	4MB	105MB.	SVGA Int.
8	Himalia	486DX66	Yes	8MB	850 MB.	SVGA Int.
9	Io	P75	Yes	8MB	50MB.	SVGA Int.
10	Leda	P75	Yes	8MB	850 MB.	SVGA Int.
11	Lysithea	P75	Yes	8MB	850 MB.	SVGA Int.
12	Pasiphae	P75	Yes	4MB	330MB.	SVGA Int.
13	Quake	486DX66	Inter.	8MB	81MB.	SVGA Int.
14	Rattle	486DX33	Inter.	4MB	170MB.	SVGA N
15	Rock	486DX66	Inter.	4MB	170MB.	I.
16	Richter	486DX66	Inter.	8MB	420MB.	SVGA N
17	Sinope	486DX10	Yes	4MB	850 MB.	I.
18	Terra	0	Inter.	16MB	420MB.	SVGA N
19	Tremor	486DX66	Inter.	4MB	170MB.	I.
20	Jupiter	486DX66	Yes	4MB	330MB.	SVGA Int.

Appendix II

Examples of Internet sites

Examples of Internet sites containing resources.

The following set of Internet Web sites contain Astronomy related content. Many of these addresses will change in the near future. Use a search engine to locate these and similar sites.

- General Mars data ---http://www.jpl.nasa.gov/mars/
- Archived images --- moons and planets ---http://www.jpl.nasa.gov/archive/images.html
- Images of objects in the Solar System --- http://photojournal.wr.usgs.gov/
- Welcome to the Planets --- http://pds.jpl.nasa.gov/planets/
- Planetary data System --- http://www-pdsimage.jpl.nasa.gov/PDS
- Planetary Images facility --- http://cass.jsc.nasa.gov/pub/library/RPIF/RPIF.html
- US Geological Survey, Flagstaff Center http://wwwflag.wr.usgs.gov/Flagstaff.html
- http://ic-www.arc.nasa.gov/ic/projects/bayes-group/Atlas/Earth/
- Mars Explorer -http://www-pdsimage.wr.usgs.gov/PDS/public/mapmaker/mapmkr.htm
- Mars Navigator --- http://wundow.wustl.edu/marsnav/

Tools are available for evaluation and often free for educational use. There are many sites displaying tools used for Internet-based: development such as:

- Stroud's CWS Apps --- http://cws.internet.com/index.html
- 32 bit Shareware --- http://www.winfiles.com/
- Tucows Internet Software --- http://tucows.ampsc.com/

Appendix III

Software and Tools

The source of the resources - software and tools - used in the PLANET module is mainly the Internet. The pictures of the features of the planets can be found at different Web sites. Examples of currently available Web sites can be found in Appendix II.

The tools, which navigate the World Wide Web (WWW), are defining the Internet, because of their appealing graphical nature. WWW Internet tools are characterized by their hypertext abilities and multimedia extensions. Hypertext is the ability to click on a word or object which has been programmed to connect the user to another section, page or site. Hypertext abilities are based upon the Hypertext Markup Language (HTML) coding, which is the structure behind the content of the WWW (Web). Using HTML is equivalent to formatting text in a word processor, and, like a word processor, graphics can also be added and hotlinked. *Netscape®*, *Opera®* and *Internet Explorer®* are WWW browsing programs used to search for and access HTML based Web pages. WWW browsers also combine the abilities of specialized Internet programs to facilitate Internet data access and manipulation. For example, WWW browsers can transfer files from a remote site to the user's computer via the File Transfer Protocol (FTP) in a manner that is similar to specialized programs like *WSFTP®* and *CuteFTP®*, and show graphical images in the same way as would programs like *Paint Shop Pro® (PSP), ACDSee®* or *LView®*. A range of 'helper applications' also exist that can be used to extend the functionality of existing WWW browsers.

Helper applications are currently necessary because:

1. the Browser has **not yet** incorporated a program to deal with a specific file or
2. the file is proprietary to another organization and can only be used when associated with a specific helper application.

