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Technology in education

Renee J. Reinhold

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Renee J. Reinhold
Capstone Abstract

Technology In Education

The Teacher Education Program at Northern Illinois University is typically divided into two sections: the methods courses/teacher preparation semesters, and the actual sixteen-week student teaching experience. This unintentional separation often leaves the students in the preparatory semesters apprehensive about what is actually going to happen when they are student teaching. The student teachers themselves also feel somewhat alienated from the program due to being off-campus.

This research project presents a model of how to connect the two divided segments of the Elementary Education program through telecommunications. Students from CIEE 344 were used to complete the model. These pre-semester students searched tools available on the internet to coincide with a thematic unit I was planning for my third grade student teaching experience.

In the end, this model grew into not only using the information sent via electronic mail, but also evolved into a technological experience for the children. The third graders learned the basic searching mechanisms on the internet to complete cooperative reports on planets which were shared with the class.

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Technology In Education

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Technology in Education

I. Background

Education in today's society is typically more reactive than progressive, careful than creative, and often times characterized by hasty short-term solutions rather than solutions which are made considering long-term implications. This resistance to change, suggested to better the curriculum as a whole, is a detriment to the nation's educational system. In an age where computers and technology dominate nearly every facet of human life, the adaption of information systems is not only a good idea--it is a must..

A few short years ago, the term "technology" was virtually synonymous with the word "computer.". The drastic increase of businesses who relied exclusively on computers caused the schools to go into a panic (National School Board 1989). If students graduating from high schools and colleges nationwide were expected to use and contend with computers on a day-to-day basis, they needed to be exposed to this hardware before their entrance into the "real world."

As a result of this panic, school districts invested a great deal of money into their information systems. Computer labs erupted, and some school districts required basic programming as a graduation requirement (National School Board 1989). Unfortunately, computers in schools, at this time, were used exclusively as tutorials, drill and practice programs in school subjects, and as word processors. The main reason, of course, being that technology at this time was nowhere near the scale it is today. One could not easily use the computer

as a searching tool for information, or a way to connect people throughout the world.

This does not mean that students necessarily needed to *have* more information to be successful, but that students needed to be able to access, and use information systems. Just as the shift from an industrial society had affected the workforce and the economy, so had it affected education (National School Board 1989). To ignore the fact that technology is an important working component in today's world would not only be ignorant, but a disservice to the preparation of children to be competent members of society.

According to the National School Board Association, technology can enhance and expand curriculum choices, encourage sharing of resources and expertise among school districts, decrease duplication of low-incidence courses, and involve the community in life-long education (1989). The key to a successful approach incorporating technology in the curriculum is to provide children with a wealth of learning opportunities. Computers in schools should be used to their full potential--integrating them whenever possible. This will prevent students and teachers both of becoming isolated and alienated from technology. People are often frightened or wary of things they do not know how to use or implement.. It is crucial not only to teach students, but also to teach the teachers how to use technology constructively.

As stated in Technology and Education Reform, many uses of technology either support the classroom status quo or occur at the margins of education (as enrichment, for example, or in classes for the gifted) rather than in the mainstream academic program (Means 1994). This suggests that, in most cases, technology in the classroom is not used in a constructive realistic way.

They have primarily been used to supplement the pre-existing curriculum rather than being used as a fantastic resource for knowledge and active research.

In many ways this should not be surprising. Past history does suggest that when an innovative or new system is introduced a person's first impulse is to use that new system in the same as they used the technology it replaced (Means 1994). Based on this, it is no wonder that teachers and administrators are reluctant to utilize new sources. It would require not only a great deal of work in discovering how to use the systems, but the thematic units and curriculum plans would need to be changed to successfully to incorporate technology.

Computers and technology could be used in an active learning environment. In such a learning atmosphere students would be seen as active seekers of knowledge and information, rather than passive recipients of information. By interacting with information children will retain more and become genuinely interested in seeking out knowledge in an independent way. In support of this, there is now widespread agreement among educators and psychologists (Collins, Brown, and Newman, 1989; Resnick, 1987) that advanced skills of comprehension and experimentation are acquired not through the transmission of facts, but through the learner's interaction with content. Through active inquiry, children can become discoverers of information as opposed to mere "sponges" for knowledge.

These suggestions for the refinement of teaching and learning processes are based on findings which parallel a learning theory called *constructivist*, or *student centered learning* (Means 1994). In this model, the acquisition of knowledge is seen as an active problem solving process in which the child builds understanding upon their previous understandings to construct knowledge. Learning is not considered the mere transmission of information from the

educator to the student.. Brown, Collins, and Duguid suggest that the process of learning is shared, developed, and refined through peer interactions (1989).

Constructivists generally believe that what children learn depends greatly on how they learn it. That is, when students are presented with new information that has relevant meaning in their everyday lives, that information is retained. If children acquire information in a context which integrates it with meaningful activities, they will probably be able to use the information as a tool in the problem solving process.

Technology can play an integral role in the integration of information in meaningful activities. It can enhance the processes of higher-order thinking and problem solving strategies by providing an authentic means to knowledge discovery. Since technology provides society today with much of its information it makes sense to incorporate it into school projects. That is what people would do on-the-job.

Presenting children with authentic and challenging tasks rather than the traditional means of instruction will provide an exciting, stimulating learning environment for students as well as teachers. It seems that too often schools break learning down into isolated subsets of information which seems to have no cohesive connection to the real world, let alone the children's daily lives. This practice will eventually demotivate students, and make it highly unlikely that the children will transfer what they have learned in school to their everyday knowledge (Means 1994). Given complex and challenging assignments will allow students to take on a more active role in their learning.

Collaborative learning is an excellent way to incorporate computers. Working cooperatively encourages children to become active, reflective thinkers. Students of different ability levels can also work together in collaborative

learning, thus allowing them to commensurate their skills. In the process of collaborating students gain experience in negotiating the purpose of their work, the meanings of the terms they use, and so on. They have experiences that mirror the activities of professionals working together (Means 1994). The process of learning how to work with a group is a valuable thing to possess--this skill will be used in the real world.

The phrase "real world" is one that is often spoken in the educational world. It seems this buzz word has taken over many curriculums and school districts across the country. Good learning, we are led to believe, prepares children for the "real world," and has a variety of "authentic" experiences. This sounds wonderful, but what exactly is "real" or "authentic?"

These terms do have several interpretations. Sheingold, Malcom and Roberts state, perhaps the key to students' learning and involvement is not so much whether the task or project is real-that is, whether its outcome is genuinely unknown or someone can use the results-as whether the task is sufficiently complex and engaging to elicit students' sustained efforts (1990). Usually, authentic tasks are those which actively involve students in the acquisition of knowledge. Group scientific exploration and discovery is an excellent way to provide students with real-world applications and experiences. This approach holds the students accountable for locating and teaching the information to one another.

Technology is a part of what it means to provide authentic learning experiences in education. It can provide us with tools to carry out the everyday functions in the classroom. In science education, for example, it can help children observe, measure, analyze, communicate, and test hypotheses (Sheingold, Malcom, and Roberts 1992).

Computers lend themselves nicely to communication through cooperative learning. Unfortunately, most schools have no choice in grouping the students on one computer due to a lack of resources. Despite this) computers can be used to supplement information learned in the classroom, or to start students in the right direction. As discussed in Technology and Education Reform, computers and communication programs and devices do not provide adequate instructional value in and of themselves. Instructional value lies in the educational activities that use the tools and communication devices, and activities must be planned by the teacher (Means 1994).

In other words, using technology as the *only* source of information for children is an inappropriate way for children to learn. The best teaching approaches involve many different strategies and methods to teach content.. Technology is not a substitute for good teaching, but a way to ensure that students are being exposed to situations that are common in the working world.

One also needs to plan extensively to make a computer or technology experience successful. Careful preparation is a must.. Not only does the teacher need to educate themselves on the programs and tools, but they have to spend time teaching the students how to use the different materials. Only after the students master the procedures can they move on and experiment with the different capabilities.

Research within the past ten years indicates that, over a period of time, schools realize the need to integrate computers into their curriculum (Becker 1989). It also seems that teachers go through certain stages upon the adoption of the new technology systems. As outlined by Roberts (1992), these stages are:

1. ~, ~, ~ -Beginning awareness

-Spread of acceptance

-Rise in comfort level

-Impact on the curriculum

The **beginning awareness** stage starts off the stages of technology awareness. This process begins when a slightly avant-garde educator purchases and uses a small amount of machinery in their classroom. Usually, this use of the new equipment causes the school to make similar purchases to accommodate the needs of all the classrooms. As more money is spent, more people become familiar with computers and their potential role in the classroom.

The next stage called, **spread of acceptance**, as coined by Roberts, involves the escalating awareness that the staff needs to be trained to use the technology effectively in their perspective classrooms. This may begin as one teacher teaching a small group of their peers, and may end up as teachers enrolling in college courses to learn how to implement the technology. As the education level rises there is a general feeling of comfort in using the systems.

Rise in comfort level is a phrase used to describe the ease with which the staff is using the technology. Teachers are generally supportive of one another, and collaborate on how and what to do with the systems, now that they are familiar with the bells and whistles.

