Assessing Student Learning in a 6th – 8th Grade Space Science Curriculum

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Executive Summary

The Great Explorations in Math and Science’s *Space Science Sequence* for sixth to eighth grade curriculum was field tested in the winter and spring of the 2006 academic year. The *Space Science Sequence* builds upon a solid body of research-based and classroom-tested astronomy/space science units from the GEMS Series, including several units developed with NASA support. The sixth – eighth grade *Space Science Sequence* is 32 class sessions in length. It is made up of four units that build key concepts in Earth and Space Science, related to our place in the Solar System, our Galaxy, and the Universe. The sequence focuses on helping students develop two important scientific skills: using evidence and understanding models. Pretest to posttest student learning gains were statistically significant for all units. Breaking down the items by type found that multiple choice and short answer gains were statistically significant across all units for short answer items and for three of the four units for the multiple-choice items. Reliability estimates for the pre/post measures range from .75 to .84. Effect sizes were statistically significant for all units and ranged from .33 to .59 indicating a moderate effect size for Unit 2 and smaller effects for Units 1, 3, and 4. Grade level comparisons (6th, 7th, and 8th) found statistically significant gains for all units across all grade levels. Limitations of the study are that results are formative as units were revised based on both student learning results and teacher feedback collected during the national field test year. Recommendations for future research include collection of curriculum calendars including CD use and analyses of embedded student work. Results suggest consistent evidence of the effectiveness of the curriculum.
**Introduction**

The current project examines student learning, as shown by unit pre/post assessment change, in the Space Science Sequence (SSS) sixth to eighth grade science curriculum developed by Great Explorations in Math and Science (GEMS) at Lawrence Hall of Science (LHS), University of California, Berkeley.

**Center for Research, Evaluation, and Assessment (REA)**

The Center, based at Lawrence Hall of Science, conducts both internal and external evaluation and research in the fields of mathematics and science education. In addition to evaluation of in-house projects, REA provides professional consultation for the evaluation of science and mathematics education programs for clients nationwide.

For the current study, REA had the responsibility for scoring and conducting data analyses for the Space Science Sequence sixth through eighth grade curriculum 2005-2006 national field test. REA also worked with the Space Science curriculum team developing the assessment items and scoring rubrics. The REA evaluation associates directing this study were familiar with both the SSS curriculum and the assessment system developed for assessing student growth. Both formative and summative results for this study were shared with the SSS curriculum team and the funders of the project.

**Evaluation Questions**

Evaluation questions for this project took into consideration concerns and interests of curriculum funders, the curriculum development team, and potential users of the curriculum. Evidence of student learning is of primary interest to all stakeholders and is therefore the overarching question for this evaluation.

**Student Learning Questions**

- As evidenced by pre/post analyses do students make significant gains in understanding for each unit?
- Are the gains made by students at different grade levels similar?
- Do students make greater gains in some units?

**Stakeholders**

Those interested in the results of this project are numerous. Funders of science curriculum development, in this case NASA, are primary stakeholders along with district science teachers and science resource personnel. Additionally the curriculum development team at LHS is interested in both formative and summative information concerning student learning to inform their work. Curriculum marketing personnel
require evidence of successful student learning outcomes for their work with district curriculum decision-makers.

*Space Science Sequence*

The *Space Science Sequence* builds upon a solid body of research-based and classroom-tested astronomy/space science units from the GEMS Series, including several units developed with NASA support. The units were sequenced, revised, and refashioned into a curricular core for Grades 3–5 and Grades 6–8. Revisions were made in light of updated science content, current theories of learning, national standards and benchmarks, key research findings in astronomy education, and the just-now-developing NASA space science education framework. In addition, the *Space Science Sequence* integrates related content about NASA missions and scientists through student readings, guided website navigation, and open inquiry investigations and environments. The Beyond the Solar System unit is brand new and deals with our solar system, galaxies, and the universe in relation to planet detection and the current on-going Kepler mission. The new unit and redesign process for the entire *Space Science Sequence* placed priority on careful selection of essential understandings and essential questions to frame major student learning goals. This outcomes-driven process in turn provided the basis and alignment for an assessment system with student progress variables, guided decisions on unit revision and sequencing, and provided the framework and content criteria for the inquiry-driven technology component.