For example, *Netscape*® incorporates the sound player: *NaPlayer*®; but, *NaPlayer*® recognizes only *au* and *aif* formatted sound files. A helper application program such a *RealAudio*® can be attached to *Netscape*®, as can *wPlany*®, *Wham*® or *Wplay*® to extend the range of sounds files *Netscape*® can play. 'Helper applications' are currently required to view most video files in *Netscape*® and to recognize and display graphical images not in the *gif or jpg* format. *Java* and *JavaScript* are helper languages that extend the functionality of WWW browsers by providing Internet users with the ability to interact with dynamic WWW pages - allowing the user to interact is a function that is significant for instructional applications.

study tool during the rest of the term.
Although it may have been possible to achieve some of the lab goals without Netscape®, it would not have imparted the same sense of immediacy among the students; the fact that they were specifying and obtaining images of Mars in real time, and in the same way as real NASA scientists would do. The lab would have had more of the sense of a textbook assignment rather than a true research project.

Well, this fulfills my telephone contractual obligation for the moment. ....

Hasta luego,
Charo [Dr. Matthews]

Appendix X

The Student 'Activity Guide'

ASTRONOMY 101/102: CHAPTER 4 - PLANETARY SURFACES
Author: Jaymie Matthews (inspired by Jim Moorhead, UWO)

4a Exploring a Planet's Surface

Introduction

1. One small step for ASTR 101...

In our study of stars (other than the Sun) and other galaxies, astronomers cannot hope to visit them, at least in our lifetime. However, the planets in our own Solar System are within reach of robot probes, and eventually, human explorers. Even so, our direct knowledge of the surfaces of other planets is still limited. Humans have set foot on only one other body in the Universe (our nearest neighbour, the Moon, a mere 400,000 km away) and space probes have touched down only on the planets Venus (two Soviet Venera landers) and Mars (two American Viking landers in 1976 and the Mars Pathfinder with Sojourner in 1997). In 1996, the Galileo atmospheric probe plunged into the clouds of the gas giant Jupiter, returning data for over an hour before being crushed by the intense pressure of the Jovian atmosphere. But the inventory of actual landing sites beyond the Moon can be counted on the fingers of one hand.

Despite this, the surface of every planet and major moon in the Solar System except Pluto and Charon has been mapped to some extent - thanks to fly-by and orbital missions by inter-planetary probes. Most of what we know about the surfaces of these worlds comes from these remote images.

In this lab, you will access the World Wide Web to import the most detailed images of the surfaces of the terrestrial planets currently available. Then you'll apply the same basic principles adopted by planetary scientists to interpret the terrain in these images and re construct some of the planet's history.

2 How old is the landscape?

2.1 Radioactive dating

The most reliable way to estimate the age of a particular area of terrain is to actually retrieve a rock from that site and subject it to the process of radioactive or radioisotopic dating. When a rock crystallizes from its molten form, unstable atoms in the rock begin to decay radioactively.

The atom decays by emitting a particle from its nucleus and becoming a new element (if the nucleus now has one fewer protons) or more commonly a new isotope (same number of protons but one less neutron). For example, uranium can decay into lead (the reverse of the ancient alchemists' dream of turning base metals like lead into precious ones like gold). The original atom is known as the parent isotope and the decay product is the daughter isotope.

The decay process is a statistical one; if you have many billions of atoms (as you would even in a tiny rock sample), then the rate of decay is mathematically predictable. For a given decay process, there is a time known as the half-life t1 = 2 during which 50% of the parent isotopes will turn into daughter isotopes.

> Take the decay of 238U (Uranium-238; the "238" refers to the total number of protons and neutrons in its nucleus) into 206Pb (Lead-206). The half-life of this decay process is t1=2= 4:5 billion years. Say a rock starts with 100 million atoms of 238U. After 4:5 x 109 years = 1 x t1=2, it will have only 50 million left (replaced by an equal number of 206Pb atoms). After 9:0 x 109 years = 2 x t1=2, 25 million will remain; after 1:35 x 1010 years = 3 x t1=2 have elapsed, there will be 12.5 million 238U atoms left in the rock; and so on. As the amount of 238U decreases, the amount of 206Pb in the rock increases correspondingly.

In a sense, these radioactive isotopes act as an internal clock, which starts ticking as soon as the rock crystallizes. By measuring the relative amounts of 238U and 206Pb in a rock sample, one can determine how many half-lives have gone by since the rock formed. Rocks generally contain many different radioactive isotopes (each with different half-lives) so scientists can measure various isotopic ratios to refine their estimate of the rock's age. (The radioactive isotope 14C, Carbon-14, has a half-life of only 5770 years, so it can even be used to date artifacts over historical time scales as opposed to geological or astrophysical ones.)