The last stage, **impact on the curriculum**, describes what the school does to accommodate their new systems. It explains how a teacher moves from learning about an innovation to changing the way that they think about the learning process. This can be illustrated in a subtle move from teacher-directed learning to active-student learning, or in the way information is presented.

Of course the goal in this four-step model is to accept computers not as just a supplement, but as a way to change instruction. Instead of a passive,

inactive role in learning, students can become active seekers of knowledge in a child-centered classroom. Learning in this way offers information to be incorporated in a meaningful way into the child's pre-existing knowledge base. This may enhance retention and motivation to learn.

In the past few decades the task of learning how to use and implement technology in every day life has become harder.. Change in what is considered "new" is modified so rapidly that what educators teach children in their classrooms no longer applies in their adulthood. Each generation must be flexible in their ability to adapt and use new systems because society will be changing. More powerful computers will be manufactured, and people can either adapt to the changes, or remain ignorant to the technological advances.

Either way, educators must remain on the cutting edge of what is used in the mainstream of society. The obvious reason being that teachers are responsible for the education of the future members of the workforce, and to prepare these pre-service workers for the "real world" their in-school experiences should be a reflection of what they may run accross as adults. To ignore this would be a disservice to the education of children everywhere.

II. Research Model

In fulfillment of my Capstone Honors Project, I decided to construct a model which would connect the Teacher Education Program at Northern Illinois University with the actual student teaching experience by means of telecommunications. This model was slightly more complex an undertaking than

I had anticipated, and required a great deal of planning and communication. In this model, the processes used would determine the results.

This model was created in hopes of making the two segments of the Education Program more cohesive in nature. Throughout the Teacher Education Program the pre-service educator hears much about the final sixteen-week student teaching experience. Much of what is heard is fact, some of it fiction, but generally all of it remains a virtual mystery until the pre-service teachers dive into student teaching themselves.

Having been through the first two professional semesters, one begins to wonder if there could be a way to connect the in-class learning with what is actually going on in the schools. Of course the clinical observations give students a taste of what teaching is, but these observations do not require extensive planning for thematic units with long-range outcomes. Actually pairing up with a class for a semester during a student teaching experience would be an excellent way for these students to see what is involved in long-range planning. These second professional students could also send lesson ideas and teaching strategies they have developed to the student teacher to test out in the classroom. This would show the students how what they plan is actually implemented in the classroom.

In addition to benefiting the second professional students, this model would also enhance the student teacher's teaching styles and lesson content, along with affecting the knowledge gained by the students. Since most student teaching experiences occur in an off-campus setting, there is little opportunity to take advantage of the resources pre-service teachers have on-campus. Science labs and learning centers are just two of the things available to on-campus students. Once student teachers begin their sixteen week experience there is

little chance, if any, to return to the campus and retrieve these materials. The second professional^{5~M} students could act as "information seekers" for the student teacher, not only on facts, but on lessons and unit ideas as well.. The children in the class would benefit by getting the planning and preparation time of not just one individual, but thirty people.

After deciding on what the Capstone would be about, a process needed to be determined to achieve the desired results. There would be three roles in this model: information seekers, active learners, and the facilitator.. As information seekers, the second professional students would be responsible for gathering information on stated topics, investigating hands-on activities, and seeking out the answers to questions generated by students. The students would serve as active learners, in which they were responsible for the organization, collection, and observation of data taken, as well as being responsible for the generation of relevant questions. As facilitator, the student teacher would need to gather and sort the information sent, and integrate it into the classroom instruction. Each person in the model had an active learning role.

The problem still existed--how would communication and transformation of information take place? Telephone and mail surely could have worked, but these means were costly and highly ineffective. Instead, the student teacher could communicate with the pre-service students through electronic mail.. This process is both fast and cost-efficient. . Also, the pre-service teachers could "surf" the internet or the World Wide Web for needed information, and send this information via electronic mail..

The question then came: Which second professional students are used? For this model students from CIEE 344 (Science Methods for Elementary Education) were used as the second professional students. Since these

students were enrolled in a science education class, it seemed appropriate to center this model around science instruction.

While I was going to be student teaching, the science unit covered was going to be "Space." Therefore, I electronically mailed the CIEE 344 students that I needed information ⁶⁷ on space. They then would actively look for things on the internet and in the Science Lab which would relate to space. I also electronically mailed these students copies of the children's generated questions, so they could begin to look for answers to them. See Figure 1-Appendix (A detailed unit overview of Space is provided in section IV)

The steps outlined above was the actual framework for this Capstone project.. Some of what was proposed was modified, some of it was kept consistent.. As mentioned earlier, the processes in this model were to determine the effectiveness of the results.

III. Student Teaching Information

I received a student teaching assignment in Palatine Community Consoliated School District Fifteen. I was extremely excited upon leaving the school on the first visit because the school seemed to be heavily reliant on using collaborative learning and hands-on activities in solving problems. Every facet of the curriculum revolved around science and social studies, which was staggered every six weeks. (For six weeks the children learned about social studies, then upon completing that six-week unit, the students received six weeks of science instruction.) The only textbooks used on a regular basis were the math books, and even those were supplemented with problem solving opportunities as well as manipulatives.

This promised to be a fantastic learning experience! Creativity in planning was a must for every teacher in this school.. Since there were no manuals from which to plan, it was necessary to think of innovative and stimulating activities independently. Content materials needed to be sought out by each teacher on their own.

In the way of technology, this school was well-equipped with up-to-date materials. Each teacher had a Power Macintosh with a CD-ROM for their personal classroom use. These computers had Microsoft 6.0, Claris Works, Scholastic Super Print, and many educational programs which enabled them to create and distribute newsletters and spreadsheets. Accompanying each computer was a black and white Style Writer printer. Each classroom had an IBM 286 computer with a dot-matrix printer. This computer contained mostly tutorial and drill and practice programs, and possessed word-processing capabilities.

The resource center had fantastic capabilities. In a large section of the center were 30 IBM 286 computers (the same ones available in each classroom). Again, these programs were used to help children master skills, or for word processing. This lab was available to any class at any time. In the front of the lab were nine computers, five of which were Macintosh, the other four IBM. All had ^{uC} hookups and access to the World Wide Web, as well as America On Line, and Prodigy. These machines also could be used for electronic mail. Unfortunately, the children are not allowed to use the World Wide Web or electronic mail, due to policy issues within the district. However, the children are permitted to use America On Line to locate information.

IV. Procedures

As I began the thematic unit on space, I received several documents from the students of CIEE 344 (See example, Figure 2-Appendix). The things sent to me were great sources of information, and peaked my interest on the kinds of things I would be able to find on the internet myself. I began to "surf the net" for any useable information I could find on space. I was especially interested in finding photographs of the surfaces of different satellites, since teachers were forbidden to use textbooks. I spent a great deal of time searching under different subheadings off the server, *Yahoo!* as well as the World Wide Web.

It did take me about a week to become familiar with the basics of the different programs and searching mechanisms. I was just learning myself the ins and outs of the information superhighway, and the procedures were just as foreign to me as they were to many children in the school.. However, I thought it was an excellent resource, as well as being the next big thing to sweep education, so I stuck with it.

As my unit continued, I began to incorporate things I found on the internet into my daily lessons (See figure 3-Appendix). The more I showed the children the different items I found, their interest began to surge in the capabilities of the internet.. Unfortunately, I had to explain that they were not permitted to use the Web, or the internet, for any types of searches. This realization was met with a deprecating amount of moans followed by comments such as, "We never get to do anything *really* fun!"

I began to wonder about this issue more and more as the days went on. The more pictures and charts I showed to them, the more desirous they became of seeking out the information themselves. I figured that there had to be a way

to get around the policy somehow, so I met with the resource teacher and inquired about reaching information through America On Line. Finally a door opened. She informed me that NASA had the exact same page for the World Wide Web as was available on America On Line. This news was great--the children were permitted to search for things on AOL, so I could actually let them do what they seemed highly interested in, and provide them with an authentic classroom assignment. .

I decided to incorporate this computer experience into the information finding portion of the planet reports I had them completing. The assignment was for them to research one of the planets, in cooperative groups of three, create visual aids, and teach the information to the other students in the class. I made available for them books, charts, and pictures, but part of their research was to get information from America On Line to coincide with their planet.. (See Figure S-Appendix) I especially encouraged the students to locate pictures of their planet taken from satellites.

This program worked very well.. I took them to the resource center in groups of three while my cooperating teacher supervised the others. At first I modeled how to conduct a search, and how to narrow down a broad topic such as space. After that, it was up to them to locate the appropriate sources. The children were astonished at the amount of information available to them. An entire group was willing to give up their lunch recess just to be able to search for more information.

In all, I saw a dramatic rise in enthusiasm for learning when I let the children become the researcher, teacher, and learner all in one. Instead of a teacher relaying the information to them, they were given the responsibility of

locating information, and teaching it to their peers. This was, by far, the best teaching experience I undertook as a student teacher..

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As a teacher one can read all the research and books they can about how important it is to actively engage students in learning. It is simple to agree with what the "experts" have to say about learning, but to actually see the results first-hand is a totally different experience. It may take a great deal of planning and research to involve the students in active research, but the time is well-spent.. Not only do I think the students enjoyed this project, but they also learned more from researching and investigating themselves.

