A Teacher’s Guide to the Universe

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This Senior Thesis was written in accordance with Princeton University Honor Code regulations, and represents my own work.

Today, at the threshold of the 21st Century, this nation has recognized the need for a scientifically literate public. Knowledge of science and technology is becoming increasingly important to the enduring success of our nation's students. Unfortunately, too many of our students are turned off to science at an early age and are therefore unmotivated to pursue degrees and employment in scientific fields. For example, students at the elementary school level are often interested in Astronomy and Cosmology but lose interest by the time they reach high school as the mathematics becomes more difficult. This trend is especially prevalent among minority students, including women. In order to achieve the national goal of a scientifically literate public, methods of science teaching must be reworked so that they excite and captivate more students. For this reason, the National Academy of Sciences has set out to promote a new style of science education based on the principles of scientific inquiry. The Academy describes inquiry as

> more than 'science as process,' in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills.[1]

Teachers must have a great deal of preparation and motivation to successfully use scientific inquiry in the classroom. Inquiry also requires many resources, the most important of which is time. This work is designed to help busy secondary school teachers by providing lesson plans in the field of cosmology written in the spirit of scientific inquiry.

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[1] National Research Council, National Science Education Standards (Washington, DC: National Academy Press, 1996) p 2

In order to encourage the use of efficient inquiry in the classroom, the National Academy of Sciences also outlined the essential content concepts for science education in The National Education Science Standards. These lesson plans reference both the National Science Education Standards and the New Jersey Core Curriculum Content Standards because education in this country is most closely regulated by the state. The New Jersey Standards are meant to serve as guidelines for science education and were designed to "define the results expected but do not limit district strategies for how to ensure that their students achieve these expectations."[2] The Core Curriculum also defines an assessment standard which "will define the state high school's graduation requirements"[3] This work contains units designed primarily to address the content required by New Jersey's Core Curriculum Content Standard 5.11, which states that "All students will gain an Understanding of the Origin, Evolution and Structure of the Universe,"[4] and specifically progress indicator 8, which says that the students should be able to "evaluate evidence that supports scientific theories of the evolution of the universe."[5] These lesson plans are also aligned with many other standards and progress indicators as described in the New Jersey Core Curriculum Content Standards and the National Science Education Standards the details of which will be discussed in Section III.

In response to the standards suggested on the national level, the National Aeronautics and Space Administration committed itself to education by bringing forth both Strategic and Implementation Plans for Education that require close connection to

[2] New Jersey Department of Education, New Jersey Core Curriculum Content Standards (http://www.injersey.com/Education/NJDOE/01intro.html, 3/2/98) p 1
[3] Ibid., p 1

the National Science Education Standards. As a result, the Microwave Anisotropy Probe (MAP) Satellite Mission, is dedicated to Education and Public Outreach and therefore has supported these lesson plans to increase interest among students in cosmology and science in general as well as bring information and scientific inquiry to classroom teaching.

To promote inquiry in the classroom, the lesson plans presented here are written in a flexible format. Students and teachers should use the information provided as starting points for bigger or more complete investigations. At all times, students should be encouraged to pursue individual interests with follow up projects, to communicate their results to audiences in the classroom and outside the classroom using a variety of technologies, and question their results and the results of their peers.

These activities include a range of hands-on activities that explore the usually hands-off realm of the indirectly observed universe. Students often find cosmology difficult because of the math involved or the indirect way of studying it. These activities hope to bring the universe into the classroom and allow students to manipulate data and discover the laws governing the universe themselves.

In order to disseminate information as quickly and efficiently as possible, these lesson plans have been made publicly available on the WWW to encourage broad use in schools. They can be found at http://www.astro.princeton.edu/~clark/teachersguide.html or on a read-only compact disk in the back of this text. Samples of the lesson plans are included in the next section.

[4] New Jersey Department of Education, New Jersey Core Curriculum Content Standards (http://www.injersey.com/Education/NJDOE/10scistan5_11.html, 3/2/98) p 1
[5] Ibid.

Lesson Plans

The next 62 pages contain selected examples from the Teacher's Guide to the Universe web site. The full text is available at http://www.astro.princeton.edu/~clark/teachersguide.html . Reference material including footnotes for this section are available online at http://www.astro.princeton.edu/~clark/footnote.html .

Evaluating the Lessons

In order to ensure that both NASA's Strategic Plan for Education and the National Science Education Standards become utilized and do not merely remain a description of ideal classroom practice, both NASA and the National Council on Science and Technology have begun to devise methods of curriculum material evaluation. At this time, neither project is finished and therefore this work has been tested by the author in a manner that she believes is closest to the description of the coming evaluation.

First, a sample of the lessons were field tested in high school classrooms in two sessions. Both sessions tested the Parallax Activity and the Supernovae Lab; the first session classroom contained a group of accelerated physics students and the second session utilized three classrooms of conceptual physics students. All students were given a preliminary questionnaire (See Appendix I). The lessons were taught by the author over a period of about a week and then the students were given a final questionnaire which differed from the first session to the next (See also Appendix I). Between the two sessions, directions were clarified and modified somewhat, and the resulting changes appear on the web site. Accounts of the experiences of the author during these two sessions are located at the end of this section.

The students who made up the field testing groups were two levels of physics students at Princeton high school in Princeton, New Jersey. The first section was an accelerated level and the second section had three classes of conceptual physics students; all were usually taught by Mr. Mark Volpe. Princeton high school is a suburban, public school with diversity that reflects the local diversity levels of about 20 percent minorities. The students range in grade level from 10^{th} through 12^{th} grades and their highest level math class from Algebra II to AP Calculus BC. Specifically, of those students who answered the final questionnaires, the accelerated class reported 5 senior males, 5 senior females, 4 junior males, 2 junior females, 1 male sophomore and one unreported female grade level. The conceptual class reported on their final questionnaires a class makeup of 9 senior males, 9 senior females, 11 junior males, 10 junior females and 3 unreported grade levels (1 male, 2 female).

	Accelerated Class	
Grade	M	F
12	5	5
11	4	2
10	1	0
Unreported	0	1

	Conceptual Class	
Grade	M	F
12	9	9
11	11	10
10	0	0
Unreported	1	2

Tables 1 and 2: Grade Level As Reported By Males and Females in Accelerated and Conceptual Classes

Of all the students 4 males and 4 females reported their highest level in mathematics as AP Calculus BC. 8 males and 5 females reported their highest level was AP Calculus AB. 17 males and 16 females reported Pre-Calculus as their highest level. 2 males reported Algebra III as their highest level and 7 males and 5 females reported Algebra II as their highest. One student was enrolled in Geometry and two students did not report any information concerning their math level.

	All Students	
Math Level	M	F
BC Calculus	4	4
AB Calculus	8	5
Pre-Calculus	17	16
ALG III	2	0
ALG II	7	5
Geometry	0	1
Unreported	1	1

Table 3: Math Level As Reported By All Male And Female Students

The questions on the final questionnaires for the first section of students were not easily quantifiable so they will not be discussed further, however the questionnaires were useful in determining how to construct more useful and more easily understood questionnaires for the second section of students. The questions on the final questionnaires for the second section of students revealed that overall students rated the lessons better than average and found astronomy more interesting than before having the week long lesson. When asked in question 8, "In comparison with before this week long lesson I now find Astronomy:" students averaged a rating of 4.59 on a seven point scale, where 1 corresponded to Less Interesting and 7 to More Interesting. When asked in question 10, "Overall the activities in this lesson were:" students averaged a rating of 4.88 on a seven point scale, where 1 indicated Poor and 7 indicated Excellent. However, when the students were asked in question 11, "If you were a teacher or principal how would you rate this lesson:" students gave the lessons a higher average rating of 5.27 on a seven point scale where 1 indicated Poor and 7 excellent.

	Conceptual Students		
Question #	M	F	Total
8	4.19	4.9	4.588
10	4.53	5.16	4.875
11	5.088	5.41	5.27

Table 4: Students Average Rating on Seven Point Scale

One interesting trend did emerge, however. When the student surveys were divided into groups of reported males and females, the ratings changed overall. The female group rated the lesson plans as better and astronomy more interesting than the male group. For question 8, males gave an average response of 4.19 while females gave a higher average response of 4.9 ($t=1.810$, one tailed, $p< 0.05$). For question 10, males gave an average 4.53, while females gave a higher average response of 5.16 ($t=4.697$, one tailed, $p < 0.01$). For question 11, males gave an average response of 5.088, while females gave a higher average response of 5.41 ($t=4.399$, one tailed, $p<0.01$). This could suggest that the lesson plans were more agreeable to female learners, that the female group responded more than the male group to a female role model, or that the females simply rated the lessons more favorably.

Statistics		
Question #	t	p
8	1.81	<0.05
10	4.697	<0.01
11	4.399	<0.01

Table 5: Statistical Results from One-Tailed T test

Questionnaires were also distributed to teachers at a NJPTA meeting. A presentation was made describing the web site and teachers were asked to respond to the questionnaire either in paper or electronic form. Due to a variety of factors only one survey was returned from this applicant pool. Two other surveys were completed by teachers from the high school in which the lessons were tested. The author is very open to more teacher evaluation, since this is the intended audience for the work, but unfortunately teachers with free time on their hands to read and evaluate the materials are few and far between.

Since these methods of evaluation were either inconclusive or proved impossible, the author sought descriptions of the NASA and NCST planned evaluations for curriculum materials and found the following criteria.

NASA has planned an “Agencywide, Internet-based data collection and reporting system designed for use in the field by the program managers and participants. Reports based on these data, including an annual evaluation report, will be used to improve program quality….”[6] that is based on “accomplishment of the Agencywide goals and objectives for all NASA education activities.”[7] NASA lists these goals and actions:

> Teacher/Faculty Preparation and Enhancement…
> 1. Model inquiry-based science investigations…
>
> Curriculum Support and Dissemination…
> 1. Expand use in teacher training programs
> 2. Create a guide for developers…
>
> Student Support…
> 3. Develop and field test models to involve students
>
> Educational Technology…
> 1. Produce teaching tools…
> 3. Use technology to facilitate communication
> 4. Use technology to involve educators in NASA missions
> 5. Research new teaching and learning practices…[8]

NASA also discusses three strategies and two outcomes for their Education Program:

> *Contribute to Educational Excellence*
> In the execution of our activities, we strive to make a positive contribution to the goals established by the education community. In particular, our programs are based on national curriculum standards, State and local curriculum frameworks, and the research agenda of NASA and the higher education community. NASA's Education Program seeks to be judged by the external education community as a valuable asset. Our performance in carrying out activities and our success as a program will be judged on our ability to meet the educational communities requirements.
>
> *Develop Alliances…*
>
> *Involve the Education Community*
> …We will actively engage students, teachers, faculty, schools colleges, universities, professional associations, and national, state and local education authorities in our projects and programs to enhance knowledge and contribute to the NASA mission.
>
> *Outcomes:*
> …*Excellence*-…we will attempt to maintain an “Excellence” rating ranging between 4.3 and 5.0 (on a 5.0 scale).