2.2 Chunks of other worlds

To use this technique, of course, you first need an actual rock sample. It's easiest to start with ones beneath our feet by dating rocks from the Earth's surface. Their age depends on where they are found. Mountain chains like the Rockies are relatively recent in Earth history – the rocks there are only about 60 million years old. The oldest known rocks in the world have been found in the Canadian Shield, a very stable region geologically. These rocks are up to 4 billion years old. (Some isolated crystals - not complete rocks - from the Australian shield are believed to be as old as 4.3 billion years.) These upper limits on ages of rocks place a lower limit on the age of the Earth. Our planet must be at least 4.3 billion years old.

Thanks to the Apollo missions and the Soviet Lunakhod robot landers, we also have Moon rocks to analyze. Samples from the vast dark plains known as maria (believed to be vast dried lava beds) are dated at about 3:2-3:8 billion years. The oldest samples from the heavily cratered and mountainous highland regions crystallized about 4.6 billion years go. Sometimes, meteorites survive their fiery descent through the Earth's atmosphere and are recovered from the ground. The oldest recovered meteorites are about 4.4 - 4.6 billion years old. About a dozen meteorites have been identified as coming from Mars, since the gases trapped in these rocks match the composition of the Martian atmosphere analyzed by the Viking landers in the mid-1970's. These rocks are believed to be debris ejected from the Martian surface by asteroid collisions, which then floated through space until being trapped by the Earth's gravity. One of these meteorites, ALH 84001, first crystallized about 4.5 billion years ago. (The others are about a third that age.)

The fact that we find no Earth, lunar, or meteoric rocks older than about 4.5 billion years suggests to astronomers that the Solar System must have been formed about that long ago.

However, in our quest to understand the details of what happened to the planets in the meantime, we have no direct samples of any of the other terrestrial planets or the moons of the Jovian planets for radioactive dating. Instead, we must rely on indirect (and less reliable!) approaches.

2.3 Counting craters: A history of bombardment

When looking from space at the surface of a planet with no atmosphere, we can make a rough guess at the age of various regions from the local crater number density - the number of craters (of a given size) per unit surface area; e.g. 500 craters (5 km or more across) per 1000 km2 . (If the planet has a thick atmosphere and weather, then erosion will obliterate the craters overtime and this approach is no longer valid.)

Figure 1: Two regions of equal area on a planet with no atmosphere. The circles represent craters of various diameters left by meteoric impacts. Which do you think is the older part of the surface?

The principle is simple: There is considerable meteoric debris left in the Solar System, which rains down upon the planets. Currently, several hundred tonnes of meteoroids collide with the Earth's atmosphere every day! (Most of this material burns up before it hits the ground, leaving only a streak of light - a meteor trail or "falling star" - as evidence of its arrival.) On a planet with no atmospheric protection, however, this bombardment will leave impact craters on the surface. When an area of a planet's surface first cooled from lava and became solid rock, it was like a clean unmarked slate. Over time, meteoric bombardment leaves scars on that surface. The older the surface, the higher the number of such scars. In Figure 1, two regions of an airless planet's surface are shown schematically. Both have equal area. Region A shows only a few craters; the rock there must have solidified recently since it hasn't been around long enough to accumulate many craters. Region B is heavily cratered, and includes some large impact features.

This must be a much older surface relative to A. The higher cratering density means t has been exposed to impacts longer; the fact that there are large craters means the surface was solid earlier in the history of the Solar System, when there were larger fragments of debris not yet swept up by the gravities of the young planets.

If we could be sure the rate of meteoric impacts was constant with time, then we could just take a ratio of the two crater densities to get a ratio of the ages of these two regions. However, the best theories of the origin and history of the Solar System suggest that there was much more debris raining down on the planets in their early history than there is today.

This is supported by observations of the crater densities of different regions of the Moon, compared to the ages of lunar rock samples from those sites returned by the Apollo astronauts and Soviet Lunakhod robot probes. We have been able to piece together a crude record of the impact rates in the Earth-Moon system for the past 4.5 billion years as shown in Figure 2.