As mentioned in Section I of this paper, providing children with authentic tasks is extremely important.. In the real world today, people look for information in hundreds of different places. Until this project, twenty out of twenty-six students in my class had *never* used the Internet as a source of information. I feel that I have provided these children with a beginning knowledge of the capabilities of technology today, however, it is up to the educators that follow this grade to build upon that foundation.

V. Unit Overview

The space unit was an seven-week long experience for the children. Due to the overwhelming amount of information available on the topic, I decided to break it up into three sub-units. Two weeks were spent on the moon, two were spent on the sun and stars, and three were spent on the planets. This breaking down of the information made it a little easier for the children to follow. On Fridays, art takes the place of the allotted time for science, so the weeks are actually four-days long. Also, there were a few institute days, in which science

topics were not covered. Science instruction was typically in the afternoon for about thirty-five minutes, but really, the children were learning about space in all subjects. The outline presented here reflects what was done in the thirty-five minute "science time."

Weeks one and two:

Day one: Read How the Sun and Moon Got In the Sky (fairytale). Discuss unit plan with children (expectations, general plans). Generate questions they have about the moon through KWL (Know, Want to Know, What I Learned chart) on moon (See Figure 4-Appendix).

Day two: Discuss questions formulated about the moon. Explain moon journals to students. (They were expected to observe the moon on a nightly basis, and record both what was seen as well as written observations) Show students Figure 3 (In Appendix). Discuss "Man on the Moon." Lead in to discussion of moon's surface features. Show students pictures of Clementine exploration (Figure 2-Appendix). *Day three:* Discuss what students recorded the previous night.. Venn Diagram comparing the surfaces of the earth and the moon. Sharing time.

Day four: Discuss gravity. Ask students to demonstrate how astronauts look when they walk on the moon--discuss reasons for this. Explain that the earth has six times more gravity than that of the moon. Participate in "Moon Jumping" (students record how many inches they can jump, and multiply their answer by six to see how high they could jump on the moon).

Day five: Introduce terms rotation and revolution to students. Demonstrate rotation and revolution to students (One student is sun, one is moon, one is earth). Have them rotate and revolve around one another (Have all children try).

Discuss phenomena such as seasons, and night and day. Check progress in moon journals.

Day six: Discuss observations of the moon so far. Lead students to say that they've noticed it changing shape from night to night. Read The Moon Seems to Change. Discuss phases, and reasons for moon changing shape.

Day seven: (Phases continued) Have students sit in a circle. Place a styrofoam ball, one side black, the other white, in the center of the circle. Have students draw the phase they see. When all students are finished drawing, have them hold up what they've drawn, and it will show all phases. At home: have students classify phases in moon journals. Show students the information the NIU CIEE 344 students located for them--this information was based on the questions the students formulated in the KWL. (Figure 1-Appendix)

Day eight: In partners have students create a fifteen question quiz with an answer key. This will be used, along with the moon journals, as an assessment tool.

Day nine Art: Have students create "Moon Rocks."

Weeks three-four:

Day one: Give students books by Seymour Simon on stars and, in pairs, have them locate the following information: star colors, star types, how stars were formed, sizes, and how stars die,

Day two: Allow time to research more information. Share with class. Show students computer-generated pictures of constellations taken from America On Line. Introduce the Northern Crown.

Day three: Read students "The Legend of Big Bear," discuss reasons constellations were named.

Day four. Discuss binary stars. Demonstrate using a ruler with a beach ball and a small styrofoam ball tied to it. At home: have students star gaze through a toilet paper roll, and count how many stars they see in ten samples. This information will be used as a math lesson in how to find averages.

Day five: Discuss sun--surface features and composition.

Day six: Discuss solar and lunar eclipses. Demonstrate with students, and discuss why this will not happen frequently.

Day seven: Students will take a twenty-point cooperative quiz on the sun and stars.

Day eight: Have students locate their astrological sign on the constellation map, and recreate it using stick-on stars glued to a piece of black paper. Then have students draw lines connecting the stars.

Weeks five-seven:

Day one: Divide students into groups to read Planets. Have them take down information they find interesting about each planet. Share glossaries found on internet. (Figure 6-Appendix)

Day two: Explain to students that they will be divided into groups of three to complete planet reports. Discuss expectations (visual aids, book research, America On Line time). Explain that they will be the "resident experts" on their given planet, and that they will be responsible for teaching it to the class upon completion of reserach. Share with children some of the information I found.

Day three: Take three planet groups to computer lab. (See Figure 5 for an example of things they were finding) Others: Research materials, library passes permitted.

Day three: Take three more planet groups to lab. Others: Research continues.

Day four. Take two planet groups to the lab. Others continue research. Upon return explain that on Monday the students will begin their "team teaching" to the class.

Day five: Mercury and Venus presentations.

Day six: Earth and Mars presentations.

Day seven: Jupiter and Saturn presentations.

Day eight: Uranus, Neptune, and Pluto presentations.

Day nine: Have students evaluate each of their group members participation, cooperation, and how "on-task" they were as a group. This information will be taken into account when grades are finalized. Discuss the information they gathered for their planet, as well as the others.

Day ten: Create planet chart, as a class, to compile and organize learned information. Each student should complete a chart, as well for their own reference.

Day eleven: Create paper-mache models of their planets.

Day twelve: Paint models.

VI. Conclusions

The children truly enjoyed the information in this unit, which is what made it so successful. Every student participated willingly in projects as well as demonstrations. The most fun the children had, however, came when I let go, and let their own curiosity take over and dictate their learning.

I do admit that I was terrified of letting the class do their own research. The apprehensiveness came from a fear that once I let them go, I would not be able to get them "back." I feared losing control. I think that is why I started out

slowly. The activities for the moon were slightly traditional in nature. Even though the children were given time to work with a partner, the activities were teacher-directed. In the stars segment of this unit, I let them do a little of their own research in the beginning, but the activities which followed were more teacher-directed. Once I saw that they were learning and enjoying finding their own information, I decided to give active research a try.

When I asked one of the more outspoken children in my class if he liked the planet research, he replied: "Yeah. I get bored listening all the time." What a truthful statement. . Doesn't everybody get bored of "listening all the time?" Engaging and interacting with information is an excellent way to learn. After this experience, I am completely convinced that children need time to explore their own curiosities on topics.

What this research proves is that children do acquire and retain more information when they are allowed to experiment with, and actively find, information. Using technology is an excellent way to provide authentic and challenging tasks to children. Through using computers in learning, children can gain experience and knowledge which will benefit them in both their present and future lives. Educators have the tremendous responsibility of ensuring that children receive an education which prepares them for a modern world. To ignore technology in the classroom would be a crippling disservice to students everywhere. Adequately prepared children need to be able to use technology as a resource if they are to be contributors in a world which is becoming highly automated.

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VIII. Appendix

FIGURE 1

The Moon

Some basic facts:

radius = 1738 km \approx 2000 km
compare to earth radius \sim 6000 km

orbit semimajor axis = 3.84 x 10⁵ km
So $a \sim 60R_E$

orbit period: 1 month
rotation period is the same: Man in the Moon always faces us.
density \sim 3300 kg/m³
compare to earth density \sim 5500 kg/m³

What about the Moon's atmosphere?

What do you suppose it is like inside?

What is the surface like?

What history does this suggest?

What are tidal forces?

What do the tidal forces do?

Where did the Moon come from?

The Moon's Atmosphere

there isn't any.
holding an atmosphere is a competition between gravity and temperature.

gravity isn't strong enough because the Moon's mass is so small. (roughly 1/100 of Earth's)
The Moon's Interior

Clues

density is 3300 kg/m³.
this is less than Earth's density of 5500 kg/m³.
so there must be more crust and mantle, less core.
[This suggests that the Moon didn't just accrete material from same rock supply as Earth.]

no magnetic field.
so no liquid Fe core.
only very mild moonquakes.
so no plate tectonics.

study of moonquake wave propagation indicates a crust about 65 km thick.
moonquakes most frequent at new moon and full moon
suggests they are from bending and stretching of rocks due to gravity of Earth and Sun.
centers of moonquakes go down very deep (to 1000 km)
so rock is brittle to that depth.

Resulting picture:

crust (65 km)
mantle, hard (lithosphere) to 1000 km at least
mantle, soft (asthenosphere) inward from there
core less than 700 km in radius (or else it would make the average density too high).
The Moon's Surface

Two main kinds of surface

maria.
highlands

Region near the lunar pole.

Images from Galileo spacecraft.
The far side has only highlands.

Various groups of astronauts have gone there.
Note the mountains in the background.
There are little craters everywhere.

Sometimes there are bigger craters.
Note the footprints.

Here are some more footprints.
The whole surface is covered with regolith = ground up rock.
What was that channel?
Here is is from space.
Presumably it is a crack in the lava flow.

There are big rocks too.

This region is called the Taurus-Littrow region.

The far side is pretty cratered.
Where did the Moon come from?

Collected itself at same time as Earth?
Then it should have same density as Earth.
Density is too low.
Popped out of the Earth's mantle?
Density could be right.
But detailed composition of rocks don't match.
Moon rocks relatively lacking in volatile elements.
"Just popped out" doesn't sound very likely.