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[6] NASA, NASA Implementation Plan for Education 1999-2003 (http://www.hq.nasa.gov/education , 2/22/99) p. 10
[7] Ibid.
[8] Ibid., p 5

> -quality rating by the educational customer of NASA's performance
> -Use standards/state curriculum frameworks to structure K-12 programs
> -Number of alliances
> *Involvement*-NASA strives to involve the educational community in our endeavors…we seek to maintain a current level of participant involvement of approximately three million…
> -Total number of students/teachers/faculty involved in NASA programs
> -Number of programs using NASA assets and types of assets used[9]

This work has made efforts to be evaluated by the educational customer which to date have not yet been successful. In the future, efforts will be made to maintain an excellence rating as suggested by the NASA outcome stated above. This project has contributed to producing NASA's outcome by involving at least 3 professors, 2 teachers, 1 undergraduate student and just under 100 students. In the future, this web site will be advertised and (hopefully) will involve many more educators and students.

NCST's strategy involves a very complete investigation of curriculum materials, not only for content but also for instructional strategies. They explain this choice in the following way: The Core Curriculum Content Standards are perfect curriculum materials if they are judged only by content, however they contain no strategy for instruction, no information concerning how students should achieve these content goals, and certainly no one would suggest that they be used for a student text book.[10] They describe their procedure in brief:

> **Preliminary Inspection**. This is to determine whether the material merits further analysis and. if so, to identify the learning goals that will serve as the focus of further study.
> **Content Analysis**. The purpose here is to determine whether the content in the material matches specific learning goals- not just whether the topic headings are similar…

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[9] Ibid., p 10

[10] Roseman, J., Kesidou, S., & Stern, L., Identifying Curriculum Materials for Science Literacy A Project 2061 Evaluation Tool, (http://project2061.aaas.org/newsinfo/research/roseman/roseman2.html, 3/27/99) p. 2

> **Instructional Analysis**. This looks at the match between the material's treatment of specific learning goals and what is known about student learning and effective teaching. The purpose here is to estimate how well instructional strategies in the material support student learning those very ideas and skills for which there is a content match. It should be possible to point to evidence of effective instruction in the material, benchmark by benchmark. (It is possible that materials would both (a) show a content match to particular benchmarks and (b) have plausible instructional strategies in general, yet not focus those strategies on those particular benchmarks.) [11]

As a result of both the strategies suggested by NASA and the NCST for curriculum evaluation, the author tried to specifically site examples of the lessons which align with the standards and progress indicators specified in the NSES and the NJCCCS. These comments can be found along with the appropriate standards in Appendix II.

Journal of Parallax and SuperNovae Lab field testing

Feb 2-5, 1999

Prior to Feb 2nd:

- I visited the class and observed a physics lab session. This particular class is an accelerated physics class, later I hope to teach three sections of conceptual physics (lower level, less math). They were conducting an experiment to measure g the gravitational acceleration using pendulums.
- I designed two lab activities on distance measurement to be tested in this classroom situation. One lab was about parallax, the other used Super Novae as standard candles.

Feb 2nd:

I began the fifty minute class with a personal introduction explaining my position as an educational outreach coordinator for the MAP satellite mission and that as a university student I was working to complete a Senior Thesis. I explained that I hoped the students would find the lessons interesting and that they would learn something, but also that I hoped

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[11] Ibid.

to improve my lesson plans with their comments. For that reason I explained that I had made up a simple questionnaire which asked the students to quantify their interest in astronomy as well as answer some preliminary questions about the material they were about to learn. The purpose of these questionnaires and the post lesson questionnaires (I hoped) was to show both an increase in interest in astronomy after I presented my lessons and to show improvement in the quality of the students answers about the material. I allowed the students about 15 minutes to complete the questionnaires and then moved on to speak more specifically about measuring distance, directly indirectly and by using estimation, beginning with small distances and working to much larger astronomical distances. Then I broke the students up into small groups asking them to discuss possible ways to indirectly measure the distance to a planet. I gave them a hint suggesting that they think about how human bodies measure distances to objects (binocular vision). Several of the groups came up with ideas similar to parallax, perhaps lacking in a few details. So we moved on to the parallax lab. I asked one of the students who had worked out a reasonable guess to explain how he thought the lab might work. Then I passed out the directions to the parallax lab. I explained briefly how the astrolabe worked. Then I let the groups work. At this point I realized, that although the directions were specific perhaps they could have been more clear, and certainly better understood if I had made sure each of the students had read the directions and understood how to work the astrolabe. My cooperating teacher suggested that he usually allows the students first to read the directions and then has one student explain the directions to the class, and then if they are still unclear allows the members of the groups to explain the directions to each other. He explained that unless a student is forced to put the directions in their own words they may not understand. Since we were near the end of class, I asked the students to clean up their materials and for homework to draw a diagram of the experiment and come up with questions about the lab. Also, for the students who better understood the lab at the beginning, I asked them to come up with ideas to improve the experiment.

Thursday, Feb 4th

In spite of my requests, many students did not have diagrams of the experiment nor did they appear to have thought about it much since the last class. However, we did have a double period so I made the best of it and used the technique suggested by my cooperating teacher. I had several students make diagrams on the board of the experiment and explain which distances were to be measured and how the astrolabe was to be used. Unfortunately, some students still had difficulty understanding…perhaps better equipment will help. However, we were able to come to several conclusions: First, our measurements were duplicable and consistent if not accurate. Students who were standing easily ten feet from the meter stick calculated distances of less than 100 centimeters however, students who were closer to the stick calculated smaller distances than those who were far away and those few student groups who had used larger base distances had more accurate answers. We discussed both human error and measurement error (imprecise equipment). So then we began to discuss how we could improve our measurements and how astronomers could improve upon that by using larger and larger base distances. We also discussed reasons why this is not the best distance indicator that astronomers can use (atmosphere and small distances). Then we talked about using standard candles as a method of distance measurement. This lead into the next lab, the super novae lab, and I explained that I had included background information on super novae and red shift for them to read for homework. I asked them to begin the supernovae in class and finish it for homework.

Friday, Feb. 5th

To my surprise, most students brought in completed graphs of supernovae distances plotted against their red shift. After a more in depth discussion of red shift I asked the students to interpret their graphs, discussing straight line fits, the slope of the line (Hubble's constant) and the implications of the y intercept (the big bang). To supplement my discussion of the big bang I used the expanding universe demonstration using enlarged transparencies to illustrate the idea of expanding simultaneously from every point. After answering a few directly related questions about Big Bang theory and red shift (including some confusion over similar symbols) I asked the students to begin filling out post-lesson questionnaires which they were then instructed to complete for homework. Then I left time to answer a few questions about astronomy in general.

Overall, I wish my directions for the parallax lab had been more clear and that the experiment had produced at least slightly more precise answers. A few students complained that the super novae lab was too repetitive and monotonous, however, I hope to eventually computerize this lab making some of the calculations less repetitive. Personally, I need to find some way to ensure student participation at home. Also I need to develop a questionnaire which better shows the change in quality of answers and interest.

March 15th:

One of the beauties of going back to high school is that you remember the elation of hearing your school mentioned on the radio for snow closing. I had exactly this experience on Monday morning and consequently had to cancel my teaching for this day. I still had the remainder of the week to teach my lesson plans, and since I had blocked extra time, the rest of the week was not uncomfortably rushed.

March 16th:

I arrived to a crowd of well rested (due only to the snow day) Sophomores, Juniors, and Seniors in first period Conceptual Physics. Several of them were abuzz with college acceptance news and worries. Luckily, their teacher Mr. Mark Volpe was able to settle them down and direct their attention to me. I had decided not to change anything drastically from the last session I taught, only to clarify the directions for the parallax lab and in general take more time with these students because they were not part of the accelerated physics program like the last group of students. I believe I was more successful with these students than the last section. Perhaps my success was due to my increased comfort level due to the repetition of the lesson, or perhaps the lesson was paced better for this level of student. In any event I would like to share the experience in more detail to illustrate how the students' attention was captured and how their understanding of cosmology grew.

I began each of three class sections with a brief introduction of myself and the MAP Satellite project. I was sure to highlight the fact that I needed the students' help with evaluating the materials they were about to use (the activities described in the lesson plans) and that their comments would ensure that the activities would be "student approved" for classrooms in the future. I then handed out the preliminary questionnaires explaining that they would help me to determine how much I taught the students versus how much they already knew. I allowed the students 15-20 minutes to complete the questionnaires and then began with a discussion of estimation of distance. For example, I asked them to estimate and then come up with a way to measure the distance to a table in the room, the flagpole in front of the school, the main street of the town, the Moon, and the planet Mars. One student hit upon the most accurate way to measure the distance to the Moon while trying to be disruptive. He suggested using the laser from his key chain to bounce off of the Moon and measure the distance somehow. Little did he know, scientists use lasers bounced off of mirrors placed on the Moon to measure very accurately the Moon's position. I then had students form groups, which had been previously assigned by their teacher, and try to diagram a way to measure the distance to Mars. After few minutes, I gave them a leading question about the human body, "How do your eyes measure the distance to something?" Many groups had a general idea how to measure the distance from this example and about one group in each class drew an excellent diagram. I asked one student from each section to put their diagram of the human eyes measuring the distance to an object and then asked another student to explain how this diagram would relate to a measurement of the distance to Mars. Since the time for a fifty minute period was just about up, I passed out the directions for the next day's Parallax lab and asked them to read them for the next day as well as write up a paragraph summary of the directions so that they were sure to process the directions as they read them. Unfortunately, even with this assignment one student said to me that she did not understand the purpose of the lab. Perhaps I should take more time to explicitly state the purpose, maybe in story form…(Your friend is stuck on Mars, you need to send a rocket to get there. Luckily, you find a preconstructed rocket site and need only program the computer with the distance to Mars to send the rocket to save her. How do you quickly measure the distance so you can save her) or in historical form, (you are a paid astronomer for Italy in the 1600's you will be rich and famous if you can calibrate the system of Astronomical Units, how do you measure the distance to Mars to begin the calibration and make your bundle?)

March 17th:

On Wednesdays, Princeton High school has shortened class periods so each class is 30 minutes. While it was not an ideal day to begin lab work, I went ahead to see if we could get through part of the parallax lab. I began by asking the students to take out their directions and paragraph summaries of the directions. In the first section, I tried having students act out the directions and then quickly reviewed them myself. In the first period class there was definitely some remaining confusion which resulted in my working individually with each group to solidify what the students were to be doing. This process was time consuming, and since the first period class also had to construct the astrolabes they did not complete the measurements in this short period. As a result of the first period's slow progress, I tried to hasten the demonstration of the lab and use of the astrolabe with the third and sixth period classes. I eliminated the student demonstration of the astrolabe, and instead spent a little longer doing my demonstration. This seemed to help somewhat although individual clarification of the directions was necessary in both sections. I still am unclear whether the problem was with the directions (i.e. they were too complicated or just confusing) or with students reading and following the directions. Perhaps the demonstration, although brief allowed the students to feel as though they did not need to read the directions word for word and therefore important steps were missed. Even though some of the parallax lab was not complete, at the end of this second class period I asked the students to read the Red Shift Background section of my web site and a page on Super novae for homework, as well as coming up with a diagram of the parallax lab, with angles and distances labeled.