Figure 2: The history of impact rates in the Earth-Moon system. The boxes indicate the uncertainties in the age and impact rate data. The left vertical axis shows the rate of impacts compared to what is experienced today by the Earth and Moon, on a logarithmic scale; at the time of planet formation 4.5 billion years ago, the impact rate was roughly a million times greater

than today. (The right-hand scale shows the base-10 logarithm of that relative rate.) This figure was adapted from an article by G.W. Wetherill (1977, Proceedings of the Lunar Science Conference, Vol. 8, p. 1 .)

Soon after the Sun and planets formed, the planets underwent heavy bombardment by the "leftover" material that had not yet accreted into planetary bodies. It is believed that about 100 million years after planetary formation, only a few very large asteroids (100's - 1000's of km in diameter) were left. Therefore, the oldest surfaces should also have more large craters. In fact, these surfaces should be saturated by craters, leaving no area unscathed.

A good example is shown in Figure 3: a telescopic photo of part of the lunar surface showing the edge of one of the maria (Mare Nubium) and the highlands beyond. Notice the flat dark mare with only a few `small' (10-km diameter or so) craters and no large ones. The highlands at the top of the photo are saturated by crater laid on top of crater, with many craters more than 100 km across.

If a planet is volcanically active, an eruption can cover part of the surface with molten lava, obscuring the earlier evidence of cratering. This is a fresh surface on which new craters will begin to accumulate. If the volcanism occurred long after the interval of heavy bombardment, then there will be few large meteorites left to be swept up by the planet's gravity, and only smaller craters will accumulate. We see this kind of cratering record in the smooth flat maria of the Moon (e.g., Figure 3), which are believed to have been flooded with lava about 3.5 billion years ago, near the end of the epoch of intense bombardment (cf. Figure 2).

Figure 3: Mare Nubium (bottom) and the lunar highlands (top). Note the difference in crater density and size between the two regions. The horizontal edge of the photo covers about 800 km. (Photo credit: Hale Observatories, California)

By comparing crater number densities and sizes from different regions on a planet or moon with little or no atmosphere (e.g., Mercury, Moon, Mars, the Galilean satellites of Jupiter), we can estimate the order in which those areas last solidified in the planet's history. Then, by calibrating those crater densities with values for the areas of the lunar surface whose ages are known by radioactive dating of rock samples, we can assign absolute ages for those regions. (We must also correct for the difference in gravity between the Moon and the other planet, since this affects the efficiency of sweeping up meteorites onto the surface.) Such ages are far less reliable than direct radioactive dating, but in most instances, we have no other choice but to rely on this approach.

2.4 Superposition of features

We have another approach to tracing the history of events on a planetary surface which sounds even simpler than crater counting: the fact that newer (younger) features will occur on top of (or partially obliterate) an older feature. Although the principle is simple, it can be very subtle in practice. Even so, we can often reconstruct the chronological sequence of events on a surface in this way, and combine this independent information with crater density measurements to determine how the surface evolved over time.

For example, Figure 4 is a sketch of a hypothetical region on a Mars-like planet. The figure could easily cover an area of about 100 x 100 km. North is to the top.

The following features are visible:

A crater of moderate size

B a large crater with a deep irregular rim

C a small crater

D a rift fault cutting along the surface from southwest to northeast

E several scattered craters

(which we will assume in this case are the same age)

F a chain of craters similar to those seen on the Moon

(probably left by a disrupted asteroid or comet like Shoemaker-Levy)

G a volcano

(whose last eruption produced a dark lava flow to the west and north)

Notice that crater A is over-top of the rim of crater B. Crater B has obviously been disrupted by rift fault D, but crater chain F has not been. Features A and D are both younger than B; F is younger than D.

Q1: Try to list the features A - G in Figure 4 in chronological order, from youngest to oldest. Some features may have a range of possible ages in your listing. Justify ranking them the way you did.

Figure 4: Using superposition of features to establish the chronology of events on a surface. Features labeled A - G are various craters, rift faults, crater chains and a volcano which occurred at different times. Can you place them in order from youngest to oldest?

2.5 Reminders of home

In Viking orbiter images of Mars, Magellan radar images of Venus, and Galileo spacecraft images of the moons of Jupiter, we find many features reminiscent of geological and other processes on the Earth. Mars has sinuous valleys which were almost certainly created by flowing water at some time in its past. Io and perhaps Venus have active volcanoes; Mars has volcanoes similar in form to those which created the chain of Hawaiian islands. Europa has ice floes like the terrestrial Arctic.