Created in a collision?

Density could be right.
Composition could work: some of volatile elements lacking in Moon rocks could have been boiled away.
On the other hand, it seems to make the Earth rather special.
But why not? Venus and Mars don't have big moons.

My conclusion: we just don't know. But the collision idea seems promising.
The Moon

Luna

Moon Facts

The Moon is the only natural satellite of Earth:
distance from Earth: 384,400 km
diameter: 3476 km
mass: 7.35×10^{22} kg

Called Luna by the Romans, Selene and Artemis by the Greeks.

The Moon, of course, has been known since prehistoric times. It is the second brightest object in the sky after the Sun.

Due to its size and composition, the Moon is sometimes classified as a terrestrial "planet" along with Mercury, Venus, Earth and Mars.

The Moon was first visited by the Soviet spacecraft Luna 2 in 1959. It is the only extraterrestrial body to have been visited by humans (picture 4.3). The first landing was on July 20, 1969 (do you remember where you were?); the last was in December 1972. The Moon is also the only body from which samples have been returned to Earth. In the summer of 1994, the Moon was very extensively mapped by the little spacecraft Clementine.

The gravitational forces between the Earth and the Moon cause some interesting effects. The most obvious is the tides. The Moon's gravitational attraction is stronger on the side of the Earth nearest to the Moon and weaker on the opposite side. Since the Earth, and particularly the oceans, is not perfectly rigid it is stretched out along the line toward the Moon. From our perspective on the Earth's surface we see two small bulges, one in the direction of the Moon and one directly opposite. The effect is much stronger in the ocean water than in the solid crust so the water bulges are higher. And because the Earth rotates much faster than the Moon moves in its orbit, the bulges move around the Earth about once a day giving two high tides per day.

But the Earth is not completely fluid, either. The Earth's rotation carries the Earth's bulges get slightly ahead of the point directly beneath the Moon. This means that the force between the Earth and the Moon is not exactly along the line between their centers producing a torque on the Earth and an accelerating force on the Moon. This causes a net transfer of rotational energy from the Earth to the Moon, slowing down the Earth's rotation by about 1.48 milliseconds/century and raising the Moon into a higher orbit by about 3.5 centimeters per year. (The opposite effect happens to satellites with retrograde

orbits such as Phobos and Triton).

The asymmetric nature of the gravitational force is also responsible for the fact that the Moon rotates synchronously, i.e. it is locked in phase with its orbit so

that the same side is always facing toward the Earth. Just as the Earth's rotation is now being slowed by the Moon's influence so in the distant past the

Moon's rotation was slowed by the action of the Earth, but in that case the effect was much stronger. When the Moon's rotation rate was slowed to match its

orbital period (such that the bulge always faced toward the Earth) there was no longer an off-center torque on the Moon and a stable situation was achieved.

The same thing has happened to most of the other satellites in the solar system. Eventually, the Earth's rotation will be slowed to match the Moon's period,

too, as is the case with Pluto and Charon.

Actually, the Moon appears to wobble a bit (due to its slightly non-circular orbit) so that a few degrees of the far side can be seen from time to time, but the

majority of the far side (picture 2) was completely unknown until the Soviet spacecraft Luna 3 photographed it in 1959.

The Moon has no atmosphere. Recent evidence from Clementine that suggested that there might be water ice in some craters near the Moon's poles has

turned out to be inconclusive. But the possibility still exists that ice may exist mixed with lunar soil.

The Moon's crust averages 68 km thick and varies from essentially 0 under Mare Crisium to 107 km north of the crater Korolev on the lunar farside. Below

the crust is a mantle and possibly a small core. Unlike the Earth's mantle, however, the Moon's is only partially molten. Curiously, the Moon's center of mass

is offset from its geometric center by about 2 km in the direction toward the Earth. Also, the crust is thinner on the near side.

There are two primary types of terrain on the Moon: the heavily cratered and very old highlands and the relatively smooth and younger maria. The maria

(which comprise about 16% of the Moon's surface) are huge impact craters that were later flooded by molten lava. Most of the surface is covered with

regolith, a mixture of fine dust and rocky debris produced by meteor impacts. For some unknown reason, the maria are concentrated on the near side.

In addition to the familiar features on the near side, the Moon also has South Pole-Aitken on the far side which is 2250 km in diameter and 12 km deep

making it the largest impact basin in the solar system and Orientale on the western limb which is a splendid example of a multi-ring crater.

A total of 382 kg of rock samples were returned to the Earth by the Apollo and Luna programs. These provide most of our detailed knowledge of the

Moon. They are particularly valuable in that they can be dated. Even today, 20 years after the last Moon landing, scientists still study these precious samples.

(picture 18)

Most rocks on the surface of the Moon seem to be between 4.6 and 3 billion years old. This is a fortuitous match with the oldest terrestrial rocks which are

rarely more than 3 billion years old. Thus the Moon provides evidence about the early history of the Solar System not available on the Earth.

Prior to the study of the Apollo samples, there was no consensus about the origin of the Moon. There were three principal theories: co-accretion which

asserted that the Moon and the Earth formed at the same time from the Solar Nebula; fission which asserted that the Moon split off of the Earth; and

capture which held that the Moon formed elsewhere and was subsequently captured by the Earth. None of these work very well. But the new and detailed information from the Moon rocks led to the impact theory: that the Earth collided with a very large object and that the Moon formed from the ejected material. There are still details to be worked out, but the impact theory is now widely accepted.

The Moon has no global magnetic field. But some of its surface rocks exhibit remanent magnetism indicating that there may have been a global magnetic field early in the Moon's history.

With no atmosphere and no magnetic field, the Moon's surface is exposed directly to the solar wind. Over its 4 billion year lifetime many hydrogen ions from the solar wind have become embedded in the Moon's regolith. Thus samples of regolith returned by the Apollo missions proved valuable in studies of the solar wind. This lunar hydrogen may also be of use someday as rocket fuel.

The Brightest

There are 12 major bodies brighter than magnitude 6 (as viewed from Earth). All of these can be seen with the naked eye or with binoculars.

Name	Distance Orbits (000 km)	Radius (km)	Vo *
Sun?	0	697000	-26.8
Moon	Earth	384	1738 -12.7
Venus	Sun	108200	6052 -4.4
Jupiter	Sun	778000	71492 -2.7
Mars	Sun	227940	3398 -2.0
Mercury	Sun	57910	2439 -1.9
Saturn	Sun	1429000	60268 0.7
Ganymede	Jupiter	1070	2631 4.6
10	Jupiter	422	1815 5.0
Europa	Jupiter	671	1569 5.3
Uranus	Sun	2870990	25559 5.5
Callisto	Jupiter	1883	2400 5.6

*Note: Vo = Object's magnitude in visible light at opposition.

Note: Comets are often quite bright during their brief passage near the Sun.

Warning: Do NOT look directly at the Sun. Looking directly at the Sun can cause severe eye damage; doing so with binoculars or a telescope can cause permanent blindness.

Motions of the Moon

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The moon moves rapidly with respect to the background stars. It moves about 3 degrees (26 times its apparent diameter) in 24 hours (slightly greater than its own diameter in one hour)! Its rapid motion has given it a unique role in the history of astronomy. For thousands of years it has been used as the basis of calendars. Isaac Newton got crucial information from the Moon's motion around the Earth for his law of gravity. Almost everyone has noted that we see the same face of the Moon all of the time. It's the "man in the moon", "woman in the moon", "rabbit in the moon" etc. One thing this shows us is that the moon turns exactly once on its axis each time that it goes around the Earth. Later on we'll find out how tidal forces have caused this face-to-face dance of the Earth and Moon. It drifts eastward with

respect to the background stars (or it lags behind the stars). It returns to the same position with respect to the background stars every 27.323 days. This is its sidereal period.

Phases and Eclipses

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One of the most familiar things about *the* Moon is that it goes through phases from new (all shadow) to first quarter (It appears to be in shadow) to full (all lit up) to third quarter (opposite to the first quarter) and back to new. This cycle takes about 29.53 days. This time period is known as the Moon's synodic period. Because the moon moves through its phases in about four weeks, new moon, first quarter, full moon, third quarter, and new moon occur at nearly one-week intervals. We know that the phases are due to how the Sun illuminates the Moon and the relative positioning of the Earth, Moon, and Sun. We observe that not much of the Moon is illuminated when it is close to the Sun. In fact, the smaller the angular distance between the Moon and the Sun, the less we see illuminated. When the angle is within about 6 degrees we see it in a new phase. Sometimes that angle = 0 degrees and we have a solar eclipse-the moon is in new phase and it is covering up the sun. Conversely, the greater the angular distance is between the Moon and the Sun, the more we see illuminated. Around 180 degrees we see the Moon in full phase. Sometimes (about twice a year) the Moon-Sun angle is exactly 180 degrees and we see the Earth's shadow covering the Moon-a lunar eclipse.

Why are the synodic and sidereal periods not equal to each other? For a reason similar to the reason why the solar day and sidereal day are not the same. Remember that a solar day was slightly longer than a sidereal day because of the sun's apparent motion around the Earth (caused by the Earth's motion around the Sun). The Moon's synodic period is longer than its sidereal period because of its motion around the Earth. At new moon, the Sun and Moon are seen from the Earth against the same background stars. One sidereal period later, the Moon has returned to the same place in its orbit and to the same place among the stars, but in the meantime, the Sun has been moving eastward, so the Moon has not yet caught up to the Sun. The Moon must travel a little over two more days to reach the Sun and establish the new moon geometry again.