March 18^{th} and 19^{th}:

Between these two days each class had three 50 minute sections, two of which were double sessions (i.e. lab days). Some sections had to finish parallax measurements, while other sections had their measurements and had to figure out their diagrams and how to calculate the distance to "Mars". Some students informed me after a few minutes that they had not had trigonometry yet…this made this lab somewhat challenging for them but after a bit of explaining I think they got the hang of it. Once the students had calculated their distances and had put their work on the board, we discussed the results of the lab. We then discussed error and some of the students weren't really convinced even of the relative accuracy. So as a class we decided that we could perform this experiment more accurately and in ways that would reduce the error, but that it would be better to find a new way to measure distance to astronomical objects.

We then discussed using Super novae explosions as standard candles. Since I conducted this part of the class as a board lecture, most of the pressure was on me, but I feel that I became much more comfortable and clear discussing this material with these students as a result of the practice I had with the previous class. I found it was necessary and helpful to write clear definitions on the board of terms we were using, saying their definitions was not enough. However, I would like to improve my organization on the board and work to not stall verbally as much as I do now. I could also work on speaking as I write on the board. After I finished this material I asked the students to begin the Super Novae lab in class. They were allowed to work in their lab groups and divide up the calculations so that the lab was not so tedious (the last class complained about that…). Depending upon how the periods fell, most students had to finish this lab and complete a graph of the data for homework.

When we next met, most of the students had completed the graph, either because they found the lab interesting, or because they were told their teacher would check it for a homework grade. In either case, a much higher percentage of students had a completed graph. Some students did have difficulty making the graph, however. They either crammed the graph together so that it was difficult to find a best fit line, or they misunderstood the redshift table because the columns weren't labeled and some of the students mistook the Supernova name for the redshift.

Overall, with an example of the graph drawn on the board a discussion of the distance modulus, redshift and their relation went well. I used both the transparency model of the big bang and a method using a group of students to explain the big bang and Hubble's constant. I could perhaps redo the transparency part to be more similar to Jim Peeble's demonstration which I recently saw. It has the same idea but includes the fact that two observers observing the same object will see a redshift which related to the distance from them (ie twice as far away twice the red shift…) Students were able to explain the outliers on the graph using dust as an explanation and were impressed by the accuracy of the published version of this graph. I then asked the students to fill out the final survey, thanked them for their participation and answered any remaining questions they had.

Conclusion

Although the production of the web site containing the lesson plans is an ongoing project that will extend beyond the completion of this thesis, there are a few points that should be made in conclusion. First, a web site that discusses cosmology is not complete without a section concerning the early universe. This web site will have a section describing ways to learn about “the Big Bang” and the early universe (hopefully) within the nest year. Second, an important part of this paper was a discussion of the methods used to evaluate curriculum materials. Although the preliminary methods discussed seem to suggest that the page is being written in a useful way, the page could certainly benefit from a more rigorous evaluation and scrutiny of the alignment of the standards with the activities. Furthermore, in the future the voice of the educational consumer will be actively sought out, especially the suggestions and opinions of high school teachers.

Overall, the feedback from students and teachers seemed positive and the lesson plans successful. The real lesson gleaned from writing this work is that teaching is hard work; teaching well is even harder work, and learning by teaching makes all the hard work worth it.

Works Consulted

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Appendix I

Questionnaire

Name: (Optional)

M F

Year in high school:

Highest level Math completed or enrolled in:

Have you had any academic exposure to astronomy? Please describe:

On a scale of 1-10 how interesting do you find astronomy? Why?

On a scale of 1-10 how hard do you think studying astronomy is? Why?

Explain the relationship between the effects of the position of the Earth and Sun during the Winter and Summer months:

Can you describe Big Bang Theory or Hubble's constant? Have you heard of them? Where did you hear of them?

In a scientific experiment, how would you describe a correct result?

What is an indirect measurement?

Can you think of a way to measure the distance to an object without touching it?

What if you knew how bright the object was?

Final Questionnaire (First Version)

Name:

M F

Year:

1. On a scale of 1-10 (10 being the most interesting) how interesting do you now find astronomy? Please recall your last rating and note any difference in rating.
2. On a Scale of 1-10 (10 being Hardest) how hard do you now find astronomy after completing two exercises in astronomical distance measurement? Please recall your last rating and note any difference in rating.
3. How were the results of our parallax lab correct in some ways even if they may not have been precise measurements?
4. Describe as best you can two different ways to make indirect distance measurements to astronomical object. Use the back if necessary.
5. Explain any relationship you can see between the two indirect distance measurements that we studied and Hubble's constant and Big Bang Theory.
6. What were our major sources of error in the Parallax Lab? Which types of error could we fix and how could we fix them? How do some of our assumptions change when we assume that we are far (the distance to a planet) from the object being measured? How does the experiment change if we are very far (the distance to another galaxy) from the object being measured?

Final Questionnaire
Name:

M F

Year:

Questions about the content of the labs (this section will help me learn what you understood from the lesson): If at any point you run out of room please write on the back.

1. How were the results of our parallax lab correct even if they may not have been precise measurements?

2. Explain, in your own words, two different ways to make indirect distance measurement to astronomical objects. Write a paragraph as if you were describing the process to a friend who had never taken astronomy, but had a test on indirect measurement the next day. You may use diagrams and number examples to help explain the process.

3. Write a few sentences connecting the terms Hubble's Constant, Big Bang theory and the two forms of indirect distance measurement we studied. Think of all the relationships you can between these concepts and write them down in sentence form.

4. What were our major sources of error in the parallax lab?

5. Which types of error could we fix (how could we fix them?) and which types could we not fix?

6. Why is parallax measurement only good for certain ranges of distances, what is that range approximately?

7. How does the effectiveness of parallax change when we try to measure something that is very, very far away (the distance to another galaxy)?

Questions about the style of the labs (this portion will let me know how well you liked the labs):

8. In comparison with before this week long lesson, I now find astronomy:

1-------------2-------------3-------------4------------5------------6-------------7
Less Interesting More Interesting

9. In comparison with before this week long lesson, I now find astronomy:

1-------------2-------------3-------------4------------5------------6-------------7
Easier than I expected Harder than I expected

10. Overall the activities in this lesson were:

1-------------2-------------3-------------4------------5------------6-------------7
Poor Excellent

11. If you were a teacher or principal how would you rate this lesson:

1-------------2-------------3-------------4------------5------------6-------------7
Poor Excellent

12. Name at least three things you liked about the lesson.

13. Name at least three ways to improve the lesson. (i.e. If your friends were going to be in my class next week how would you want me to change it before I taught them)

14. Please add any additional comments you have about the parallax lab, the supernova lab, or my teaching style in general, remember I need your feedback so that these lesson plans are fun and you learn from them. Thanks for your help –Lindsay Clark

15. Honestly, how hard did you try to complete this survey?

1-------------2-------------3-------------4------------5------------6-------------7
My very Hardest   Not hard at all

16. Honestly, How long did you spend completing this survey:

1-------------2-------------3-------------4------------5------------6-------------7
10 min   30 min   Hour or longer

Appendix II

This appendix contains three tables. The first table, Table 6, shows the three main activity sets that are contained in this lesson series along with the New Jersey Core Curriculum Content Standards and National Science Education Standards that they are aligned with. In order to align with a standard, part of the activity set must contribute to student learning of at least one progress indicator that describes the standard. The details of each standard are listed in Tables 7 and 8. Table 7 contains the National Science Education Standards and progress indicator along with a comment column that attempts to describe specific ways in which the lesson plans contribute to fulfilling the standard. Similarly, Table 8 contains the New Jersey Core Curriculum Content Standards along with their progress indicators, a column which contains the activity sets aligned with the standards and a comment column. In this comment column, there is a description of how the activity sets mentioned in the previous column contribute to the fulfillment of the progress indicators and there is a rating system for indicators as follows:

- 3 stars (***) indicate that there are several activities in the set designed to communicate the standard.
- 2 stars (**) indicate that some part of the activity set helps to partially communicate a standard or to practice the content of the standard.
- 1 star (*) indicates that some knowledge of the standard was used in the activity, but the activity was not designed specifically to teach the standard material.
- No mark ( ) indicates that this standard or indicator was not addressed specifically by any part of the lesson plan.

In both Tables 7 and 8, some standards that did not relate to the lesson plans at all were omitted (such as the NJ Core Curriculum Content Standards for World Languages). Standards were also only rated if the lesson plan was aligned with high school standards. Some of the lower level standards were included and rated because the high school standards included building upon earlier indicators. For a full listing of standards see http://www.injersey.com/Education/NJDOE/ and http://www.nap.edu/readingroom/books/nses/html.

Activity Set	The National Science Education Standards	The New Jersey Core Curriculum Content Standards
The Size of the Universe Activities	Teaching Standards A, B, C, D, E Professional Development Standards A, B, D Assessment Standards A, B, C, D, E Content Standards, Unifying Program Standards A, B, D System Standards D	Cross Content Workplace Readiness Standards 1, 2, 3, 4 Mathematics Standards 4.2, 4.4, 4.5, 4.6, 4.9, 4.10, 4.16 Science Standards 5.2, 5.5, 5.11
The Expanding Universe Activities	Teaching Standards A, B, C, D, E Professional Development Standards A, B, D Assessment Standards A, B, C, D, E Content Standards, Unifying Program Standards A, B, D System Standards D	Cross Content Workplace Readiness Standards 1, 2, 3, 4 Language Arts and Literacy Standards 3.1, 3.3 Mathematics Standards 4.1, 4.2, 4.4, 4.5, 4.6, 4.9, 4.10, 4.11, 4.12, 4.13, 4.16 Science Standards 5.2, 5.3, 5.5, 5.11
The Shape of the Universe Activities	Teaching Standards A, B, C, D, E Professional Development Standards A, B, D Assessment Standards A, B, C, D, E Content Standards, Unifying Program Standards A, B, D System Standards D	Cross Content Workplace Readiness Standards 1, 2, 3, 4 Language Arts and Literacy Standards 3.3 Mathematics Standards 4.1, 4.2, 4.4, 4.5, 4.7, 4.9, 4.10, 4.11, 4.13, 4.16 Science Standards 5.2, 5.5, 5.9, 5.10, 5.11