The 6th – 8th grade portion of the *Space Science Sequence* is 32 class sessions in length. It is made up of four units that build key concepts in Earth and Space Science, related to our place in the Solar System, our Galaxy, and the Universe. The sequence focuses on helping students develop two important scientific skills: using evidence and understanding models.

<table>
<thead>
<tr>
<th>Table 1. Primary Science Content by Unit and Estimated Instructional Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
</tr>
</tbody>
</table>
Method

Participants

A call for applications to participate in the 2006 national field test was sent to GEMS associates that had previously participated in research related to GEMS curriculum and/or sites with GEMS centers. The application was also posted on the GEMS website. Requirements for selection were that each teacher have a 6th – 8th grade science class, each teacher would teach between one and four of the curriculum units as specified by the GEMS curriculum team, and teachers with computer access were offered the technology component (CD) that was designed with the curriculum.

In order to answer the evaluation question regarding possible differences in student learning over grade levels a stratified sample was chosen in order to have similar number of student papers for scoring and data analyses. Table 2 contains the overall number for each unit analyses as well as the number in each grade level category by unit. Units 3 and 4 did not have any 7th grade papers as very few were returned. As a result, a conscious decision was made to focus on sixth and eighth grade student achievement.

<table>
<thead>
<tr>
<th>Table 2. Number of Papers Used in Data Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>How Does the Sun Affect The Earth? (Unit 1)</td>
</tr>
<tr>
<td>Sixth Grade</td>
</tr>
<tr>
<td>Seventh Grade</td>
</tr>
<tr>
<td>Eighth Grade</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
</tr>
<tr>
<td>Sixth Grade</td>
</tr>
<tr>
<td>Seventh Grade</td>
</tr>
<tr>
<td>Eighth Grade</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
</tr>
<tr>
<td>Sixth Grade</td>
</tr>
<tr>
<td>Seventh Grade</td>
</tr>
<tr>
<td>Eighth Grade</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
</tr>
<tr>
<td>Sixth Grade</td>
</tr>
<tr>
<td>Seventh Grade</td>
</tr>
<tr>
<td>Eighth Grade</td>
</tr>
</tbody>
</table>
As there were a large number of pre/posttest returned, a stratified sample of papers were chosen for scoring and data analyses. In order to represent a wide variety of papers, across sites and grade level, random sample papers were chosen from each teacher and class for the analyses.

Pre/Post Assessment Measure Development

Items used for the pretest/posttest assessments were developed by the SSS curriculum team and REA assessment specialist at LHS. Tests were constructed to include multiple-choice and short answer items. Key science concepts presented in each unit guided the development of items. Multiple-choice items included content considered essential to students’ ability to communicate space science information. Short answer items provided students with the opportunity to develop and present their own thinking. Table 3 shows test item type (multiple-choice and short answer) frequency by unit.

Table 3. Item Type by Unit

<table>
<thead>
<tr>
<th>Unit</th>
<th>Multiple Choice Items</th>
<th>Short Answer Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Pre/post assessment items were developed from items in previously published GEMS curriculum and then adapted to the SSS curriculum as well as new items specifically designed for the 6th – 8th grade sequence. All items were piloted in classrooms and revised for the field test by the SSS curriculum development team after reviewing comments/recommendations received from teachers and analyzing student pre/post-tests. The assessment specialist in the REA conducted final review of the items.

Pre/Post Administration

Forms of pre/posttests were sent to participating teachers. Teachers were asked to administer the pre/posttests for each unit taught. Pretests were to be administered just before the unit was taught and posttests were to be administered as indicated in the curriculum at the end of the unit.
Teachers were asked to return the pre/posttests for all of their students. Pre/posttests were matched prior to scoring for all of the units. For the current study, only matched pre/posttest were scored and analyzed.