The modern model has the moon going around the Earth with the Sun far away. At different positions in its orbit we see different phases all depending on the relative positions of the Earth-Moon-Sun. Another possible model was presented by the highly-esteemed Harvard graduates. They proposed that the dark part of the moon is the result of portions of the moon lying in the shadow of the Earth. Question: If the Harvard model was true, what would be the difference in Moon rise time and the sun rise time for a New Moon or first quarter phase? What would be the angular separation between the Moon and the Sun for a New Moon or first quarter phase in the Harvard model?
Eclipse Details: Lunar Eclipse

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Let's talk a little more about lunar and solar eclipses. Remember that an eclipse happens when an object passes through another object's shadow. Any shadow consists of two parts: an umbra which is the region of total shadow and the penumbra which is the outer region of partial shadow. If the Moon were to pass

through the Earth's umbra, a Moon observer would not be able to see the Sun at all-she would observe a solar eclipse! An Earth observer would see a total lunar eclipse. The Earth's shadow is pretty big compared to the Moon so a total lunar eclipse lasts about 1 hour 45 minutes. If the Moon only passed through the outer part of the shadow (the penumbra) then the Moon observer would see the Sun only partially covered up-a partial solar eclipse. The Earth observer would see the Moon only partially dimmed-a partial lunar eclipse. During a total lunar eclipse we see another interesting effect-the Moon turns a coppery (or bloody) red. This is due to sunlight refracting or bending through the Earth's atmosphere. Dust particles in the Earth's atmosphere have removed much of the bluer colors in the sunlight so only the redder colors make it to the Moon. The amount of dust determines the deepness of the red colors. This is also why the Sun appear redder at sunset on Earth. The Moon observer would see a reddish ring around the Earth.

Eclipse Details: Solar Eclipse

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The Moon's shadow also has an umbra and penumbra. The shadow is much smaller than the Earth's. Only if the Moon is in the ecliptic plane when it is exactly New Moon will we have the Moon's shadow hitting the Earth. Where the umbra hits the Earth, we'll see a total solar eclipse. Where the penumbra hits the Earth, we'll see a partial solar eclipse. In a total solar eclipse the bright disk of the sun is completely covered up by the Moon and we see the other parts of the sun like the corona, chromosphere, and prominences. Unfortunately, only the tip of the Moon's umbra reaches the Earth (the tip hitting the Earth is 270 km [168 miles] in diameter) and it zips along the Earth's surface at over 1600 kph (1000 mph) as the Moon moves around the rotating Earth so a total solar eclipse can last a maximum of only 7.5 min. Usually total solar eclipses only last 3-4 minutes. Because of the orbital motion of the Moon and the rotation of the Earth, the umbra makes a long, narrow path of totality. Question: Why is the path of totality different each time? Why does the latitude of the path vary? Why can the totality path be more than 23.5 degrees in latitude from the equator?.

Sometimes, the umbra does not reach the Earth at all (only the penumbra) even though the Moon is on the ecliptic and it is exactly in New Moon phase. We see a bright ring around the Moon when it is lined up with the Sun-an annular eclipse (because of the annulus of light around the Moon). Question: Why would the umbra not touch the Earth? What does the fact that we sometimes observe annular eclipses and sometimes total solar eclipses indicate about the shape of the Moon's orbit?

Moon Introduction

The Moon has fascinated mankind throughout the ages. By simply viewing with the naked eye, one can discern two major types of terrain: relatively bright highlands and darker plains. By the middle of the 17th century, Galileo and other early astronomers made telescopic observations, noting an almost endless overlapping of craters. It has also been known for more than a century that the Moon is less dense than the Earth. Although a certain amount of information was ascertained about the Moon before the space age, this new era has revealed many secrets barely imaginable before that time. Current knowledge of the Moon is greater than for any other solar system object except Earth. This lends to a greater understanding of geologic processes and further appreciation of the complexity of terrestrial planets.

On July 20, 1969, Neil Armstrong became the first man to step onto the surface of the Moon. He was followed by Edwin Aldrin, both of the Apollo 11 mission. They and other moon walkers experienced the effects of no atmosphere. Radio communications were used because sound waves can only be heard by travelling

through the medium of air. The lunar sky is always black because diffraction of light requires an atmosphere. The astronauts also experienced gravitational differences. The moon's gravity is one-sixth that of the Earth's; a man who weighs 82 kilograms (180 pounds) on Earth weighs only 14 kilograms (30 pounds) on the Moon.

The Moon is 384,403 kilometers (238,857 miles) distant from the Earth. Its diameter is 3,476 kilometers (2,160 miles). Both the rotation of the Moon and its revolution around Earth takes 27 days, 7 hours, and 43 minutes. This synchronous rotation is caused by an unsymmetrical distribution of mass in the Moon, which has allowed Earth's gravity to keep one lunar hemisphere permanently turned toward Earth. Optical librations have been observed telescopically since the mid-17th century. Very small but real librations (maximum about $0^{\circ}.04$) are caused by the effect of the Sun's gravity and the eccentricity of Earth's orbit, perturbing the Moon's orbit and allowing cyclical preponderances of torque in both east-west and north-south directions.

Four nuclear powered seismic stations were installed during the Apollo project to collect seismic data about the interior of the Moon. There is only residual tectonic activity due to cooling and tidal forcing, but other moonquakes have been caused by meteor impacts and artificial means, such as deliberately crashing the Lunar Module into the moon. The results have shown the Moon to have a crust 60 kilometers (37 miles) thick at the center of the near side. If this crust is uniform over the Moon, it would constitute about 10% of the Moon's volume as compared to the less than 1% on Earth. The seismic determinations of a crust and mantle on the Moon indicate a layered planet with differentiation by igneous processes. There is no evidence for an iron-rich core unless it were a small one. Seismic information has influenced theories about the formation and evolution of the Moon.

The Moon was heavily bombarded early in its history, which caused many of the original rocks of the ancient crust to be thoroughly mixed, melted, buried, or obliterated. Meteoritic impacts brought a variety of "exotic" rocks to the Moon so that samples obtained from only 9 locations produced many different rock types for study. The impacts also exposed Moon rocks of great depth and distributed their fragments laterally away from their places of origin, making them more accessible. The underlying crust was also thinned and cracked, allowing molten basalt from the interior to reach the surface. Because the Moon has neither an atmosphere nor any water, the components in the soils do not weather chemically as they would on Earth. Rocks more than 4 billion years old still exist there, yielding information about the early history of the solar system that is unavailable on Earth. Geological activity on the Moon consists of occasional large impacts and the continued formation of the regolith. It is thus considered geologically dead. With such an active early history of bombardment and a relatively abrupt end of heavy impact activity, the Moon is considered fossilized in time.

The Apollo and Luna missions returned 382 kilograms (840 pounds) of rock and soil from which three major surface materials have been studied: the regolith, the maria, and the terrae. Micrometeorite bombardment has thoroughly pulverized the surface rocks into a fine-grained debris called the regolith. The regolith, or lunar soil, is unconsolidated mineral grains, rock fragments, and combinations of these which have been welded by impact-generated glass. It is found over the entire Moon, with the exception of steep crater and valley walls. It is 2 to 8 meters (7 to 26 feet) thick on the maria and may exceed 15 meters (49 feet) on the terrae, depending on how long the bedrock underneath it has been exposed to meteoritic bombardment.

The dark, relatively lightly cratered maria cover about 16% of the lunar surface and is concentrated on the nearside of the Moon, mostly within impact basins. This

concentration may be explained by the fact that the Moon's center of mass is offset from its geometric center by about 2 kilometers (1.2 miles) in the direction of Earth, probably because the crust is thicker on the farside. It is possible, therefore, that basalt magmas rising from the interior reached the surface easily on the nearside, but encountered difficulty on the farside. Mare rocks are basalt and most date from 3.8 to 3.1 billion years. Some fragments in highland breccias date to 4.3 billion years, and high resolution photographs suggest some mare flows actually embay young craters and may thus be as young as 1 billion years. The maria average only a few hundred meters in thickness but are so massive they frequently deformed the crust underneath them which created fault-like depressions and raised ridges.

The relatively bright, heavily cratered highlands are called terrae. The craters and basins in the highlands are formed by meteorite impact and are thus older than the maria, having accumulated more craters. The dominant rock type in this region contain high contents of plagioclase feldspar (a mineral rich in calcium and aluminum) and are a mixture of crustal fragments brecciated by meteorite impacts. Most terrae breccias are composed of still older breccia fragments. Other terrae samples are fine-grained crystalline rocks, formed by shock melting due to the high pressures of an impact event. Nearly all of the highland breccias and impact melts formed about 4.0 to 3.8 billion years ago. The intense bombardment began 4.6 billion years ago, which is the estimated time of the Moon's origin.

How Old Is The Earth, And How Do We Know?