Much of the science of planetary surfaces is based on extrapolating our know ledge of familiar geological and erosion mechanisms on the Earth to our snapshots of these other worlds. In making these comparisons, one must allow for how the gravity, surface temperature, rock composition, etc. differ from conditions on Earth.

3. Using Netscape® and the Web as scientific tools

In the following exercises, you will take advantage of the considerable resources of the World Wide Web (WWW) to obtain high-quality images and data on the terrestrial planets to apply the techniques described in Section 2. The software used for this lab - PLANET; (the PLAnetary NETscape® interface) - will remain part of the ASTR 101 computer menu for the rest of the term so you can take advantage of it as a tutorial/study aid on Solar System course material.

It is also available remotely at the site http://www.astro.ubc.ca/test/planets.html so you can use it at home if you have a computer equipped with *Netscape®*.

When you sit down at the computer terminal in the lab, double-click on the ASTR 101 folder. In the menu of programmes, double-click on the icon labeled "Planetary Surfaces".

This will activate *Netscape®*, a Web browser that is designed to link to various sites on the World Wide Web and display the text and graphics located at those sites. You will be automatically connected to the home page of the Planetary Surfaces Lab. This is a site designed jointly by Doug Bilesky (a teacher and a graduate student in the Faculty of Education) and your instructor, Jaymie Matthews (a misfit in the Department of Physics & Astronomy), especially for use in ASTR 101.

An example of a PLANET screen is shown in Figure 1. By using the mouse to click on various menu items, you are automatically connected to pre-selected Web sites maintained by NASA, the Canadian and U.S. Geological Surveys, the Jet Propulsion Laboratory, the U.S. National Volcano Observatory, and other space/astronomy organizations. Depending on the amount of "traffic" on the Internet, it may take up to several seconds or a minute to connect to a particular site, so please be patient.

Within a given site, there are often options to enter choices (e.g., latitude and longitude coordinates on an interactive map of a planet) or to click on images, icons or high; lighted text to connect to further sites or see more details.

Figure 5: The Mars page of the Planetary Netscape® interface. The real screen is in full colour.

At any point, you can always return to a particular page by clicking on the appropriate item in either the vertical or horizontal menu bars. Netscape® itself has a horizontal menu bar at the very top of the screen but you will not need to use it in this lab. In fact, it is a good idea not to enable any of the Netscape® options from that top menu bar. For example, enabling the `Location' option in Netscape® will reduce the size of the window - making it necessary to scroll the screen more than usual - and only show you the address of the PLANET home page, which you already have.

4. The PLAnetary NETscape® interface

You will see a menu bar running vertically down the left-hand side of the screen. If you click on any of these menu items, you will activate a new sub-menu running horizontally across the top of the screen. The main menu items and their contents are listed below:

Introduction This contains the text of the instructions you have in your hand right now.

Overview General data about each of the four terrestrial planets; displays of planetary orbits; comparative information about volcanism on those planets; a glossary of planetary science terms; history of Solar System exploration; an interactive quiz on planetary science

Mercury General information; surface features; Mariner 10 space probe explorations; animations depicting the formation of Mercury and the Caloris impact basin on its surface

Venus General information; topography; 3-D perspective views of terrain; craters; volcanoes; Magellan space probe explorations via radar mapping; Venera probe views of the Venusian surface; Mariner 10

Earth General information; interactive map of the western United States photographed from orbit; view of the Earth from space from any angle; volcanoes; images of terrestrial impact craters

Mars General information; various maps of the surface photographed by the Viking orbiters; volcanoes; surface images from the Viking landers; cratering; Mars Today (the daily orbital position of the planet and local weather conditions on Mars); evidence for Life on Mars?

Moons of the inner Solar System Table of information on moons in the Solar System; the Martian moons Phobos and Deimos; The Earth's Moon. (Note that Mercury and Venus have no moons.)

Current events Information about various current or planned space missions (e.g., Galileo, Mars Pathfinder); studies of Martian meteorites on Earth (including arguments for ancient bacterial life on Mars); a calendar of space-related events; a tool to locate planets in their orbits and in the Earth's night sky

Please Comment With this feature, you can e-mail questions, comments, suggestions and/ or criticisms on this lab to Jaymie. Please include your Lab Section, date/time and T.A. name, but your own identity remains anonymous.