Table 6: Activity Sets and Aligned Education Standards

Table 7: National Science Education Standards and Indicators

Standard	Indicator	Comments
Teaching Standard A: Teachers of Science plan an inquiry based science program for their students.		These activity sets were designed to allow teacher flexibility to tailor lesson plans to specific students' interests and understanding since there are many activities that describe similar concepts. Students must learn to work together as a community of science learners to complete experiments efficiently and understand their implications as well as describing their results to others. Teachers may choose to work together in teams across disciplines and grade levels by requiring students to use a variety of communication skills to describe results to a variety of audiences.
	Develop a framework of yearlong and short-term goals for students	
	Select Science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students.	
	Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners	
	Work together as colleagues within and across disciplines and grade levels	
Teaching Standard B: Teachers of Science Guide and facilitate learning. In doing this teachers:		These activity sets were designed to encourage student inquiry. While each activity set is planned out, there is always room for the student to investigate individual inquiry. Students are required to ask questions and contemplate their answers, which encourages scientific skepticism. The group aspects of many of the activities require students to become responsible for the learning of others and also allows each student to use individual strengths to communicate results to the class.
	Focus and support inquiries while interacting with students	
	Orchestrate discourse among students about scientific ideas	
	Challenge students to accept and share responsibility for their own learning	
	Recognize and respond to student diversity and encourage all students to participate fully in science learning.	
	Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
Teaching Standard C: Teachers of Science engage in ongoing assessment of their teaching and of student learning. In doing this teachers:		In both the supernovae and parallax lab there are a variety of possible performance and content indicators to evaluate students' interest and understanding of the activity. Teachers observe and listen to students as they work individually and in small groups. "They interview students and require formal performance tasks, investigative reports, written reports, pictoral work, models, inventions, and other creative expressions of understanding."(p.38) Assessments that were tried during the development of this curriculum include asking students to write paragraphs rewording directions, and to draw diagrams which model the parallax lab. Teachers may require that students draw Hubble diagrams which chart the supernovae magnitude data and show relationships between variables. Students were interviewed as to their interest in the activity and were required to complete a formal performance task that demonstrated their newfound understanding for the big bang. Teachers are encouraged to use these types of assessments along with interactive activities to guide their further instruction. These types of assessment activities often show students which material they still have trouble with and can guide students in self-evaluation.
	Use multiple methods and systematically gather data about student understanding and ability	
	Analyze assessment data to guide teaching	
	Guide students in self-assessment	
	Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makers and the general public.	
Teaching Standard D: Teachers of Science Design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this teachers:		These activity sets do require extended lab periods to complete full investigations. Teachers can collaborate to double time and teach multiple disciplines at once. Making use of several outside resources as suggested in the activities also makes for a richer learning environment as well as providing diverse resources for the classroom.
	Structure the time available so that students are able to engage in extended investigations.	
	Create a setting for student work that is flexible and supportive of science inquiry	
	Ensure a safe working environment	
	Make the available science tools, materials, media, and technological resources accessible to the students	
	Identify and use resources outside the school	
	Engage students in designing the learning environment	
Teaching Standard E: Teachers of Science develop communities of science learners that reflect the intellectual rigor of scientific inquiry		Since these activities were written with the spirit of scientific inquiry, hopefully the teachers who use them will bring this spirit to the classroom with them. In order to do this teachers must allow students to use their

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
and the attitudes and social values conductive (Teaching Standard E: Continued) to science learning. In doing this, Teachers:		diverse strengths in group work allowing many styles and method of communication. Through collaboration students can learn from each other, and also by questioning others' arguments students can learn to question their own arguments.
	Display and demand respect for diverse ideas, skills, an experiences of all students	
	Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community	
	Nurture collaboration among students	
	Structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse	
	Model and emphasize the skills, attitudes, and values of scientific inquiry	
Teaching Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program. In doing this, teachers:		
	Plan and develop the school science program	
	Participate in the decisions concerning the allocation of time and other resources to the science program	
	Participate fully in planning and implementing professional growth and development strategies for themselves and for their colleagues	
Professional Development Standard A: Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry. Science learning experiences for teachers must:		These activities are new to teachers too, so they will be actively investigating these phenomena for the first time. The topics in cosmology today that these activities investigate are cutting edge questions that fascinate most young minds and yet are mostly unsolved problems. Often students and teachers are easily motivated to study planets and the greater universe even when physics and math are of relatively low interest levels for them. These activities are web based and easy to use to support teacher use of web technology. Teachers are encouraged to seek out these activities and others. Since data that can dramatically change what is thought about the universe today, is still being collected, what teachers may have learned even a few years ago can be enhanced and possibly refuted. Astronomy also often provides a new way of examining old problems and building on the teacher's current understanding, for example using Trigonometry in space. The teacher is always welcome to jump from these activities onto further inquisitive investigation,
		if they feel upon reflection that further inquiry is needed. If a step is needed to allow for more in depth student inquiry, please make that

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
(Professional Development Standard A: Continued)		adjustment. These activities are designed so that teachers collaborate (circumference of the earth) across the country and the school building. Please make efforts to ease workload by allowing cooperation among teachers and students.
	Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding	
	Address issues, events, problems, or topics significant in science and of interest to participants	
	Introduce teachers to scientific literature, media, and technological resources that expand their ability to access further knowledge	
	Build on the teacher's current science understanding, ability, and attitudes	
	Incorporate ongoing reflection on the process and outcomes of understanding science through inquiry	
	Encourage and support teachers in efforts to collaborate	
Professional Development Standard B: Professional Development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. Learning experiences for teachers must:		
	Connect and integrate all pertinent aspects of science and science education	
	Occur in a variety of places where effective science teaching can be illustrated and modeled, permitting teachers to struggle with real situations and expand their knowledge and skills in appropriate contexts	
	Address teachers' needs as learners and build on their current knowledge of science content, teaching and learning.	The background material sections hope to provide learning material for those teachers who need to learn more about astronomy in order to teach it.
	Use inquiry, reflection, interpretation of research, modeling, and guided practice to build understanding and skill in science teaching	
Professional Development Standard C: Professional Development for teachers of science requires building of understanding and ability for lifelong learning. Professional development activities must:		
	Provide regular, frequent opportunities for individual and	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
	collegial examination and reflection on classroom and institutional practice.	
(Professional Development Standard C: Continued)	Provide opportunities for teachers to receive feedback about their teaching and to understand, analyze, and apply that feedback to improve their practice	
	Provide opportunities for teachers to learn and use various tools and techniques for self-reflection and collegial reflection, such as peer coaching, portfolios, and journals.	
	Support the sharing of teacher experience by preparing and using mentors, teacher advisors, coaches, lead teachers, and resource teachers to provide professional development opportunities	
	Provide opportunities to know and have access to existing research and experiential knowledge	
	Provide opportunities to learn and use the skills of research to generate new knowledge about science and the teaching and learning of science	
Professional Development Standard D: Professional development programs for teachers of science must be coherent and integrated. Quality preservice and inservice programs are characterized by:		These activities were designed both to be congruent with National Science Education Standards and to be part of a NASA funded Public Outreach Program. This required collaboration between Princeton University Professors, Undergraduate students, Public High school teachers and high school students. I have also tried to assess the program myself from the perspectives of the groups of people involved through a variety of questionnaires and research projects. Since both of these formative bodies are relatively new they do not have standard evaluation programs in place. The best guidelines have been these standards and I have worked hard to write the lessons in their spirit.
	Clear, shared goals based on a vision of science learning, teaching, and teacher development congruent with the National Science Education Standards.	
	Integration and coordination of the program components so that understanding and the ability can be built over time, reinforced continuously, and practiced in a variety of situations	
	Options that recognize the developmental nature of teacher professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency	
	Collaboration among the people involved in programs, including teachers, teacher educators, teacher unions, scientists, administrators, policy makers, members of professional and scientific organizations, parents, and businesspeople, with clear respect for the perspectives and expertise of each	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
	Recognition of the history, culture and organization of the school environment	
(Professional Development Standard D: Continued)	Continuous program assessment that captures the perspectives of all those involved, uses a variety of strategies, focuses on the process and effects of the program, and feeds directly into the program improvement and evaluation	
Assessment Standard A: Assessments must be consistent with the decisions they are designed to inform		Since I am trying my best to encourage teachers to follow the curricula and methods suggested by the NSES and NJCCCS, I am doing my best to demonstrate the compatibility of these lessons with these standards.
	Assessments are deliberately designed	
	Assessments have explicitly stated purposes	
	The relationship between the decisions and the data is clear	
	Assessment procedures are internally consistent	
Assessment Standard B: Achievement and opportunity to learn science must be assessed		Although most of these activities are designed to focus on a rather narrow set of curricula standards, they can be used to fulfill several others. Achievement data may not focus on the content of these lessons, however, the methods of inquiry and thought encouraged by the lesson plans will continue to be an important part of all science learning and endeavors.
	Achievement data collected focus on the science content that is most important for students to learn	
	Opportunity to learn data collected focus on the most powerful indicators	
	Equal attention must be given to the assessment of opportunity to learn and to the assessment of student achievement	
Assessment Standard C: The technical quality of the data collected is well matched to the decisions and actions taken on the basis of their interpretation.		Assessments based upon activities that use scientific inquiry must also use this feature. Assessment tasks based upon these lesson plans should also encourage inquisitive thought.
	The feature that is claimed to be measured is actually measured	
	Assessment tasks are authentic	
	An individual student's performance is similar on two or more tasks that claim to measure the same aspect of student achievement	
	Students have adequate opportunity to demonstrate their achievements	
	Assessment tasks and methods of presenting them provide data that are sufficiently stable to lead to the same decisions if used at different times	
Assessment Standard D: Assessment		These activities do not suggest specific assessments; however, any

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
practices must be fair		assessments used should certainly be aligned with these standards.
(Assessment Standard D: Continued)	Assessment tasks must be reviewed for the use of stereotypes, for assumptions that reflect the perspectives or experiences of a particular group, for language that might be offensive to a particular group, and for other features that might distract students from the intended task	
	Large scale assessments must use statistical techniques to identify potential bias among sub-groups	
	Assessment tasks must be appropriately modified to accommodate the needs of students with physical disabilities, learning disabilities, or limited English proficiency	
	Assessment tasks must be set in a variety of contexts, be engaging to students with different interests and experiences, and must not assume the perspective of a particular gender, racial, or ethnic group	
Assessment Standard E: The inferences made from assessments about student achievement and opportunity to learn must be sound		
	When making inferences from assessment data about student achievement and opportunity to learn science, explicit reference needs to be made to the assumptions on which the inferences are based	
Content Standard, Unifying		
	As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:	
	Systems, order and organization	Students learn about planets, solar systems, galaxies, clusters, and the universe in the scaling activity.
	Evidence, models and explanation	Making the Hubble diagram in the Super Nova Activity shows evidence for and an explanation of the Big Bang.
	Constancy, change and measurement	The Shape of the universe activity uses the concept of conservation of energy in the universe, and the scaling the universe activity shows the constancy of the speed of light.
	Evolution and equilibrium	The shape of the universe activity talks about the evolution of the universe and the possible equilibrium of energetic forces.
	Form and function	
Content Standard D, Earth and Space Science 5-8, As a result of their activities in grades 5-8 all students should develop an understanding of:		Content Standards will be examined in detail in the next Table.
	Structure of the earth system	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
	Earth's history	
	Earth in the solar system	
Content Standard A: As a result of their activities in grades 9-12, all students should develop:		
	Abilities necessary to do scientific inquiry	
(Content Standard A: Continued)	Understandings about scientific inquiry	
Content Standard B: As a result of their activities in grades 9-12, all students should develop an understanding of:		
	Structure of atoms	
	Structure and properties of matter	
	Chemical reactions	
	Motions and forces	
	Conservation of energy and increase in disorder	
	Interactions of energy and matter	
Content Standard C: As a result of their activities in grades 9-12 all students should develop an understanding of		
	The cell	
	Molecular basis of heredity	
	Biological evolution	
	Interdependence of organisms	
	Matter, energy, and organization in living systems	
	Behavior of organisms	
Content Standard D: As a result of their activities in grades 9-12, all students should develop an understanding of:		
	Energy in the earth system	
	Geochemical cycles	
	Origin and evolution of the earth system	
	Origin and evolution of the universe	
Content Standard E: As a result of activities in grades 9-12, all students should develop		
	Abilities of technological design	
	Understandings about science and technology	
Content standard F: As a result of activities in grades 9-12, all students should develop understanding of:		
	Personal and community health	
	Population growth	
	Natural resources	
	Environmental quality	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
	Natural and human induces hazards	
	Science and technology in local, national and global challenges	
Content Standard G: As a result of activities in grades 9-12, all students should develop understanding of:		
	Science as human endeavor	
(Content Standard G: Continued)	Nature of scientific knowledge	
	Historical perspectives	
Program Standard A: All elements of the K-12 science program must be consistent with the other NSES and with one another and developed within and across grade levels to meet a clearly stated set of goals		Since these activities and materials have been designed with the NSES in mind, hopefully they will fit well into a whole science program based on the Standards.
	In an effective science program, a set of clear goals and expectations for students must be used to guide the design, implementation, and assessment of all elements of the science program	
	Curriculum frameworks should be used to guide the selection and development of units and courses of study	
	Teaching practices need to be consistent with the goals and curriculum framework	
	Assessment policies and practices should be aligned with the goals, student expectations, and curriculum frameworks	
	Support systems and formal and informal expectations of teachers must be aligned with the goals, student expectations and curriculum frameworks	
	Responsibility needs to be clearly defined for determining, supporting, maintaining, and upgrading all elements of the science program	
Program Standard B: The program of study in science for all students should be developmentally appropriate, interesting, and relevant to the students' lives; emphasize student understanding through inquiry; and be connected with other school subjects.		These activities are aligned with several standards and inquiry using material that is often interesting to students as well as being connected to other subjects such as math and even English.
	The program of study should include all of the content standards	
	Science content must be embedded in a variety of curriculum patterns that are developmentally appropriate, interesting and relevant to students' lives	
	The program of study must emphasize student understanding through inquiry	