The generally accepted age for the Earth and the rest of the solar system is about 4.55 billion years (plus or minus about 1%). This value is derived from several different lines of evidence:

Unfortunately, the age cannot be computed directly from material that is solely from the earth. There is evidence that energy from the earth's accumulation caused the surface to be molten. Further, the processes of erosion and crustal recycling have apparently destroyed all of the earliest surface.

The oldest rocks which have been found so far (on the Earth) date to about 3.8 to 3.9 billion years ago (by several radiometric dating methods). Some of these rocks are sedimentary, and include minerals which are themselves as old as 4.1 to 4.2 billion years. Rocks of this age are relatively rare, however rocks that are at least 3.5 billion years in age have been found on North America, Greenland, Australia, Africa, and Asia.

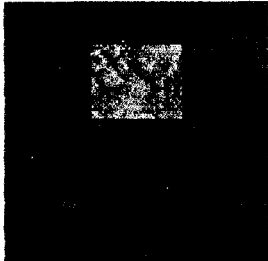
While these values do not compute an age for the Earth, they do establish a lower limit (the Earth must be at least as old as any formation on it). This lower limit is at least concordant with the independently derived figure of 4.55 billion years for the Earth's actual age.

FIGURE 2

Clementine Imagery

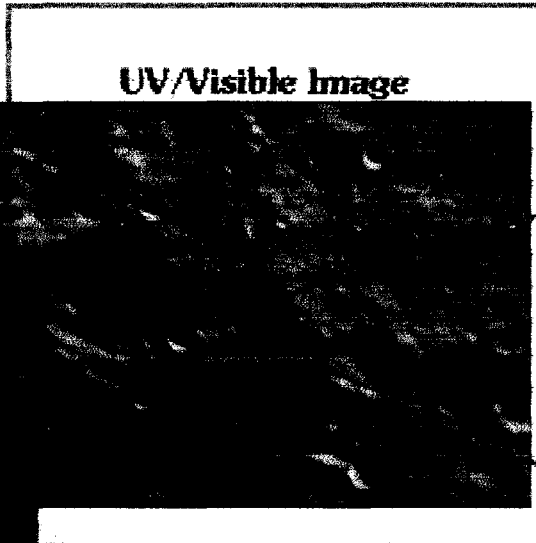
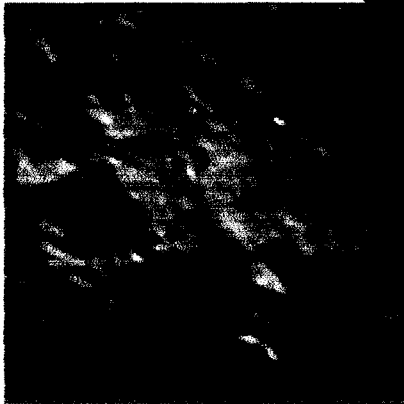
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U.S. Geological Survey

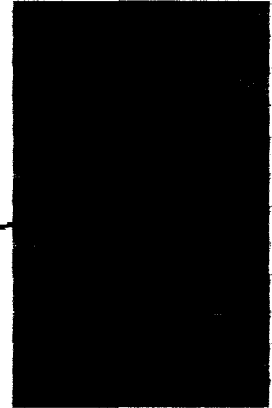


Lunar North Pole Map

Near Infrared Image

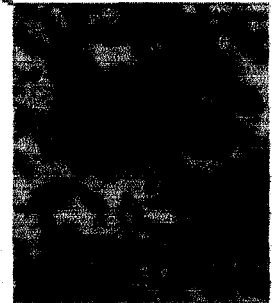


UV/Visible Image



High Resolutive Image

LongWawe Infrared Image



The Women in the Moon

There is a WOMAN IN THE MOON but many people have never seen her. She is much more obvious than the "Man in the Moon." Seen in profile, the appearance of THE WOMAN IN THE MOON changes with varying light.

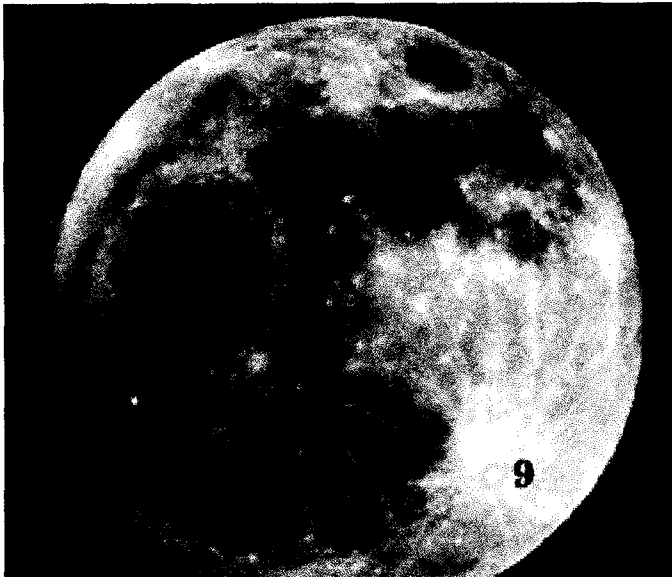


Can you see THE WOMAN IN THE MOON in this photograph?

Try using binoculars to look for her between the first quarter and the full Moon.



Numerous maria, ancient lava flows of dark basalt, help to outline THE WOMAN IN THE MOON. When these dark areas were first viewed with optical devices, observers mistook them for large areas of water.



Her hair is formed by:

1. Sea of Serenity (Mare Serenitatis)
2. Sea of Tranquillity (Mare Tranquillitatis)
3. Sea of Fertility (Mare Feunditatis)
4. Sea of Nectar (Mare Neectaris)

Other features are:

5. Sea of Vapor (Mare Vaporum) her eye.
6. Seething Bay (Sinus Aestuum) her nose.
7. Central Bay (Sinus Medii) her mouth.
8. Sea of Clouds (Mare Nubium) is under her chin.
9. Tycho is a crater that is sometimes a gem on a chain of craters around the neck of THE WOMAN IN THE MOON.

MAY SHE ALWAYS SMILE ON YOU ...

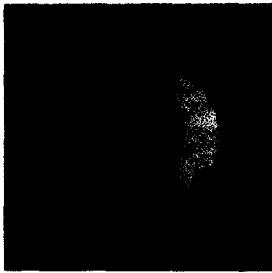
... Created and maintained by George Leonberger



Email Address: gleonber@emerald.tufts.edu

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1 2 0 3



Mercury

Planet Profile

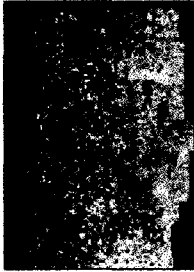
Mass (kg).....	3.3 x 10 ²³
Diameter (km).....	4878
Mean density (kg/m ³)	5420
Escape velocity (m/sec).....	4300
Average distance from Sun (AU).....	0.387
Rotation period (length of day in Earth days).....	58.65
Revolution period (length of year in Earth days).....	87.97
Obliquity (tilt of axis in degrees)	0
Orbit inclination (degrees).....	7
Orbit eccentricity (deviation from circular)	0.206
Mean surface temperature (K).....	452
Maximum surface temperature (K).....	700
Minimum surface temperature (K).....	100
Visual geometric <u>albedo</u> (reflectivity)	0.12
Largest known surface feature	Caloris Basin (1350 km diameter)
Atmospheric components	trace amounts of hydrogen and helium



Mosaic of Mercury

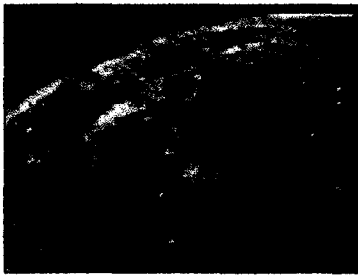
This photomosaic of the planet Mercury was assembled from individual high-resolution

images taken by Mariner 10 shortly before closest approach in 1974. The sun is shining from the right, and the terminator is at about 100 degrees west longitude. Crater Kuiper, named after astronomer Gerard P. Kuiper, can be seen just below the center of the planet's illuminated side. The landscape is dominated by large craters and basins with extensive plains between craters.



Caloris Basin

Seen here is part of the enormous Caloris Basin, which is thought to be similar to the large circular basins found on the moon. Probably formed by a giant impact early in Mercury's history, this basin was subsequently filled by lava flows. The nature of the wrinkle ridges on its floor is arguable: some scientists claim tectonics while others suggest they are due to volcanic flows escaping from fractures.



Southwest Mercury

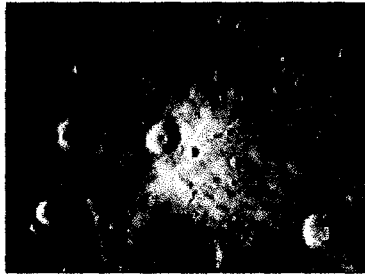
The southwest quadrant of Mercury is seen in this image taken March 29, 1974, by the Mariner 10 spacecraft. The picture was taken four hours before the time of closest approach when Mariner was 198,000 km (122,760 mi) from the planet. The largest craters seen in this picture are about 100 km (62 mi) in diameter.



Hills of Mercury

"Weird terrain" best describes this hilly, lineated region of Mercury. Scientists note that this area is at the antipodal point to the large Caloris basin. The shock wave produced by the Caloris impact may have been reflected and focused to the antipodal point, thus jumbling the crust and breaking it into a series of complex blocks. The area covered is about 800 km (497

mil on a side.