Scoring

Scoring of each of the questions was based on a rubric designed to assess students’ understanding of science concepts. Comparisons were made across four levels of understanding of science concept in order to an accurate profile of students’ understanding. By using this approach, misconceptions and key concepts can be identified. Description of the general rationale for each scoring level is shown in Table 4 below.

<table>
<thead>
<tr>
<th>Score</th>
<th>Level Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Missing, illegible, irrelevant, off topic</td>
</tr>
<tr>
<td>1</td>
<td>Inaccurate Information</td>
</tr>
<tr>
<td>2</td>
<td>Insufficient Information</td>
</tr>
<tr>
<td>3</td>
<td>Partial Understanding</td>
</tr>
<tr>
<td>4</td>
<td>Complete Understanding</td>
</tr>
</tbody>
</table>

Scoring of matched pretests/posttests was conducted by REA using undergraduate science major students at the University of California, Berkeley. The REA assessment specialist trained scorers. Ten posttest papers, not being used for analyses, for each unit were chosen for use in scorer training. Reliability tests were performed with all of the scorers after they received training. All scorers had a 90% or higher reliability score for each of the unit measures. Matched pre/post assessments were scored and analyzed for all each of the four units. The REA assessment specialist to ensure scorer consistency.
completed a 10% read-behind of the pre/post assessments. The scores were recorded on a scantron form in order to facilitate reliable data entry.

Data Analyses

Analyses focused on mean pretest/posttest/gain percent correct comparisons for total score percent correct gain, multiple-choice item percent correct gain, and short answer percent correct gain by unit. Paired sample t-tests were conducted for all pretest posttest gains. Reliability and effect size estimates were calculated for each unit as well.

Individual item pretest/posttest/gain percent correct were calculated in order to provide curriculum development team with specific feedback on the concept learning contained in each item. For those items that had qualitative notations made during scoring, frequencies of the various response categories were provided as well. This individual item feedback allowed the development team to review the assessment items to learn how much previous knowledge students had prior to instruction as well as discovering any misconceptions students may have had about the unit concepts. Appendix A contains both the quantitative and qualitative data for each item.

Results

Descriptive statistics were calculated for pretest/posttest data to review the distribution of scores for each unit. Pretest scores for all units were approximately normally distributed with a slight skew to the left. Posttest scores were also normally distributed with a slight skew to the right.

Reliability and Effect Sizes

Reliability (Cronbach’s alpha) for unit pretest/posttest measures ranged from .75 to .84. The How Does The Sun Affect The Earth? unit pretest/posttest assessment had the lowest reliability. Given the relatively small number of items for each unit the reliability estimates are acceptable. Table 5 contains reliability estimates by unit.

<table>
<thead>
<tr>
<th>Table 5. Reliability Estimates by Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>How Does The Sun Affect The Earth?</td>
</tr>
<tr>
<td>(Unit 1)</td>
</tr>
<tr>
<td>Why Are There Seasons?</td>
</tr>
<tr>
<td>(Unit 2)</td>
</tr>
<tr>
<td>The Solar System</td>
</tr>
<tr>
<td>(Unit 3)</td>
</tr>
<tr>
<td>Beyond The Solar System</td>
</tr>
<tr>
<td>(Unit 4)</td>
</tr>
</tbody>
</table>
Overall, unit effect sizes (Table 6) for the pretest to posttest gains ranged from .33 to .59. Using Cohen’s (1988) general guidelines for interpreting effect sizes (.20 — .50 = small effect size; .50 – .80 = moderate effect size; > .80 = large effect size) Units 1, 3, and 4 had the smallest effect sizes at .33, .36, and .36 respectively. Unit 2 had a moderate effect size of .59. These effect sizes are respectable given the relatively short instructional time of the units (see Table 1).