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
	The program of study in science should connect to other school subjects	
Program Standard D: The K-12 science program must give students access to appropriate and sufficient resources, including quality teachers, time materials and equipment, adequate and safe space, ad the community		These activities were written partially to provide outreach from a NASA mission. They can help students reach beyond the classroom. Web based activities also give students exposure to computers and the internet.
(Program Standard D: Continued)	The most important resource is professional teachers	
	Time is a major resource in a science program	
	Conducting scientific inquiry requires that the students have easy, equitable, and frequent opportunities to use a wide range of equipment, materials, supplies, and other resources for experimentation and direct investigation of phenomena	
	Collaborative inquiry requires adequate and safe space	
	Good science programs require access to the world beyond the classroom	
Program Standard E: All students in the K-12 science program must have equitable access to opportunities to achieve the National Science Education Standards		
Program Standard F: Schools must work as communities that encourage, support, and sustain teachers as they implement an effective science program		
	Schools must explicitly support reform efforts in an atmosphere of openness and trust that encourages collegiality	
	Regular time needs to be provided and teachers encouraged to discuss, reflect, and conduct research around science education reform	
	Teachers must be supported in creating and being members of networks of reform	
	An effective leadership structure that includes teachers must be in place	
System Standard A: Policies that influence the practice of science education must be congruent with the program, teaching, professional development, assessment, and content standards while allowing for adaptation to local circumstances.		

Table 7: National Science Education Standards and Indicators - Continued

Standard	Indicator	Comments
System Standard B: Policies that influence science education should be coordinated within and across agencies, institutions and organizations		
System Standard C: Policies need to be sustained over sufficient time to provide the continuity necessary to bring about the changes required by the standards		
System Standard D: Policies must be (System Standard D: Continued) supported by resources		These activities have been supported and partially funded by NASA, specifically the MAP Satellite mission.
System Standard E: Science education policies must be equitable		
System Standard F: All policy instruments must be reviewed for possible unintended effects on the classroom practice of science education		
System Standard G: Responsible individuals must take the opportunity afforded by the standards-based reform movement to achieve the new vision of science education portrayed in the standards		

Table 8: new Jersey Core Curriculum Content Standards and Indicators

Standard	Indicator	Aligned Activities	Comments
Cross Content Workplace Readiness Standard 1: All students will develop career planning and workplace readiness skills		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	These activities may help students develop an early interest in astronomy or other sciences that allows them the opportunity to more easily pursue a career in those fields.
All Students:	Demonstrate employability skills and work habits, such as work ethic, dependability, promptness, and getting along with others, needed to get and keep a job.		*
	Describe the importance of personal skills and attitudes to job success		
	Identify career interests, abilities and skills		**
	Develop an individual career plan		
	Identify skills that are transferable from one occupation to another		
	Select a career major and appropriate accompanying courses		**
	Describe the importance of academic and occupational skills to achievement in the work world		
	Demonstrate occupational skills developed through structured learning experiences, such as volunteer, community service, and work based experiences or part-time employment		
	Identify job openings		
	Prepare a resume and complete job applications		
	Demonstrate skills and attitudes necessary for a successful job interview		
	Demonstrate consumer and other financial skills		
Cross Content Workplace Readiness Standard 2: All students will use information, technology and other tools		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	These activities are designed so students must learn to choose from a variety of technologies to find and process data in order to communicate the results of their experiments to the class. Specifically they can use web searches, presentation programs, word processing, and charting programs to communicate their results from lab activities as well as calculators and spreadsheets to find results.

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
All Students:	Understand how technological systems function		*
(Cross Content Workplace Readiness Standard 2: Continued)	Select appropriate tools and technology for specific activities		*
	Demonstrate skills needed to effectively access and use technology-based materials through keyboarding, trouble-shooting, and retrieving and managing information		**
	Develop, search and manipulate databases		
	Access technology based communication and information systems		
	Access and assess information on specific topics using both technological (e.g. computer, telephone, satellite) and print resources available in libraries or media centers		**
	Use technology and other tools to solve problems, collect data, and make decisions		**
	Use technology and other tools, including word processing, spreadsheet and presentation programs, and print or graphic utilities, to produce products		**
	Use technology to present designs and results of investigations		**
	Discuss problems related to the increasing use of technologies		
Cross Content Workplace Readiness Standard 3: All students will use critical thinking, decision making and problem solving skills		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	These activities are designed to encourage critical thinking and problem solving skills. Specifically, students must identify patterns in the data they receive about supernovae, they must validate their own thinking by questioning reasons given to explain the results. They are also asked to redesign the parallax experiment to reduce error.
All Students:	Recognize and define a problem, or clarify decisions to be made		*
	Use models, relationships, and observations to clarify problems and potential solutions		*
	Formulate questions and hypotheses		*

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Identify and access resources, sources of information, and services in the school and the community		*
	Use the library media center as a critical resource for inquiry and assessment of print and non-print materials		*
(Cross Content Workplace Readiness Standard 3: Continued)	Plan experiments		**
	Conduct systematic observations		*
	Organize, synthesize, and evaluate information for appropriateness and completeness		**
	Identify patterns and investigate relationships		**
	Monitor and validate their own thinking		**
	Identify and evaluate the validity of alternative solutions		*
	Interpret and analyze data to draw conclusions		**
	Select and apply appropriate solutions to problem-solving and decision-making solutions		
	Evaluate the effectiveness of various solutions		
	Apply problem solving skills to original and creative design projects		
Cross Content Workplace Readiness Standard 4: All students will demonstrate self-management skills		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	Since most of these activities are completed in groups and under some time constraints, students must learn how to effectively complete tasks in groups. They must ensure that each step is done well and should learn to constructively criticize the work of other group members.
All Students:	Set short and long term goals		*
	Work cooperatively with others to accomplish a task		**
	Evaluate their own actions and accomplishments		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Describe constructive responses to criticism		*
	Provide constructive criticism to others		*
	Describe actions which demonstrate respect for people of different races, ages, religions, ethnicity and gender		
	Describe the roles people play in groups		
(Cross Content Workplace Readiness Standard 4: Continued)	Demonstrate refusal skills		
	Use time efficiently and effectively		*
	Apply study skills to expand their own knowledge and skills		
	Describe how ability, effort and achievement are interrelated		
Cross Content Workplace Readiness Standard 5: All students will apply safety principles			
Language Arts and Literacy Standard 3.1: All students will speak for a variety of real purposes and audiences		The Expanding Universe	The debate activity, which is located in the expanding universe section, requires that students prepare a well-researched extemporaneous speech to debate the size of the universe as in the 1920's.
By the end of grade 12:	Identify the elements of debate		
	Prepare for and participate in structured debates and panel discussions		**
	Present an extemporaneous speech		**
	Demonstrate interview skills in real life situations, such as college admissions or employment		
Language Arts and Literacy Standard 3.3: All students will write in clear, concise organized language that varies in content and form for different audiences and purposes		The Expanding Universe The Shape of the Universe	Students will be asked to make presentations or write paragraphs explain the results of a lab activity, similar to the articles written by professional scientists.
By the end of grade 12:	Write for real audiences and purposes		**
Mathematics Standard 4.1: All Students Will Develop The Ability To		The Expanding Universe The Shape of the Universe	The supernovae activity and the shape of the universe section use

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Pose And Solve Mathematical Problems In Mathematics, Other Disciplines, And Everyday Experiences			discovery oriented and inquiry based approaches to help students apply math to the discipline of astronomy.
By the end of grade 12:	Use discovery-oriented, inquiry-based, and problem-centered approaches to investigate and understand the mathematical content appropriate to the high school grades.		**
	Recognize, formulate, and solve problems arising from mathematical situations, everyday experiences, applications to other disciplines, and career applications.		**
(Mathematics Standard 1: Continued)	Monitor their own progress toward problem solutions.		*
	Explore the validity and efficiency of various problem-posing and problem-solving strategies, and develop alternative strategies and generalizations as needed.		*
Mathematics Standard 4.2: All Students Will Communicate Mathematically Through Written, Oral, Symbolic, And Visual Forms Of Expression		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	The Supernovae activity and other expanding universe activities require that students read write and speak about their interpretations of graphical evidence for the Big Bang. These skills build on a number of the following indicators. Many activities in all three activity sections require that students share their results using many forms of communication.
Grade 4:	Discuss, listen, represent, read, and write as vital activities in their learning and use of mathematics.		**
	Identify and explain key mathematical concepts, and model situations using oral, written, concrete, pictorial, and graphical methods.		**
	Represent and communicate mathematical ideas through the use of learning tools such as calculators, computers, and manipulatives.		**
	Engage in mathematical brainstorming and discussions by asking questions, making conjectures, and suggesting strategies for solving problems.		**
	Explain their own mathematical work to others, and justify their reasoning and conclusions.		**