It

Mercury Close Up

The small, bright halo crater (center) is 10 km (6 mil in diameter. The prominent crater further left, which has a central peak, is 30 km (19 mil across. The darker, lightly cratered area (upper left) may be an ancient lava flow. Mercury's surface is similar to that of Earth's moon, where a history of heavy cratering is followed by volcanic filling.



Welcome to the Planets Home Page



GLOSSARY

aa -- A basaltic lava with a rough, jagged surface.

achondrite -- A stony meteorite, coarsely crystallized, with sizable fragments of various minerals visible to the naked eye.

Adams -- John Couch Adams (1819-1892) English astronomer. One of the discoverers of the planet Neptune.

Akna -- In Native American traditions from Mexico and from the Arctic, "Moon" (Wife of the Sun) and "The Mother" (Goddess of Childbirth), respectively.

albedo -- The ratio of the amount of solar radiation reflected from an object to the total amount incident upon it.

Alcott -- Louisa May Alcott (1832-1888) American author.

altimetry -- The measurement of elevation or altitude.

anorthosite -- A type of igneous rock composed almost entirely of feldspar, a group of minerals that make up about 60% of the Earth's crust.

antipodal point -- The opposite point with respect to any given point.

Aphrodite -- One of the twelve Greek Olympian gods. Goddess of Love (Roman name, Venus), daughter of Zeus and Dione.

ApoBo -- In Greek mythology, one of the twelve Olympian gods. God of prophecy, healing, archery, music, youth, plastic arts, science and philosophy.

arachnoid -- Spider or cobweblike feature on the surface of Venus, typically having a diameter of about 100-km and a central volcanic structure surrounded by a complex network of lineaments.

arcuate -- Curved or bent.

Ariel -- In Alexander Pope's poem "The Rape of the Lock", a spirit of the air, chief of the sylphs.

asteroid -- One of many small rocky bodies orbiting the Sun; a concentration of these bodies makes up the Asteroid Belt between Mars and Jupiter.

Atla -- In Norse mythology, a giantess, mother of Heimdall.

Atlas -- In Greek mythology, brother of Prometheus and grandfather of Hermes (Mercury). Condemned to stand forever supporting the heavens on his shoulders. The Atlantic Ocean is named for him.

Ba'het -- In Egyptian mythology, goddess of wealth and abundance.

Balch -- Emily Balch (1867-1961) American economist, Nobel Laureate.

Barton -- Clara Barton (1821-1912) Founder of American Red Cross.

basalt -- Fine-grained igneous rock (rich in mafic minerals) that has erupted onto the surface.

basin -- A depressed area with no surface outlet.

bedrock -- Continuous solid rock that underlies regolith and is exposed at outcrops.

breccia -- Coarse-grained rock composed of angular fragments of pre-existing rock..

caldera -- A large volcanic depression at the summit of a volcano, caused by collapse or explosion.

Callisto -- In Greek mythology, a nymph, follower of Artemis. Zeus wanted to woo her, and so disguised himself as Artemis and seduced her. To hide her from his jealous wife Hera, Zeus changed Callisto into a bear.

Candor -- Candor Chasma - from the Latin, candor, meaning "blaze" or "the white" from its appearance.

Carson -- Rachel Carson (1907-1964) American biologist and author..

Cassini -- Gian Domenico Cassini (1625-1712) Astronomer, born in Italy, later a naturalized French citizen. Discovered four of Saturn's satellites, observed a dark division in Saturn's ring (the Cassini Division).

Centaur -- In Greek mythology, a being with the head, arms, and torso of a man, and the

body and legs of a horse. The personification of wisdom and beastliness: the two natures of humankind.

Cerberus -- In Greek mythology, the three-headed dog that guards the entrance to the underworld.

Charon -- In Greek mythology, ferryman of the River Styx, who carried the dead to the underworld. Each dead person was buried with a coin in his mouth or on his eyelids to pay for the crossing.

chasma -- A large canyon.

chondrite -- A stony meteorite, composed of finely crystallized material.

coma -- A roughly spherical region of diffuse gas which surrounds the nucleus of a comet. Together, the coma and the nucleus form the comet's head.

comet -- A small celestial body composed at least partially of ices. Comets either orbit the Sun or pass through the Solar System on hyperbolic orbital paths.

Cordelia -- In William Shakespeare's *King Lear*, the youngest daughter of the king.

corona -- A circular to elongate feature which is surrounded by multiple concentric ridges. Coronae are thought to be formed by hot spots.

crater -- An approximately circular depression, sometimes surrounded by a raised rim. Craters are typically formed by explosion during meteorite impact.

crust -- The outermost layer of the lithosphere.

cusate -- Shaped like a cusp; a sharp projection of material.

Dactyl -- In Greek mythology, a legendary being that lived on Mount Ida.

Danu -- The greatest of the goddesses of ancient Ireland.

Deimos -- In Greek mythology, a son of Ares (Mars) who, with brother Phobos, was a constant companion to his father.

Derceto -- Philistine fertility goddess.

Dione -- In Greek mythology, the mother of Aphrodite, and daughter of Zeus.

drift -- A general term for all rock debris transported from one place and deposited in another, and distinguished from solid bedrock.

Eistla -- In Norse mythology, a giantess.

ejecta - Material thrown out of a volcano or impact crater.

Enceladus -- In Greek and Roman mythology, a giant, son of Titan and Gaea. Buried by an angry Zeus under Mount Etna. When the giant hisses and thrusts out his fiery tongue, Mount Etna erupts.

Encke -- Johann Franz Encke (1791-1865) German astronomer at the Seeberg Observatory, Switzerland. Determined period of the comet discovered by Pons and showed it to be identical with comets of other years.

escarpment -- A long, more or less continuous cliff or relatively steep slope facing in one general direction, produced by erosion or faulting.

Europa -- In Greek mythology, a mistress of Zeus to whom he appeared as a gentle white heifer. Zeus persuaded her to take a ride on his back, and then he carried her away across the sea.

fault -- A fracture or zone of fractures in a planet's crust, accompanied by displacement of the opposing sides.

feldspar -- A group of rock-forming minerals that make up about 60% of the Earth's crust.

Fortuna -- In Roman mythology, goddess of fortune, chance and luck.

Galileo -- Galileo Galilei (1564-1642) Italian mathematician, astronomer, and physicist. First to use a telescope to observe the skies.

Galle -- Johann Gottfried Galle (1812-1910) German astronomer who discovered the crepe ring of Saturn (1838) and was a co-discoverer of Neptune (1846).

Ganymede -- In Greek mythology, a beautiful Trojan boy, son of Troas and Calirhoe. Befriended by Zeus and made cupbearer to the Olympian gods.

Gaspra - Russian resort and spa near Yalta, Crimea, where Leo Tolstoy was treated.

geomorphology -- The study of the external structure, form, and arrangement of rocks in relation to the development of landforms.

geyser -- A type of hot spring that intermittently erupts jets of material.

Giotto -- Giotto di Bondone (1267?-1337) Italian medieval painter, architect, and sculptor.

graben -- A long, relatively depressed crustal unit or block that is bounded by faults along its sides; a trough.

Gula -- One of the primary goddesses of the Akkadian and Babylonian peoples. The mother-goddess and great physician, she had the power to inflict as well as cure disease.

Hadley -- John Hadley (1682-1744) English mathematician and inventor. Built first serviceable reflecting telescope and invented an improved quadrant known as Hadley's quadrant.

Halley -- Edmond Halley (1656-1742) English astronomer. In 1758, predicted accurately the return of a comet previously observed in 1531, 1607, 1682. The body was subsequently named Halley's Comet.

Hellas -- The Greek name for Greece.

Herschel -- Sir William Herschel (1738-1822). British astronomer. Built reflecting telescope of superior quality and with it discovered planet Uranus. Discovered satellites of Uranus and of Saturn.

Hestia -- In Greek mythology, one of the twelve Olympian gods. Sister of Zeus and goddess of the hearth and home (Roman name, Vesta).

Hubble -- Edwin Powell Hubble (1889-1953) American astronomer known for seminal work in modern cosmology.

hummocky -- Uneven; describing a terrain abounding in irregular knolls, mounds, or other small elevations.

Humomm -- Mare Humorum - Latin for "Sea of Humors" or "Sea of Moisture".

Hyperion -- In Greek mythology, a Titan, son of Uranus and Gaea. Husband of Theia and father of Eos (the Dawn). A handsome wanderer, his name is said to signify height or superiority.

Iapetus -- In Greek mythology, a son of Uranus and Gaea. Father of Atlas, Epimetheus, Menoetius, and Prometheus.

Ida -- In Greek mythology, the mountain on Crete where Zeus spent his childhood.

igneous rock -- Rock solidified from a molten state.

Imbrium -- Mare Imbrium - Latin for "Sea of Rains".

Inverness -- In William Shakespeare's Macbeth, the location in Scotland of Macbeth's castle.

Io -- In Greek mythology, a young woman seduced by Zeus, who then transformed her into a heifer to protect her from his jealous wife.