**Table 6. Effect Size Statistics Overall by Unit**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
<td>.33*</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td>.59*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td>.36*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td>.36*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000

**Overall Results**

Total score mean pretest/posttest gains, multiple-choice mean pretest/posttest gains, and short answer mean pretest/posttest gains were statistically significant for all units and item types with Unit 2, Why Are There Seasons?, having the largest gain overall (22%) and Unit 1, How Does The Sun Affect The Earth? having the smallest gain overall (11%). Table 7 shows the total score pretest/posttest/gain mean percent correct for each unit.

**Table 7. Total Score Mean Percent Correct by Unit**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Total Score Pretest Mean % Correct</th>
<th>Total Score Posttest Mean % Correct</th>
<th>Total Score Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
<td>59</td>
<td>70</td>
<td>11*</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td>44</td>
<td>66</td>
<td>22*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td>60</td>
<td>73</td>
<td>13*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td>54</td>
<td>71</td>
<td>17*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000
Multiple-choice item gains by unit (Table 8) ranged from 0% gain (How Does the Sun Affect The Earth?) to 27% gain (Why Are There Seasons?). The surprising result of 0% gain in Unit 1 may be due to that unit having only one multiple-choice item in the pre/post assessment and/or to a problem with the item itself. Review of the curriculum found that the concepts were not covered as well as they could be and the development team enhanced the concepts in the curriculum and the assessment item was revised accordingly.

Short answer item gains (Table 9) were more consistent across units ranging from 11% - 17% with the greatest gain in the Beyond The Solar System unit.

### Table 8. Multiple Choice Mean Percent Correct by Unit

<table>
<thead>
<tr>
<th>Unit</th>
<th>Multiple Choice Pretest Mean % Correct</th>
<th>Multiple Choice Posttest Mean % Correct</th>
<th>Multiple Choice Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
<td>31</td>
<td>31</td>
<td>0</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td>41</td>
<td>68</td>
<td>27*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td>70</td>
<td>84</td>
<td>14*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td>51</td>
<td>67</td>
<td>16*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000

### Table 9. Short Answer Mean Percent Correct by Unit

<table>
<thead>
<tr>
<th>Unit</th>
<th>Short Answer Pretest Mean % Correct</th>
<th>Short Answer Posttest Mean % Correct</th>
<th>Short Answer Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth? (Unit 1)</td>
<td>66</td>
<td>79</td>
<td>13*</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td>50</td>
<td>65</td>
<td>15*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td>56</td>
<td>67</td>
<td>11*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td>57</td>
<td>74</td>
<td>17*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000
Figure 1 shows the pattern of overall score gains across units and item type. The largest gains are seen in Unit 2, Why Are There Seasons?, and the smallest gains are found in Unit 1, How Does The Sun Affect The Earth? Units 3 and 4, The Solar System and Beyond The Solar System, respectively have similar gains.

Grade Level Comparisons

Unit pretest/posttest/gain mean percent correct comparisons were made across grade levels. Grade-level effect sizes (Table 10) for the pretest to posttest gains are statistically significant for all grade levels and units.

Differences in effect sizes across grade levels are significant. Seventh grade effect sizes for How The Sun Affects The Earth? and Why Are There Seasons? units were the smallest at .16 and .43 respectively. In three of the four units (Why Are There Seasons?, The Solar System, and Beyond the Solar System) eighth grade effect sizes are the larger than sixth grade by an average of 12%. Unit 1, How Does The Sun Affect The Earth? had the largest effect size for sixth grade students.
Table 10. Grade Level Effect Size Statistics by Unit

<table>
<thead>
<tr>
<th>Unit</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does The Sun Affect The Earth?</td>
<td></td>
</tr>
<tr>
<td>(Unit 1)</td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>.45*</td>
</tr>
<tr>
<td>Seventh</td>
<td>.16*</td>
</tr>
<tr>
<td>Eighth</td>
<td>.40*</td>
</tr>
<tr>
<td>Why Are There Seasons?</td>
<td></td>
</tr>
<tr>
<td>(Unit 2)</td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>.52*</td>
</tr>
<tr>
<td>Seventh</td>
<td>.43*</td>
</tr>
<tr>
<td>Eighth</td>
<td>.65*</td>
</tr>
<tr>
<td>The Solar System</td>
<td></td>
</tr>
<tr>
<td>(Unit 3)</td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>.25*</td>
</tr>
<tr>
<td>Eighth</td>
<td>.37*</td>
</tr>
<tr>
<td>Beyond The Solar System</td>
<td></td>
</tr>
<tr>
<td>(Unit 4)</td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>.36*</td>
</tr>
<tr>
<td>Eighth</td>
<td>.46*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000