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Grade 8:	Identify and explain key mathematical concepts and model situations using geometric and algebraic methods.		**
	Use mathematical language and symbols to represent problem situations, and recognize the economy and power of mathematical symbolism and its role in the development of mathematics		*
	Analyze, evaluate, and explain mathematical arguments and conclusions presented by others.		**
Grade 12: Build on all above plus:	Formulate questions, conjectures, and generalizations about data, information, and problem situations.		**
	Reflect on and clarify their thinking so as to present convincing arguments for their conclusions.		**
Mathematics Standard 4.3: All (Mathematics Standard 4.3: Continued) Students Will Connect Mathematics To Other Learning By Understanding The Interrelationships Of Mathematical Ideas And The Roles That Mathematics And Mathematical Modeling Play In Other Disciplines And In Life			
Grade 4:	View mathematics as an integrated whole rather than as a series of disconnected topics and rules.		
	Relate mathematical procedures to their underlying concepts.		
	Use models, calculators, and other mathematical tools to demonstrate the connections among various equivalent graphical, concrete, and verbal representations of mathematical concepts.		
	Explore problems and describe and confirm results using various representations.		
	Use one mathematical idea to extend understanding of another.		
	Recognize the connections between mathematics and other disciplines, and apply mathematical thinking and problem solving in those areas.		
	Recognize the role of mathematics in their daily lives and in society.		
Grade 8:	Recognize and apply unifying concepts and processes, which are woven throughout mathematics.		
	Use the process of mathematical modeling in mathematics		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	and other disciplines, and demonstrate understanding of its methodology, strengths, and limitations.		
	Apply mathematics in their daily lives and in career-based contexts.		
	Recognize situations in other disciplines in which mathematical models may be applicable, and apply appropriate models, mathematical reasoning, and problem solving to those situations.		
Grade 12:	Recognize how mathematics responds to the changing needs of society, through the study of the history of mathematics.		
Mathematics Standard 4.4: All Students Will Develop Reasoning Ability And Will Become Self-Reliant, Independent Mathematical Thinkers (Mathematics Standard 4.4: Continued)		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	Many of the lesson plans, such as Mapping the Solar System and the Parallax and Supernovae Labs, require that students check their answers and results from activities using only logic and other experimental tests of their results. Students must also use mathematical models to predict the behaviors of the universe in the Shape of the Universe section.
Grade 4:	Make educated guesses and test them for correctness.		
	Draw logical conclusions and make generalizations.		**
	Use models, known facts, properties, and relationships to explain their thinking.		
	Justify answers and solution processes in a variety of problems.		
	Analyze mathematical situations by recognizing and using patterns and relationships		**
Grade 8:	Make conjectures based on observation and information, and test mathematical conjectures and arguments.		
	Justify, in clear and organized form, answers and solution processes in a variety of problems.		
	Follow and construct logical arguments, and judge their validity.		*
	Recognize and use deductive and inductive reasoning in all areas of mathematics.		
	Utilize mathematical reasoning skills in other disciplines and in their lives.		*

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Use reasoning rather than relying on an answer-key to check the correctness of solutions to problems.		**
Grade 12: building on 2, 5, 8, 9, 10, 11 above:	Make conjectures based on observation and information, and test mathematical conjectures, arguments, and proofs.		**
	Formulate counter-examples to disprove an argument.		**
Mathematics Standard 4.5: All Students Will Regularly And Routinely Use Calculators, Computers, Manipulatives, And Other Mathematical Tools To Enhance Mathematical Thinking, Understanding, And Power		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	Many of these activities can be adapted so that results can be determined and communicated with technology. Some activities are even designed to be completed online.
Grade 4:	Select and use calculators, software, manipulatives, and other tools based on their utility and limitations and on the problem situation.		
	Use physical objects and manipulatives to model problem situations, and to develop and explain mathematical concepts involving number, space, and data.		
(Mathematics Standard 4.5: Continued)	Use a variety of technologies to discover number patterns, demonstrate number sense, and visualize geometric objects and concepts.		
	Use a variety of tools to measure mathematical and physical objects in the world around them.		
	Use technology to gather, analyze, and display mathematical data and information.		**
Grade 8:	Use a variety of technologies to evaluate and validate problem solutions, and to investigate the properties of functions and their graphs.		
	Use computer spreadsheets and graphing programs to organize and display quantitative information and to investigate properties of functions.		**
Grade 12: building on 1,2,3,5,7 above:	Use calculators and computers effectively and efficiently in applying mathematical concepts and principles to various types of problems.		**
Mathematics Standard 4.6: All Students Will Develop Number Sense And An Ability To Represent Numbers In A Variety Of Forms And Use Numbers In Diverse Situations			
Grade 4:	Use real-life experiences, physical materials, and technology		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	to construct meanings for whole numbers, commonly used fractions, and decimals .		
	Develop an understanding of place value concepts and numeration in relationship to counting and grouping.		
	See patterns in number sequences, and use pattern-based thinking to understand extensions of the number system .		
	Develop a sense of the magnitudes of whole numbers, commonly used fractions, and decimals .		
	Understand the various uses of numbers including counting, measuring, labeling, and indicating location .		
	Count and perform simple computations with money.		
	Use models to relate whole numbers, commonly used fractions, and decimals to each other, and to represent equivalent forms of the same number .		
	Compare and order whole numbers, commonly used fractions, and decimals .		
	Explore real-life settings which give rise to negative numbers.		
Grade 8:	Understand money notations, count and compute money, and recognize the decimal nature of United States currency .		
	Extend their understanding of the number system by constructing meanings for integers, rational numbers, percents, exponents, roots, absolute values, and numbers represented in scientific notation .		
	Develop number sense necessary for estimation.		
(Mathematics Standard 4.6: Continued)	Expand the sense of magnitudes of different number types to include integers, rational numbers, and roots .		
	Understand and apply ratios, proportions, and percents in a variety of situations .		
	Develop and use order relations for integers and rational numbers.		
	Recognize and describe patterns in both finite and infinite number sequences involving whole numbers, rational numbers, and integers .		
	Develop and apply number theory concepts, such as primes, factors, and multiples, in real-world and mathematical problem situations .		
	Investigate the relationships among fractions, decimals, and percents, and use all of them appropriately .		
	Identify, derive, and compare properties of numbers .		
Grade 12:	Extend their understanding of the number system to include real numbers and an awareness of other number systems.		
	Develop conjectures and informal proofs of properties of number systems and sets of numbers.		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Extend their intuitive grasp of number relationships, uses, and interpretations, and develop an ability to work with rational and irrational numbers .		
	Explore a variety of infinite sequences and informally evaluate their limits.		
Mathematics Standard 4.7: All Students Will Develop Spatial Sense And An Ability To Use Geometric Properties And Relationships To Solve Problems In Mathematics And In Everyday Life		The Shape of the Universe	Both the parallax lab and Shape of the Universe Activities require high levels of mathematics. The parallax Lab uses trigonometry and the Shape of the Universe Activities explore curvature of shapes, properties of parallel lines in Euclidean and Non-Euclidean Geometries, and they show applications of geometry.
Grade 4:	Explore spatial relationships such as the direction, orientation, and perspectives of objects in space, their relative shapes and sizes, and the relations between objects and their shadows or projections.		*
	Explore relationships among shapes, such as congruence, symmetry, similarity, and self-similarity .		
	Explore properties of three- and two-dimensional shapes using concrete objects, drawings, and computer graphics .		
	Use properties of three- and two-dimensional shapes to identify, classify, and describe shapes .		*
	Investigate and predict the results of combining, subdividing, and changing shapes .		
(Mathematics Standard 4.7: Continued)	Use tessellations to explore properties of geometric shapes and their relationships to the concepts of area and perimeter.		
	Explore geometric transformations such as rotations (turns), reflections (flips), and translations (slides) .		
	Develop the concepts of coordinates and paths, using maps, tables, and grids.		
	Understand the variety of ways in which geometric shapes and objects can be measured.		
	Investigate the occurrence of geometry in nature, art, and other areas .		**
Grade 8:	Relate two-dimensional and three-dimensional geometry using shadows, perspectives, projections and maps .		**
	Understand and apply the concepts of symmetry, similarity and congruence .		
	Identify, describe, compare, and classify plane and solid		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	geometric figures .		
	Understand the properties of lines and planes, including parallel and perpendicular lines and planes, and intersecting lines and planes and their angles of incidence .		**
	Explore the relationships among geometric transformations (translations, reflections, rotations, and dilations), tessellations (tilings), and congruence and similarity .		
	Develop, understand, and apply a variety of strategies for determining perimeter, area, surface area, angle measure, and volume .		**
Grade 12: building on 16, 19 above:	Understand and apply the Pythagorean Theorem.		**
	Explore patterns produced by processes of geometric change, relating iteration, approximation, and fractals .		
	Investigate, explore, and describe geometry in nature and real-world applications, using models, manipulatives, and appropriate technology .		**
	Understand and apply properties involving angles, parallel lines, and perpendicular lines .		**
	Analyze properties of three-dimensional shapes by constructing models and by drawing and interpreting two-dimensional representations of them.		**
	Use transformations, coordinates, and vectors to solve problems in Euclidean geometry .		**
	Use basic trigonometric ratios to solve problems involving indirect measurement.		**
	Solve real-world and mathematical problems using geometric models.		**
(Mathematics Standard 4.7: Continued)	Use inductive and deductive reasoning to solve problems and to present reasonable explanations of and justifications for the solutions.		
	Analyze patterns produced by processes of geometric change, and express them in terms of iteration, approximation, limits, self-similarity, and fractals .		
	Explore applications of other geometries in real-world contexts.		**
Mathematics Standard 4.8: All Students Will Understand, Select, And Apply Various Methods Of Performing Numerical Operations			

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Grade 4:	Develop meaning for the four basic arithmetic operations by modeling and discussing a variety of problems.		
	Develop proficiency with and memorize basic number facts using a variety of fact strategies (such as counting on and doubles) .		
	Construct, use, and explain procedures for performing whole number calculations in the various methods of computation .		
	Use models to explore operations with fractions and decimals.		
	Use a variety of mental computation and estimation techniques.		
	Select and use appropriate computational methods from mental math, estimation, paper- and-pencil, and calculator methods, and check the reasonableness of results .		
	Understand and use relationships among operations and properties of operations.		
Grade 8:	Extend their understanding and use of arithmetic operations to fractions, decimals, integers, and rational numbers .		
	Extend their understanding of basic arithmetic operations on whole numbers to include powers and roots.		
	Develop, apply, and explain procedures for computation and estimation with whole numbers, fractions, decimals, integers, and rational numbers .		
	Develop, apply, and explain methods for solving problems involving proportions and percents .		
	Understand and apply the standard algebraic order of operations.		
Grade 12: building on 6 above:	Extend their understanding and use of operations to real numbers and algebraic procedures.		
	Develop, apply, and explain methods for solving problems involving factorials, exponents, and matrices .		
Mathematics Standard 4.9: All Students Will Develop An (Mathematics Standard 4.9: Continued) Understanding Of And Will Use Measurement To Describe And Analyze Phenomena		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	Many of these activities involve indirect measurement in the context of professional astronomy. Students are asked to judge the error in their results and whether or not a lab was successful. Measurement conversion is also an important feature of the scaling activity.
Grade 4:	Use and describe measures of length, distance, capacity, weight, area, volume, time, and temperature .		
	Compare and order objects according to some measurable		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	attribute.		
	Recognize the need for a uniform unit of measure.		**
	Develop and use personal referents for standard units of measure (such as the width of a finger to approximate a centimeter).		
	Select and use appropriate standard and non-standard units of measurement to solve real-life problems.		**
	Understand and incorporate estimation and repeated measures in measurement activities.		
Grade 8:	Use estimated and actual measurements to describe and compare phenomena.		**
	Read and interpret various scales, including those based on number lines and maps .		
	Determine the degree of accuracy needed in a given situation and choose units accordingly.		
	Understand that all measurements of continuous quantities are approximate.		
	Develop formulas and procedures for solving problems related to measurement.		
	Explore situations involving quantities, which cannot be measured directly or conveniently.		**
	Convert measurement units from one form to another, and carry out calculations that involve various units of measurement .		**
	Understand and apply measurement in their own lives and in other subject areas.		
	Understand and explain the impact of the change of an object's linear dimensions on its perimeter, area, or volume .		
	Apply their knowledge of measurement to the construction of a variety of two- and three-dimensional figures.		
Grade 12:	Use techniques of algebra, geometry, and trigonometry to measure quantities indirectly .		**
(Mathematics Standard 4.9: Continued)	Use measurement appropriately in other subject areas and career-based contexts.		**
	Choose appropriate techniques and tools to measure quantities in order to achieve specified degrees of precision, accuracy, and error (or tolerance) of measurements .		**
Mathematics Standard 4.10: All Students Will Use A Variety Of			The scaling activity uses many strategies to estimate scale. Both