Ishtar -- In Babylonian mythology, goddess of love and war. Ruler of the Moon, as well as the morning and evening stars (alternate names for the planet Venus).

Ithaca -- A Greek island, home of Odysseus.

Jovian -- Of or relating to the planet Jupiter..

Jupiter -- Planet fifth in order from the sun. In Roman mythology, ruler of the gods. (Greek name, Zeus).

Kennedy -- John F. Kennedy (1917-1963) 35th president of the United States. Called on NASA to put an astronaut on the moon within the decade of the 1960's, a feat that was achieved. Died by assassination in November, 1963.

Kuiper -- Gerard Peter Kuiper (1905-1973) American astronomer born in The Netherlands. Studied the origin of the solar system, and planetary atmospheres.

Lada -- A word meaning both "woman" and "goddess" in the area of Lycia in Asia Minor.

Lakshmi -- In Indian mythology, the goddess of all forms of wealth. The reverence for cows in Hindu India is based on worship of this goddess, as in that tradition cows are a representation of wealth.

Lavinia -- In Virgil's Aeneid, a beautiful woman who became the wife of Aeneas. Personification of earth's fertility.

Lee -- Robert E. Lee: (1807-1870) American Soldier. General in chief of all Confederate armies during the Civil War. Surrendered to Federal forces in April, 1865.

Leverrier -- Urbain Jean Joseph Le Verrier (1811-1877) French astronomer who performed the calculations that predicted the existence of the planet Neptune.

limb -- The outer edge of a lunar or planetary disk.

Lincoln -- Abraham Lincoln (1809-1865) Sixteenth president of the United States. Commander in Chief of Federal forces during the Civil War. Five days after the war's end Lincoln was shot. He died the following day.

lineament -- A linear topographic feature, such as a fault line, aligned volcanoes, or straight stream course.

Loki -- In Scandinavian mythology, a mischievous trickster, thief and slanderer.

Magellan -- Ferdinand Magellan (1480-1521) Portuguese navigator whose ship completed the first circumnavigation of the Earth.

magma -- Molten rock material (liquids and gases).

magnetosphere -- a region of a planet's atmosphere that is dominated by the planet's magnetic field so that charged particles are trapped in it.

mantle -- The main bulk of a planet between the crust and the core; on Earth, the mantle ranges from about 40 to 2,900 kilometers (25 to 1800 miles) below the surface.

mare -- A dark, low-lying lunar plain, filled to some depth with volcanic rocks.

Mars -- Planet fourth in order from the sun. In Roman mythology, god of war and discord (Greek name, Ares).

massif -- A massive topographical feature, commonly formed of rocks more rigid than those of its surroundings.

Mead -- Margaret Mead (1901-1978) American anthropologist, author and lecturer on contemporary social issues.

Mercury -- The planet closest to the sun. In Roman mythology, the fleet-footed messenger god and escort of dead souls to the underworld (Greek name, Hermes).

meteorite -- A stony or metallic object from interplanetary space that impacts a planetary surface.

Mimas -- In Greek mythology, a giant.

Miranda -- In William Shakespeare's *The Tempest*, the second daughter of Prospero, the magician.

morphology -- The study of structure or form.

Mylitta -- In ancient Phoenicia, a moon goddess who presided over fertility and childbirth.

Navka -- Arab mother-goddess.

Neptune -- Planet eighth in order from the sun. In Roman mythology, god of the sea (Greek name, Poseidon).

nucleus -- The frozen core of a comet which contains almost the entire cometary mass and is located in the comet's head.

Oberon -- In William Shakespeare's *A Midsummer Night's Dream*, the king of the fairies.

Olympus -- In Greek mythology, the mountain that is home to the gods.

Onatah -- In the mythology of the Native American Seneca and Iroquois people, a corn or wheat goddess; the daughter of Nokomis.

Ophelia -- In William Shakespeare's *Hamlet*, the daughter of Polonius and deserted lover of Hamlet.

Ophir -- In the Bible, a land to which King Solomon sent a naval expedition. Considered to be the eastern extremity of the known world. Thought to be modern Ethiopia, or possibly India.

Orientele -- Latin for "Eastern",

Ovda -- In Finnish mythology, a wild, ill-humored spirit who wanders through the forests looking for trespassers to tickle to death.

Oxia -- Oxia Palus - from the Latin, an oasis on the Oxus Canal, which flowed into the Oxianus Lacus (the modern-day Sea of Aral).

pahoehoe -- A basaltic lava with a smooth, undulating surface.

perihelion -- The point in the path of a planet, asteroid, comet, or other body that is closest to the sun.

Proteus -- In Greek mythology, the son of Poseidon. Personification of the shifting winds and moods of the sea.

Phobos -- In Greek mythology, a son of Ares (Mars) who, with brother Deimos, was a constant companion to his father.

plateau - Any comparatively flat area of great extent or elevation.

plume -- A buoyant mass of hot, partially molten mantle material that rises to the base of the lithosphere.

Pluto - Planet ninth in order, and farthest, from the sun. In Greek mythology, god of the dead and the underworld.

Procellarum -- Oceanus Procellarum - from the Latin, "Ocean of Storms".

Prometheus -- A Greek mythological hero who gave humankind fire.

regolith - Any solid material lying on top of bedrock, including soil and rock fragments.

relief -- The maximum regional difference in elevation.

Rhea -- In Greek mythology, mother of Zeus and wife of Cronos the Titan.

rift -- A valley formed at a divergence zone or other area of extension.

rille -- One of several trenchlike, or cracklike valleys up to several hundred km long and 1-2 km wide commonly occurring on the Moon's surface.

Sacajawea -- Sacajawea (Bird Woman) (1786?-1812) Native American who accompanied and guided the Lewis and Clark expedition from the Missouri River to the Pacific Ocean and back.

Sapas -- In Phoenician mythology, goddess of commerce and travel, and messenger of the gods.

Saturn -- Planet sixth in order from the sun. In Roman mythology, god of agriculture, and father of Jupiter (Greek name, Cronos).

scarp -- A cliff or steep slope of some extent that may form a marked topographic boundary.

Schiaparelli -- Giovanni Virginio Schiaparelli (1835-1910). Italian astronomer at the Milan Observatory who reported markings on Mars which he called "canali".

Seln - Cherokee com goddess.

shearing -- The motion resulting from stresses that cause or tend to cause contiguous parts of a body to slide relatively to each other.

shield volcano -- A broad volcanic cone with gentle slopes constructed of successive nonviscous, mostly basaltic, lava flows.

Sir -- In Scandinavian mythology, the grain goddess renowned for her long golden hair. Mate of the thunder god Thor.

SIR-C/x-SAR -- Spaceborne Imaging Radar-C and X-Band Synthetic Aperture Radar. An instrument that performs detailed observations of Earth at any time, regardless of weather or sunlight conditions.

slumping -- A landslide that results from the downward sliding of rock debris as a single mass, usually with a backward rotation relative to the slope along which the movement takes place.

Stickney -- Angeline Stickney (1830-1892) The wife of Asaph Hall, known for her persistent encouragement of her husband as he strove to and eventually succeeded in the discovery of the satellites of Mars.

stratosphere -- An upper portion of a planetary atmosphere, above the troposphere and below the ionosphere, characterized by relatively uniform temperature and horizontal winds.

tectonic -- Relating to the deformation of the crust of a moon or planet, the forces involved in or producing such deformation, and the resulting forms.

tectonics -- Structural deformation, especially folding and faulting.

terminator -- The line separating the illuminated and unilluminated parts of a celestial body; the dividing line between day and night as observed from a distance.

terrestrial -- Belonging to the class of planets that are similar to the Earth in density and composition (i.e. Mercury, Venus, and Mars).

Tethys -- In Greek mythology, a sea goddess.

Tharsis -- In the Bible, a land at the western extremity of the known world. Thought to be a region in modern-day Spain.

Theia -- Pre-Hellenic goddess of light, mother of the dawn. In Greek mythology, mother of Helios (the Sun) and Eos (the Dawn).

Titan -- In Greek mythology, Titans were the firstborn children of Uranus (the sky) and Gaea (the Earth). The ruler of the Titans was Cronos, whose Roman name is Saturn.

Titania -- In William Shakespeare's *A Midsummer Night's Dream*, the queen of the fairies.

topography -- The shape and form of the surface of a planet.

Triton -- In Greek mythology, merman, half-man, half-fish. Son of Poseidon and Amphitrite.

trough -- A long linear depression.

Umbriel -- In Alexander Pope's poem "The Rape of the Lock", a "dusky, melancholy sprite".

Uranus - Planet seventh in order from the sun. In Greek mythology, god of the sky, mate of the goddess of the Earth, and father of the Titans.

Ursula -- In William Shakespeare's *Much Ado About Nothing*, the attendant to Hero.

Valhalla -- In Norse mythology, Odin's hall, where he received the souls of slain warriors.

Venus -- Planet second in order from the sun. In Roman mythology, goddess of love (Greek name, Aphrodite).

vent -- An opening or fissure in a planet's surface through which volcanic material erupts.

Vires-akka -- In Northern European / Arctic mythology, a forest goddess.

viscosity -- A measure of resistance to flow.

volcanic rock -- Rock formed by eruption onto a planet's surface.



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