Total score mean pretest and posttest gains by grade level are statistically significant for all units and grade levels with the greatest overall gains for all grade levels in Unit 2, Why Are There Seasons?, with an average gain of 20%. The smallest gains for all grade levels were in Unit 1, How Does The Sun Affect The Earth?, with an average gain of only 10% (Table 11).

Tables 12 and 13 contain the percent correct pre to post and gain percentages for multiple choice and short answer items. Multiple choice item gains are statistically significant for Units 2, 3, and 4 for all grades. Unit 1 multiple-choice item results are not significant as noted in the overall gain results discussion earlier. Short answer item gains are statistically significant across all grade levels.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Total Score Pretest Mean % Correct</th>
<th>Total Score Posttest Mean % Correct</th>
<th>Total Score Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does the Sun Affect The Earth? (Unit 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>59</td>
<td>72</td>
<td>13*</td>
</tr>
<tr>
<td>Seventh</td>
<td>58</td>
<td>66</td>
<td>8*</td>
</tr>
<tr>
<td>Eighth</td>
<td>60</td>
<td>71</td>
<td>11*</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>42</td>
<td>63</td>
<td>21*</td>
</tr>
<tr>
<td>Seventh</td>
<td>40</td>
<td>59</td>
<td>19*</td>
</tr>
<tr>
<td>Eighth</td>
<td>48</td>
<td>72</td>
<td>24*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>58</td>
<td>70</td>
<td>12*</td>
</tr>
<tr>
<td>Eighth</td>
<td>63</td>
<td>75</td>
<td>12*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>50</td>
<td>54</td>
<td>17*</td>
</tr>
<tr>
<td>Eighth</td>
<td>54</td>
<td>75</td>
<td>21*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000
### Table 12. Multiple Choice Mean Percent Correct by Unit and Grade Level

<table>
<thead>
<tr>
<th>Unit</th>
<th>Multiple Choice Pretest Mean % Correct</th>
<th>Multiple Choice Posttest Mean % Correct</th>
<th>Multiple Choice Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does the Sun Affect The Earth? (Unit 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>29</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Seventh</td>
<td>32</td>
<td>29</td>
<td>-2</td>
</tr>
<tr>
<td>Eighth</td>
<td>32</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>38</td>
<td>65</td>
<td>27*</td>
</tr>
<tr>
<td>Seventh</td>
<td>37</td>
<td>57</td>
<td>20*</td>
</tr>
<tr>
<td>Eighth</td>
<td>45</td>
<td>73</td>
<td>28*</td>
</tr>
<tr>
<td>The Solar System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>66</td>
<td>83</td>
<td>17*</td>
</tr>
<tr>
<td>Eighth</td>
<td>74</td>
<td>85</td>
<td>11*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>50</td>
<td>67</td>
<td>17*</td>
</tr>
<tr>
<td>Eighth</td>
<td>53</td>
<td>71</td>
<td>18*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000
Table 13: Short Answer Mean Percent Correct by Unit and Grade Level