Search Various search engines used to find information on the Web by looking for key words, phrases or subjects. Examples of popular search engines are: Lycos, Alta Vista and Yahoo! This allows you to expand beyond the pre-selected Web sites used by PLANET and encompasses all possible subjects, not just Planetary Surfaces.

You will use these data resources to make the measurements and find the information required for the exercises below.

5. How old are various Martian landscapes?

5.1 Crater densities

As explained in x2.3, one of the only ways scientists can estimate the age of a planetary surface from afar, without having actual rock samples for radioactive dating, is to count the number of craters per unit area. This method is effective for a planet with no or very little atmosphere, where erosion and weathering processes are not significant. Mars, with an atmospheric pressure only 0:007x that of the Earth's at sea level, is an acceptable but not perfect candidate for this approach 1.
1 The wind speeds on Mars are very high, as you will discover for yourself later in this lab, so erosion of craters with time is not a negligible factor.

Select ``Mars" on the vertical menu bar and ``Maps" on the subsequent horizontal sub-menu. Click on the ``Multi-scale Map" option. This will activate an interactive map tool, which allows you to examine different portions of the Martian surface photographed by the Viking orbiter probes. You can select the latitude (between +47.5deg [north] and -47.5deg [south]) and the longitude (from 0deg to 360deg) and the resolution of the image in pixels per degree. (A pixel is a single element of the digital image.) Each image you call up from the map will have a size of 512 by 512 pixels. Do not change the image size since you will want every image to cover the same physical area on the Martian surface. By selecting a resolution of 32 pixels per degree, each image will be a square approximately 1000 km on a side. Therefore, you'll be examining a million square kilometres of the surface of Mars each time.) You also have the option to click on any part of the photographic map of Mars shown on this page and it will display an enlarged view of that region. You may wish to explore the gigantic Martian volcanoes and canyons in this way after you've completed the main parts of the project.

Choose a resolution of 32 pixels/degree, image size of 512 x 512 and a ``Browsing Option" of ``Return New page..." (which will display the image on the screen). Go to a latitude of +35deg and a longitude of 35deg and click on ``submit". Note that the screen menu will update to the next highest resolution of 64 pixels/degree. Don't be alarmed; your image will have the resolution you chose, but if you click the mouse on the image, you will automatically zoom in to 64 pixels/degree. In a few moments, a black and white image centred on those coordinates will appear on the screen. This is an area close to where the Viking 1 lander touched down in 1976.

Q2: Count the number of craters greater than about 20 km in diameter. (Remember that the length of each side of the image is about 1000 km.) Now go back to the main ``Maps" option, reselect the Multi-scale Map, and go to a latitude and longitude of [+35deg , 240deg] at the same resolution and image size. This corresponds to the Viking 2 robot-landing site.
Q3: Repeat your crater count for this region. Go to a latitude and longitude of [-40deg , 330deg]. This is a rugged highland area of the Martian surface.
Q4: Count the number of craters 20 km in diameter and greater in this area. Finally, bring up an image of the Mars Pathfinder landing site around coordinates [+19deg, 33deg]. This is believed to be part of a Martian flood plain, a place where liquid water was temporarily thawed from the permafrost and flowed freely on the surface for a brief time.

Q5:What is the crater count for the Pathfinder site?

Q6:Since the four images you've examined cover the same surface area (1000x1000 km = 106 km2), your crater counts all represent crater number densities in units of # = 106 km2. Which is the oldest region based on the amount of cratering? For each of the other three regions, calculate the ratio of its crater number density to that of the oldest region.

These crater density ratios tell you something about the relative ages of those parts of the Martian surface if you know something about the history of bombardment since the planet's crust first cooled and solidified. If the impact rate were constant throughout time, it would be simple to translate a crater number density into the age of the surface: you'd just divide the number of craters by the cratering rate per year to get the number of years that have elapsed. Unfortunately, nature is more complicated. Even if we make the assumption that Mars suffered the same kind of bombardment by asteroids and meteoroids as the Earth and Moon, we must take into account the fact that the cratering rate has changed over time. The history of impact rates in the Earth-Moon system is given in Figure 2; we will use this to estimate the relative ages of the four regions of Martian surface you have examined. What we need is an idea of how many craters would accumulate over a certain period of time, given the varying cratering rate in Figure 2. It's a bit like the weather statistics for rainfall. A meteorologist can tell you how many mm of rain fell on a particular day, but people often want to know the total amount of rainfall that has accumulated so far in the year.