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Estimation Strategies And Recognize Situations In Which Estimation Is Appropriate			the Parallax lab and the Supernovae lab require estimation of error. The Supernovae Lab uses real data to predict the behavior of the universe on a large scale.
Grade 4:	Judge without counting whether a set of objects has less than, more than, or the same number of objects as a reference set .		
	Use personal referents, such as the width of a finger as one centimeter, for estimations with measurement .		*
	Visually estimate length, area, volume, or angle measure .		
	Explore, construct, and use a variety of estimation strategies .		*
	Recognize when estimation is appropriate, and understand the usefulness of an estimate as distinct from an exact answer .		
	Determine the reasonableness of an answer by estimating the result of operations.		
	Apply estimation in working with quantities, measurement, time, computation, and problem solving .		*
Grade 8:	Develop, apply, and explain a variety of different estimation strategies in problem situations involving quantities and measurement .		
	Use equivalent representations of numbers such as fractions, decimals, and percents to facilitate estimation .		
	Determine whether a given estimate is an overestimate or an underestimate.		
Grade12: building on 6 above:	Estimate probabilities and predict outcomes from real-world data.		**
	Recognize the limitations of estimation, assess the amount of error resulting from estimation, and determine whether the error is within acceptable tolerance limits .		**
Mathematics Standard 4.11: All Students Will Develop An Understanding Of Patterns, (Mathematics Standard 4.11: Continued) Relationships, And Functions And Will Use Them To Represent And Explain Real-World Phenomena		The Expanding Universe The Shape of the Universe	In the Expanding Universe Activities, students must analyze graphs in order to understand the evolution of the universe.

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Grade 4:	Reproduce, extend, create, and describe patterns and sequences using a variety of materials .		
	Use tables, rules, variables, open sentences, and graphs to describe patterns and other relationships .		
	Use concrete and pictorial models to explore the basic concept of a function.		
	Observe and explain how a change in one physical quantity can produce a corresponding change in another.		
	Observe and recognize examples of patterns, relationships, and functions in other disciplines and contexts .		
	Form and verify generalizations based on observations of patterns and relationships.		
Grade 8:	Represent and describe mathematical relationships with tables, rules, simple equations, and graphs .		**
	Understand and describe the relationships among various representations of patterns and functions.		
	Use patterns, relationships, and functions to model situations and to solve problems in mathematics and in other subject areas .		
	Analyze functional relationships to explain how a change in one quantity results in a change in another.		
	Understand and describe the general behavior of functions.		
	Use patterns, relationships, and linear functions to model situations in mathematics and in other areas .		
	Develop, analyze, and explain arithmetic sequences .		
Grade 12:	Analyze and describe how a change in an independent variable can produce a change in a dependent variable.		
	Use polynomial, rational, trigonometric, and exponential functions to model real-world phenomena .		**
	Recognize that a variety of phenomena can be modeled by the same type of function.		
	Analyze and explain the general properties and behavior of functions, and use appropriate graphing technologies to represent them .		**
	Analyze the effects of changes in parameters on the graphs of functions.		**
	Understand the role of functions as a unifying concept in mathematics.		*
Mathematics Standard 4.12: All (Mathematics Standard 4.12: Continued)		The Expanding Universe	In the Expanding Universe Activities, students are asked to draw a best fit line, interpret bias of

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Students Will Develop An Understanding Of Statistics And Probability And Will Use Them To Describe Sets Of Data, Model Situations, And Support Appropriate Inferences And Arguments			data points and explain the meaning of a fitted curve.
Grade 4:	Formulate and solve problems that involve collecting, organizing, and analyzing data .		
	Generate and analyze data obtained using chance devices such as spinners and dice.		
	Make inferences and formulate hypotheses based on data.		
	Understand and informally use the concepts of range, mean, mode, and median .		
	Construct, read, and interpret displays of data such as pictographs, bar graphs, circle graphs, tables, and lists .		
	Determine the probability of a simple event, assuming equally likely outcomes .		
	Make predictions that are based on intuitive, experimental, and theoretical probabilities .		
	Use concepts of certainty, fairness, and chance to discuss the probability of actual events .		
Grade 8:	Generate, collect, organize, and analyze data and represent this data in tables, charts, and graphs .		**
	Select and use appropriate graphical representations and measures of central tendency (mean, mode and median) for sets of data .		
	Make inferences and formulate and evaluate arguments based on data analysis and data displays.		
	Use lines of best fit to interpolate and predict from data.		**
	Determine the probability of a compound event.		
	Model situations involving probability, such as genetics, using both simulations and theoretical models .		
	Use models of probability to predict events based on actual data.		
	Interpret probabilities as ratios and percents.		
Grade 12:	Estimate probabilities and predict outcomes from actual data.		**
	Understand sampling and recognize its role in statistical claims.		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Evaluate bias, accuracy, and reasonableness of data in real-world contexts .		**
(Mathematics Standard 4.12: Continued)	Understand and apply measures of dispersion and correlation.		
	Design a statistical experiment to study a problem, conduct the experiment, and interpret and communicate the outcomes.		
	Make predictions using curve fitting and numerical procedures to interpolate and extrapolate from known data.		**
	Use relative frequency and probability, as appropriate, to represent and solve problems involving uncertainty .		
	Use simulations to estimate probabilities.		
	Create and interpret discrete and continuous probability distributions, and understand their application to real-world situations .		
	Describe the normal curve in general terms, and use its properties to answer questions about sets of data that are assumed to be normally distributed .		
	Understand and use the law of large numbers (that experimental results tend to approach theoretical probabilities after a large number of trials).		
Mathematics Standard 4.13: All Students Will Develop An Understanding Of Algebraic Concepts And Processes And Will Use Them To Represent And Analyze Relationships Among Variable Quantities And To Solve Problems		The Expanding Universe The Shape of the Universe	The Shape of the Universe Activity gives graphical and geometrical meaning to algebraic solutions for the expansion of the universe.
Grade 4:	Understand and represent numerical situations using variables, expressions, and number sentences .		
	Represent situations and number patterns with concrete materials, tables, graphs, verbal rules, and number sentences, and translate from one to another .		
	Understand and use properties of operations and numbers.		
	Construct and solve open sentences (example: 3 + ___ = 7) that describe real-life situations.		
Grade 8:	Understand and use variables, expressions, equations, and inequalities .		
	Represent situations and number patterns with concrete materials, tables, graphs, verbal rules, and standard algebraic notation .		
	Use graphing techniques on a number line to model both		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	absolute value and arithmetic operations.		
	Analyze tables and graphs to identify properties and relationships.		
	Understand and use the rectangular coordinate system.		
(Mathematics Standard 4.13: Continued)	Solve simple linear equations using concrete, informal, and graphical methods, as well as appropriate paper-and-pencil techniques .		
	Explore linear equations through the use of calculators, computers, and other technology .		
	Investigate inequalities and nonlinear equations informally.		
	Draw freehand sketches of, and interpret, graphs which model real phenomena .		
Grade 12:	Model and solve problems that involve varying quantities using variables, expressions, equations, inequalities, absolute values, vectors, and matrices .		*
	Use tables and graphs as tools to interpret expressions, equations, and inequalities .		**
	Develop, explain, use, and analyze procedures for operating on algebraic expressions and matrices .		
	Solve equations and inequalities of varying degrees using graphing calculators and computers as well as appropriate paper-and-pencil techniques.		
	Understand the logic and purposes of algebraic procedures.		
	Interpret algebraic equations and inequalities geometrically, and describe geometric objects algebraically .		**
Mathematics Standard 4.14: All Students Will Apply The Concepts And Methods Of Discrete Mathematics To Model And Explore A Variety Of Practical Situations.			
Grade 4:	Explore a variety of puzzles, games, and counting problems		
	Use networks and tree diagrams to represent everyday situations.		
	Identify and investigate sequences and patterns found in nature, art, and music .		
	Investigate ways to represent and classify data according to attributes, such as shape or color, and relationships, and discuss the purpose and usefulness of such classification .		
	Follow, devise, and describe practical lists of instructions .		
Grade 8:	Use systematic listing, counting, and reasoning in a variety of different contexts .		
	Recognize common discrete mathematical models, explore		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	their properties, and design them for specific situations .		
	Experiment with iterative and recursive processes, with the aid of calculators and computers .		
	Explore methods for storing, processing, and communicating information .		
	Devise, describe, and test algorithms for solving optimization and search problems .		
Grade 12: (Mathematics Standard 4.14: Continued)	Understand the basic principles of iteration, recursion, and mathematical induction .		
	Use basic principles to solve combinatorial and algorithmic problems.		
	Use discrete models to represent and solve problems.		
	Analyze iterative processes with the aid of calculators and computers.		
	Apply discrete methods to storing, processing, and communicating information.		
	Apply discrete methods to problems of voting, apportionment, and allocations, and use fundamental strategies of optimization to solve problems .		
Mathematics Standard 4.15: All Students Will Develop An Understanding Of The Conceptual Building Blocks Of Calculus And Will Use Them To Model And Analyze Natural Phenomena			
Grade 4:	Investigate and describe patterns that continue indefinitely.		
	Investigate and describe how certain quantities change over time.		
	Experiment with approximating length, area, and volume, using informal measurement instruments .		
Grade 8:	Recognize and express the difference between linear and exponential growth.		
	Develop an understanding of infinite sequences that arise in natural situations.		
	Investigate, represent, and use non-terminating decimals .		
	Represent, analyze, and predict relations between quantities, especially quantities changing over time .		
	Approximate quantities with increasing degrees of accuracy.		
	Understand and use the concept of significant digits.		
	Develop informal ways of approximating the surface area and volume of familiar objects, and discuss whether the approximations make sense .		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Express mathematically and explain the impact of the change of an object's linear dimensions on its surface area and volume.		
Grade 12:	Develop and use models based on sequences and series.		
	Develop and apply procedures for finding the sum of finite arithmetic series and of finite and infinite geometric series.		
	Develop an informal notion of limit.		
	Use linear, quadratic, trigonometric, and exponential models to explain growth and change in the natural world .		
(Mathematics Standard 4.15: Continued)	Recognize fundamental mathematical models (such as polynomial, exponential, and trigonometric functions) and apply basic translations, reflections, and dilations to their graphs .		
	Develop and explain the concept of the slope of a curve and use that concept to discuss the information contained in graphs.		
	Understand and apply approximation techniques to situations involving initial portions of infinite decimals and measurement.		
Mathematics Standard 4.16: All Students Will Demonstrate High Levels Of Mathematical Thought Through Experiences Which Extend Beyond Traditional Computation, Algebra, And Geometry		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	These Activities provide many challenging and high-level cognitive activities which may be interesting and exciting to the high school student.
Grade 12:	Study a core curriculum containing challenging ideas and tasks, rather than one limited to repetitive, low-level cognitive activities.		**
	Work at rich, open-ended problems which require them to use mathematics in meaningful ways, and which provide them with exciting and interesting mathematical experiences.		**
	Recognize mathematics as integral to the development of all cultures and civilizations, and in particular to that of our own society.		
	Understand the important role that mathematics plays in their own success, regardless of career.		
	Interact frequently with parents and other members of their communities, including men and women from a variety of cultural backgrounds, who use mathematics in their daily lives and occupations .		
	Receive services that help them understand the mathematical skills and concepts necessary to assure success in the core curriculum.		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	Receive equitable treatment without regard to gender, ethnicity, or predetermined expectations for success .		
	Learn mathematics in classes which reflect the diversity of the school's total student population.		
	Be provided with opportunities at all grade levels for further study of mathematics, especially including topics beyond traditional computation, algebra, and geometry .		
	Be challenged to maximize their mathematical achievements at all grade levels.		
	Experience a full program of meaningful mathematics so that they can pursue post- secondary education.		
Science Standard 5.1: All Students Will Learn To Identify Systems Of Interacting Components And (Science Standard 5.1: Continued) Understand How Their Interactions Combine To Produce The Overall Behavior Of The System			
Grade 4:	Recognize that most things are made of components that, when assembled, can do things they could not do separately .		
	Recognize that since the components of a system usually influence one another, a system may not work if a component is missing .		
	Diagram the components of a system.		
Grade 8:	Describe components of a system and how they influence one another.		
	Recognize that most systems are components of larger systems and that the output of one component can become the input to other components.		
	Disassemble and reassemble the components of a system, analyzing how they interact with each other .		
Grade 12:	Recognize that the behavior of a system may be different from the behavior of its components.		
	Explain how feedback can be used to control the behavior of a system.		
	Identify and diagram feedback loops that occur in biological or ecological systems.		
	Identify and diagram feedback loops designed for common control systems, such as home light switches and thermostats .		
Science Standard 5.2: All Students Will Develop Problem-Solving,		The Size of the Universe Activities The Expanding Universe Activities	The expanding universe activities ask students to weigh evidence to