<table>
<thead>
<tr>
<th>Unit</th>
<th>Short Answer Pretest Mean % Correct</th>
<th>Short Answer Posttest Mean % Correct</th>
<th>Short Answer Gain Mean % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>How Does the Sun Affect the Earth? (Unit 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>67</td>
<td>82</td>
<td>15*</td>
</tr>
<tr>
<td>Seventh</td>
<td>65</td>
<td>74</td>
<td>8*</td>
</tr>
<tr>
<td>Eighth</td>
<td>67</td>
<td>80</td>
<td>13*</td>
</tr>
<tr>
<td>Why Are There Seasons? (Unit 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>49</td>
<td>60</td>
<td>11*</td>
</tr>
<tr>
<td>Seventh</td>
<td>46</td>
<td>63</td>
<td>17*</td>
</tr>
<tr>
<td>Eighth</td>
<td>53</td>
<td>68</td>
<td>15*</td>
</tr>
<tr>
<td>The Solar System (Unit 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>54</td>
<td>63</td>
<td>9*</td>
</tr>
<tr>
<td>Eighth</td>
<td>58</td>
<td>71</td>
<td>13*</td>
</tr>
<tr>
<td>Beyond The Solar System (Unit 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>54</td>
<td>70</td>
<td>16*</td>
</tr>
<tr>
<td>Eighth</td>
<td>58</td>
<td>78</td>
<td>20*</td>
</tr>
</tbody>
</table>

*Statistically significant p < .000

Figures 2, 3, and 4 show the mean percent change by unit and grade level for overall gain, multiple-choice, and short answer gains. These show the similarity in the pattern of gains for the SSS units over grade levels. This is important as it indicates a similar effect of the curriculum for sixth, seventh, and eighth grade which allows districts to place these units in the grade levels most appropriate for their individual standards/benchmark requirements.
Figure 2. Total score mean percent correct gains by unit and grade level.

Figure 3. Multiple-choice mean percent correct gains by unit and grade level.

Figure 4. Short answer mean percent correct gains by unit and grade level.
Individual item results by unit were shared with curriculum developers giving them information about the results for specific content included in each item and recommendations were given for revision of items, graphics, or content coverage in the curriculum. Curriculum developers when revising the curriculum for final publication used this information. Appendix A contains the individual item results by unit. The text for each item is provided but the graphics are not.

**Discussion**

The results of this study found statistically significant learning gains in total pre to post scores for all units in the *Space Science Sequence Sixth – Eighth Grade* curriculum. Why Are There Seasons? (Unit 2) had the largest gain at 22%. The smallest gain, 11% was for How Does The Sun Affect The Earth? (Unit 1). Total score gains for the two remaining units, The Solar System (Unit 3) and Beyond The Solar System (Unit 4), were 13% - 17% respectively.

An interesting finding in the Why Are There Seasons? unit (Unit 2) is that this unit has the greatest gains for total score, multiple-choice score, and short answer scores and has the shortest instructional time of only six sessions. This unit had undergone a major revision prior to the national field test. Previous research on the unit identified common concept misconceptions held by many students. The revision concentrated on addressing these misconceptions and providing additional scientific information related to those misconceptions in student understanding.

Another finding of interest was for the Beyond the Solar System unit. The results for this unit are promising in that the concepts covered in this unit have traditionally been thought of as too difficult for middle school students and as a result are most often taught only in high school. Student gains for this unit, in the current study, are significant and suggest that these concepts can be taught and understood in middle school with an expectation of respectable student concept learning gains.

Effect sizes of pretest/posttest gains per unit ranged from .33 to .59 indicating moderate effect size for the Why Are There Seasons unit and smaller effect sizes for How Does The Sun Affect The Earth?, The Solar System, and Beyond The Solar System units. These effect sizes are respectable given the relatively short instructional length of the units. However, it is important to remember that these assessments and analyses were formative, not summative, as all units were revised based on both student scores on pre/post assessment measures and feedback from teachers. Interpretation of these gains must be tempered by this fact. These gains may not be representative of student learning for the final curriculum. With revision of curriculum based on the feedback data collected, it is anticipated that student learning would be enhanced in the published curriculum.
The grade level finding of statistically significant total score gains across all units is important for a number of reasons. The curriculum sequence was designed to be taught both longitudinally and/or vertically. In this way districts can choose how the curriculum is implemented in their classrooms by allowing them to make informed decisions about curriculum placement in order to more closely match their curriculum to their local and state science standards.