In the following questions, you'll construct a graph of the cumulative meteor-fall for the Solar System during most of its existence.

Q7: First, draw a smooth curve by eye through the data boxes in Figure 2.

Strictly speaking, if we were to use this to determine the number of craters on a surface after a certain amount of time has elapsed, we would have to integrate that curve from time 0 back to the age of the surface. Since we try to avoid calculus in ASTR 101 (not wishing to send some of you into math-induced catatonic shock), we'll instead perform a crude approximation to this integration.

Take the smooth curve you've drawn, read off the relative meteoric impact rate at intervals of 0.25 Gigayears (1 Gyr = 109 yrs = 1 billion yrs), and make a table of time before present vs. impact rate. Go back as far as the time of planet formation. Leave room for three more columns. (To read impact rates from the left-hand logarithmic scale, the fine tick-marks above each thick tick-mark indicate values which are 2, 3, 4, 5, 6, 7, 8, and 9x the value of the thick tick-mark below. You may also use the log(rate) scale on the right, and convert that number into the rate by taking 10 log(rate).)

Q8: You now have a table of impact rates sampled during relatively short intervals (compared to the age of the Solar System). Multiply each number (which represents number of impacts per time) by the time interval (0.25 Gyr) and you have a rough estimate of the number of impacts during that interval. Enter these values in the third column of your table.

In this case, these numbers are scaled by the current impact rate (which you don't know) so the absolute values don't mean anything. But we can use the relative values since we'll be comparing one part of the Martian surface to another.

Q9: For each time in your table, add all the values in the third column up to and including that time and record the sum in a fourth column, labeled "Raw Cumulative Impacts". Start from zero and work up to an age of 4 Gyr. (For example, at age 1 Gyr, you would add the values at times 0, 0.25, 0.50, 0.75 and 1.00 Gyr, and enter this sum in the table.)

Q10: Since the absolute numbers in column four have no meaning, just their relative differences, you must normalize the data. Take the value for the time of 4 Gyr, divide each number in column four by this value, and record the results in a fifth column labeled "Relative Cumulative Impacts". (The values will range from 1.0 at 4 Gyr to 0.0 at 0 Gyr.) Finally, plot your relative cumulative impact values against time and draw a smooth curve through the points.

Assuming the oldest region you've examined dates back to a 500 million years after the formation of Mars itself (i.e., about 4 billion years ago), you can use your graph to estimate the ages of the other three regions. You'll compare the accumulated number of craters in one region of the Martian surface to that on the oldest part of the surface.

Q11: Take the crater number density ratio you found in Question 6 for the Viking 1 lander region. This number tells you the fraction of impacts that have accumulated at the site compared to a surface 4 Gyr old. But this is just the quantity you have plotted in your graph. Find where the curve has the Viking 1 site ratio and read off the age. This should be the approximate age of that part of the surface, to a precision of 250 million years.

Q12: Repeat for the Viking 2 and Pathfinder landing sites.

Q13: Speculate on why one part of the surface is so much younger than another on Mars. Search the Mars Pathfinder Home Page ("Current Events" menu) to see if you can find information about the presumed history and age of the Pathfinder landing site to check your result and conclusions.

5.2 Superposition of features

In S2.4, you were asked to list chronologically features in a sketch of a planetary surface (Figure 4), based on how some features overlap others. We can now apply this same principle to a real section of Martian terrain.

Use the Multi-Scale Map to view a region centred at a latitude and longitude of [+30.5deg , ~58deg], at a resolution of 32 pixels/degree.

This image, which includes regions on Mars known as Lunae Planum and Chryse Planitia, contains examples of most of the major geological processes that have shaped the surface of Mars. The largest crater near the centre of the image is about 100 km across and represents an event from the era of major impacts in the early history of the Solar System. There are channels which are remnants of enormous lava flows (evidence of volcanic activity) and also surface fractures (indicative on crustal tectonics as seen on the Earth). One can even see signs of dust spread behind small craters by high-speed winds.

Q14: Make a rough sketch of the image on the screen and label the major examples of surface features that you can distinguish. Using the principle of superposition, list the features in order of decreasing age as completely as possible. Justify your reasoning.