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Decision-Making And Inquiry Skills, Reflected By Formulating Usable Questions And Hypotheses, Planning Experiments, Conducting Systematic Observations, Interpreting And Analyzing Data, Drawing Conclusions, And Communicating Results		The Shape of the Universe Activities	come to conclusions about the evolution of the universe. The parallax lab asks students to suggest further investigation based upon the results of their activity to improve the measurement.
Grade 4:	State a problem about the natural world in the form of a question.		
	Develop strategies and skills for information-gathering and problem-solving, using appropriate tools and technologies .		
	Use technology to present the design and results of investigation.		
	Keep a journal record of observations, recognizing patterns of observations and summarizing findings .		
(Science Standard 5.2: Continued)	Learn what constitutes evidence and evaluate the data and information used to make explanations.		
Grade 8:	Identify problems that can be solved by conducting experiments.		
	Design and conduct experiments incorporating the use of a control.		
	Collect and organize data to support the results of an experiment.		
	Communicate experimental findings using words, charts, graphs, pictures, and diagrams .		**
	Evaluate the strengths and weaknesses of claims, arguments, and data .		
	Assess the risks and benefits associated with alternative actions.		
Grade 12:	Select and use appropriate instrumentation to design and conduct investigations.		**
	Use technology to present the design and results of investigation.		**
	Evaluate conclusions, weigh evidence, and recognize that arguments may not have equal merit .		**
	Explain how experimental results lead to further investigation.		**
Science Standard 5.3: All Students Will Develop An Understanding Of How People Of Various Cultures Have Contributed To The Advancement Of		The Expanding Universe Activities	The debate Activity concerning the “size of the universe” gives some insight into historical context, astronomers backgrounds, and

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Science And Technology, And How Major Discoveries And Events Have Advanced Science And Technology			what happens to scientific theory when new conflicting evidence is presented.
Grade 4:	Hear, read, write, and talk about scientists and inventors in historical context .		
	Recognize that scientific ideas and knowledge have come from men and women of all cultures.		
Grade 8:	Recognize that scientific theories emerge over time, depend on the contributions of many people, and reflect the social and political climate of their time .		
	Develop a time line of major events and people in the history of science, in conjunction with other world events .		
	Trace the historical origin of important scientific developments such as atomic theory, genetics, plate tectonics, etc., showing how scientific theories emerge, are tested, and can be replaced or modified in light of new information and improved investigative techniques .		
(Science Standard 5.3: Continued) Grade 12:	Recognize the role of the scientific community in responding to changing social and political conditions.		**
	Examine the lives and contributions of important scientists and engineers who effected major breakthroughs in our understanding of the natural world.		**
Science Standard 5.4: All Students Will Develop An Understanding Of Technology As An Application Of Scientific Principles			
Grade 4:	Develop skill in the use of tools for everyday purposes.		
	Demonstrate how tools are used to do things better and more easily or to do tasks that could not otherwise be done.		
	Examine and compare toys and other familiar objects and explain how they work.		
	Find and report on examples of how technology helps people.		
Grade 8:	Describe how tools of today are different from those of the past but may be modifications of ancient tools.		
	Describe how technology expands the ability of scientists and others to make measurements and observations.		
	Design and build simple mechanical devices to demonstrate scientific principles.		
	Explain how engineers and others apply scientific knowledge to solve practical problems.		
	Compare the advantages and disadvantages of alternative solutions to practical problems.		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Grade 12:	Recognize that technological problems often create a demand for new scientific knowledge, and cite present and past examples of the interrelationship and mutual influence of science, technology, and society .		
	Participate in a design project that identifies a problem, proposes and implements a solution, and evaluates the consequences of that solution .		
Science Standard 5.5: All Students Will Integrate Mathematics As A Tool For Problem-Solving In Science, And As A Means Of Expressing And/Or Modeling Scientific Theories		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	The supernovae activity asks students to graph data (could use graphing program). The parallax activity requires that measurement error be accounted for.
Grade 4:	Judge whether estimates, measurements, and computations of quantities are reasonable .		
	Use a variety of measuring instruments, emphasizing appropriate units		
	Use mathematical skills and concepts in ordering, counting, identifying, measuring, and describing .		
	Use tables and graphs to represent and interpret data.		
(Science Standard 5.5: Continued) Grade 8:	Recognize and comprehend the orders of magnitude associated with large and small physical quantities.		**
	Express experimental data in several equivalent forms such as integers, fractions, decimals, and percents .		
	Infer mathematical relationships among variables using graphs, tables, and charts .		
	Express the output units of the calculation in terms of the input units.		
	Select appropriate measuring instruments based on the degree of precision needed		
	Find the mean and median of a set of experimental data.		
Grade 12:	Express the results of mathematical operations based on the degree of precision of the input data.		
	Use computer spreadsheets, graphing, and database programs to assist in quantitative analysis .		*
	Evaluate the possible effects of measurement errors on calculations.		**
	Express physical relationships in terms of mathematical equations derived from collected data.		**
	Use mathematical models to predict physical phenomena		**

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Science Standard 5.9: All Students Will Gain An Understanding Of Natural Laws As They Apply To Motion, Forces, And Energy Transformations		The Shape of the Universe Activities	These activities require knowledge of many of these indicators. Many activities, especially the shape of the universe activity, can be used to illustrate forces and energy.
Grade 4:	Demonstrate that the motion of an object can vary in speed and direction.		
	Demonstrate that the position and motion of an object can be changed by pushing or pulling and that the change is related to the strength of the push or pull.		
	Recognize that some forces are invisible and can act at a distance.		
	Investigate sources of heat and show how heat can be transferred from one place to another.		
	Investigate sources of light and show how light behaves when it strikes different objects.		
	Demonstrate how sound can be produced by vibrating objects and how the pitch of the sound depends on the rate of vibration.		
	Demonstrate how electricity can be used to produce heat, light, and sound .		
Grade 8: (Science Standard 5.9: Continued)	Explain how a moving object that is not being subjected to a net force will move in a straight line at a steady speed.		
	Show that when more than one force acts on an object at the same time, the forces can reinforce or cancel each other, producing a net force that will change the speed or direction of the object .		
	Investigate how the force of friction acts to retard motion.		
	Describe the various forms of energy, including heat, light, sound, chemical, nuclear, mechanical, and electrical energy, and that energy can be transformed from one form to another .		
	Explain how heat flows through materials or across space from warmer objects to cooler ones until both objects are at the same temperature.		
	Explain that the sun is a major source of the earth's energy and that energy is emitted in various forms, including visible light, infrared and ultraviolet radiation .		
	Show how light is reflected, refracted, or absorbed when it interacts with matter and how colors appear as a result of this interaction .		*
	Show how vibrations in materials can generate waves which can transfer energy from one place to another.		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
Grade 12:	Explain the mathematical relationship between the mass of an object, the unbalanced force exerted on it, and the resulting acceleration .		**
	Prove that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object .		
	Know that gravity is a universal force of attraction between masses that depends on the masses and the distance between them.		**
	Know that electrically charged bodies can attract or repel each other with a force that depends on the size and nature of the charges and the distance between them.		
	Explain the similarities and differences between gravitational forces and electrical forces that act at a distance.		
	Know that the forces that hold the nucleus of an atom together are stronger than electromagnetic forces and that significant amounts of energy are released during nuclear changes.		
	Explain how electromagnetic waves are generated, and identify the components of the electromagnetic spectrum .		**
	Explain that all energy is either kinetic or potential and that the total energy of the universe is constant.		**
Science Standard 5.10: All Students Will Gain An Understanding Of The Structure, Dynamics, And Geophysical (Science Standard 5.10: Continued) Systems Of The Earth		The Shape of the Universe Activities	There is a web based activity designed especially for this indicator.
Grade 8:	**Compare different map projections, and explain how physical features are represented on each .**		***
Science Standard 5.11: All Students Will Gain An Understanding Of The Origin, Evolution, And Structure Of The Universe		The Size of the Universe Activities The Expanding Universe Activities The Shape of the Universe Activities	These activities were designed primarily to illustrate this standard, particularly indicator 8.
	Observe and identify objects and their apparent motion in the day and night sky.		
	Relate the motions of the earth-sun-moon system to units of time (days, months, seasons, years) .		
	Construct a model of the solar system.		***
	Describe the physical characteristics of the components of the solar system, and compare the earth to other planets .		**
	Explain how naturally occurring events on earth are related to		

Table 8: New Jersey Core Curriculum Content Standards and Indicators - Continued

Standard	Indicator	Aligned Activities	Comments
	the positions of the sun, earth, and moon .		
	Describe the technologies used to explore the universe.		
	Construct a model that accounts for variation in the length of day and night.		
	Evaluate evidence that supports scientific theories of the origin of the universe.		***
	Analyze benefits generated by the technology of space exploration.		