Recommendations for future studies include collection of curriculum calendars of instructional time spent on each unit/activity as well as information about how the CD component designed for the unit is used and how much time the students spend using the CD component and its features. Having this information would allow for additional interpretation of gains across classrooms using the CD and classrooms that do not use the CD, across units and grade levels. For instance, these additional analyses have the potentially indicate a positive effect of CD use with the curriculum.

Another recommendation is that analysis of embedded assessments in the curriculum be done. By looking at student work across the unit, it may be possible to track growth in student understanding or skill development within a content area. In addition, exemplars for embedded assessments illustrating differing levels of student achievement could be included in the published curriculum.

Even though student learning gains in this study are formative the results can be viewed with a level of confidence. Reliability estimates and effect sizes are good and the similar pattern of gains across sites and units suggest consistent evidence of the effectiveness of the curriculum.
References


Appendix A

Assessment Item Results by Unit
Unit 1 – How Does The Sun Affect The Earth?

Items:

1. What things are coming toward the Earth from the Sun? List as many things as you can, and be as specific as possible. Next to each thing you list, write if it is harmful or helpful to us and how.

1. How do people protect themselves from harmful effects of the Sun? List at least two ways.

1. Is the energy that comes from the Sun always the same? Explain how the energy is the same or different.

1. What does the Earth and Sun system look like? Draw the Earth and Sun system on the page. You must include the Sun and the Earth, and label each of them. You may include:
   A. Labels that show sizes or distances.
   A. Arrows to show how the Sun and Earth move.
   A. Anything else to show how the Sun and Earth affect each other.

5. What protects us from the harmful effects of the Sun? Circle all the correct answers. There may be more than one.
   A. The atmosphere of the Earth protects us from harmful energies.
   A. Ozone in Earth’s atmosphere protects us from harmful particles
   A. Sunscreen protects us from harmful particles.
   A. The magnetic field of the Earth protects us from harmful particles.
Unit 1 – How Does The Sun Affect The Earth?

Item 1 - Short Answer

What things are coming toward the Earth from the Sun? List as many things as you can, and be as specific as possible. Next to each thing you list, write if it is harmful or helpful to us and how.

Table 14. Unit 1 – Item 1 – Score Frequencies

<table>
<thead>
<tr>
<th>Scores</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>3</td>
<td>.5</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>3</td>
<td>.3</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>75</td>
<td>39</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>6</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 15. Unit 1 – Item 1 – Ray Response

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentioned Rays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>58</td>
<td>20</td>
</tr>
<tr>
<td>Specific</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>None</td>
<td>19</td>
<td>3</td>
</tr>
</tbody>
</table>
### Table 16. Unit 1 – Item 1 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentioned Light</td>
<td>66</td>
<td>52</td>
</tr>
<tr>
<td>Mentioned Heat</td>
<td>67</td>
<td>41</td>
</tr>
<tr>
<td>Mentioned Rays</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>Mentioned Solar Particles</td>
<td>10</td>
<td>24</td>
</tr>
</tbody>
</table>

### Table 17. Unit 1 – Item 1 – Responses – Infrared and X-Rays

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mentioned Infrared and Harmful</td>
<td>36</td>
<td>4</td>
</tr>
<tr>
<td>Mentioned X-Rays and Helpful</td>
<td>1</td>
<td>36</td>
</tr>
</tbody>
</table>
Unit 1- How Does The Sun Affect The Earth?

Item 2 – Short Answer

How do people protect themselves from harmful effects of the Sun? List at least two ways.

### Table 18. Unit 1 – Item 2 – Score Frequencies

<table>
<thead>
<tr>
<th>Scores</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>91</td>
<td>94</td>
</tr>
</tbody>
</table>
Unit 1 – How Does The Sun Affect The Earth?

Item 3 – Short Answer

Is the energy that comes from the Sun always the same? Explain how the energy is the same or different.