Q15: On your sketch, show with arrows the directions of the prevailing winds in various parts of the channel floor.

Q16: Like the other Mars images you have examined, this is a composite of several Viking orbiter images taken at various times. How can you tell this?

6 Martian weather

As you have seen, some parts of the Martian surface do show evidence for erosion by strong winds. (This is not enough to wipe out the largest craters you used to estimate ages earlier in the lab but is enough to affect smaller craters and surface features.) Despite its thin atmosphere, Mars does possess a vigourous weather system. In fact, you can use the Web to obtain a daily weather report on the Martian surface.

The Mars Pathfinder has a weather station that provides local temperature, barometric pressure, wind direction and strength. Also, the two Viking landers provided extensive meteorological information which was used to forecast Martian weather patterns.

Go to the "Mars Pathfinder" site and find today's weather report for the landing site.

Q17: What are the current temperature, atmospheric pressure and winds at the site?

Click on "Mars Today" and read the explanatory material. Scroll down until you can click to see a complete display of (i) the planet's orbital position relative to Earth, (ii) its angular size at its current distance, (ii) the hemisphere of the Martian globe facing Earth, and (iv) the weather on Mars on the current date. (This display overfills the window and you must scroll to the lower right to see the weather globe.) The weather map is a globe with false colours indicating the local surface temperature and arrows representing wind speeds and directions, based on projections of Viking data.

Q18: What is the top wind speed (in m/s and kph) in the Martian atmosphere on this date? What are today's high and low temperatures (in Kelvin and in degrees Celsius) on the sunlit face of Mars?

The principal source of heat for all the planets is the Sun. We should be able to calculate the surface temperature of a planet based on the amount of sunlight falling upon it. The amount of solar radiation E falling on each square metre of a planet's surface per second is proportional to 1=d2, where d is the distance of the planet from the Sun. If all that energy were absorbed by the surface and reradiated as heat, the surface temperature (in Kelvin) would be proportional to E1=4. (You will learn the basis of these statements in upcoming ASTR 101 lectures on the laws of light and electromagnetic radiation. Feel free to get a sneak preview by looking ahead in Chapter 5 of the text; pp. 84-87.)

Q19: Look up the semi-major axis of Mars' orbit in A.U. using the general summary available in the "Overview" menu. Using the relations between (i) solar energy and distance from the Sun and (ii) energy and surface temperature, what would you expect to be the ratio of the average surface temperatures (in K) of the Earth and Mars? What is the actual ratio? (Assume a reasonable mean temperature for the Earth based on the extremes in climate on its surface.) These ratios probably won't agree. Why not; i.e. what important factors have we left out of this calculation?

7 Fact-finding in the inner Solar System

The Web is a valuable information resource, used by professional scientists and casual `surfers' alike. In the following exercise, you are asked to find basic data on the Web. It is important that you include in your answer the particular Web site and page in which you found the information; sometimes different sites give conflicting data. Try to cross-check your results against more than one source whenever possible.

7.1 Volcanoes

Q20: Using the information on volcanoes available in various menu items, compare the sizes (diameters and heights) of the largest volcanoes on Venus, Earth and Mars.

Are there volcanoes on Mercury?

Q21: What is the estimated number of volcanoes on Venus? Are any believed to be currently active?

7.2 Life on Mars?

In 1996, NASA scientists announced what they believed to be evidence for ancient life in a meteorite (ALH 84001) found in Antarctica.

Q22: How do we know the rock came from Mars and how did it get to Earth?

Q23: What are the main arguments for and against the theory that biological activity took place in that rock?

Conditions on Mars today are not exactly hospitable to life as we know it, but the Martian climate may have been more favourable in the past.

Q24: What evidence is there that flowing water may have existed on Mars in the distant past? (Some relevant information may be found under "Specific Surface Features".) Using the topographic maps of Mars, estimate the fraction of the planet's surface that might have been covered by oceans to a depth of about 10-15 km if liquid water were plentiful on that world.

8 Leaving the PLANET

If you have any time in the lab after you have finished the required exercises, please feel free to use PLANET to explore other aspects of the terrestrial planets and moons. Finally, when you are ready to leave the lab, please shut down Netscape® by either:

clicking on { X } at the extreme upper right of the screen; or
clicking on "File" at the extreme upper left and then choosing "Exit".

-end-