<table>
<thead>
<tr>
<th>Scores</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>48</td>
<td>41</td>
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<tr>
<td>Partial Understanding (Score 3)</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>11</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 20. Unit 1 – Item 3 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mentioned Seasons</td>
<td>9</td>
<td>88</td>
</tr>
<tr>
<td>Mentioned Day or Night</td>
<td>2</td>
<td>95</td>
</tr>
</tbody>
</table>
Unit 1 – How Does The Sun Affect The Earth?

Item 4 – Short Answer

What does the Earth and Sun system look like? Draw the Earth and Sun system on the page. You must include the Sun and the Earth, and label each of them. You may include:

A. Labels that show sizes or distances.
A. Arrows to show how the Sun and Earth move.
A. Anything else to show how the Sun and Earth affect each other.

Table 21. Unit 1 – Item 4 – Score Frequencies

<table>
<thead>
<tr>
<th>Scores</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
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<td>Inaccurate Information (Score 1)</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>28</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 22. Item 4 – Does the drawing show these elements?

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Yes</th>
<th>Pretest No</th>
<th>Posttest Yes</th>
<th>Posttest No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shows Correct Orbit of Earth Around the Sun</td>
<td>61</td>
<td>39</td>
<td>58</td>
<td>40</td>
</tr>
<tr>
<td>Shows Spinning of the Earth</td>
<td>25</td>
<td>75</td>
<td>18</td>
<td>82</td>
</tr>
<tr>
<td>Shows Correct Distance Between the Earth and Sun</td>
<td>4</td>
<td>96</td>
<td>44</td>
<td>56</td>
</tr>
<tr>
<td>Shows Relative Size of Earth to Sun</td>
<td>61</td>
<td>39</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Shows Energy from the Sun</td>
<td>35</td>
<td>64</td>
<td>39</td>
<td>61</td>
</tr>
<tr>
<td>Shows Spherical Shape of Earth and Sun</td>
<td>94</td>
<td>6</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Shows Shields Protecting the Earth</td>
<td>9</td>
<td>91</td>
<td>17</td>
<td>83</td>
</tr>
</tbody>
</table>
Unit 1 – How Does The Sun Affect The Earth?

Item 5 – Multiple Choice

What protects us from the harmful effects of the Sun? Circle all the correct answers. There may be more than one.

A. The atmosphere of the Earth protects us from harmful energies.
A. Ozone in Earth’s atmosphere protects us from harmful particles
A. Sunscreen protects us from harmful particles.
A. The magnetic field of the Earth protects us from harmful particles.

Table 23. Unit 1 – Item 5 – Score Frequencies

<table>
<thead>
<tr>
<th>Scores</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
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<td>2</td>
</tr>
<tr>
<td>Inaccurate Information</td>
<td>89</td>
<td>88</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 24. Unit 1 – Item 5 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Correct)</td>
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<td>75</td>
</tr>
<tr>
<td>B (Incorrect)</td>
<td>29</td>
<td>77</td>
</tr>
<tr>
<td>C (Incorrect)</td>
<td>53</td>
<td>71</td>
</tr>
<tr>
<td>D (Correct)</td>
<td>68</td>
<td>64</td>
</tr>
</tbody>
</table>
Unit 2 – Why Are There Seasons?

Items:

1. These two pictures show the same tree on two different days at noon. Why do the Sun’s rays come in at different angles? Explain why this occurs.

1. Imagine there where two Earths. One Earth is where our Earth is. The other Earth is 8000 miles closer to the Sun. Which place on these two Earths would be hotter, A or B. Explain why you think so.

1. Why do you think it is hotter in the United States in June than in December? Circle all that are correct.
   A. Because the United States is tilted more toward the Sun in June and away from the Sun in December.
   A. Because in the United States there are more hours of daylight in June than in December.
   A. Because the Earth is closer to the Sun in June and farther away from the Sun in December.
   A. Because the Sun gives off more heat and energy in June and less in December.
   A. Because the Sun appears higher in the sky in June and its rays are more intense.
   A. Because the United States is closer to the Sun in June and farther away from the Sun in December.

4. When the Earth is closest to the Sun which of the following is true? Circle the letter of the best answer.
   A. The distance to the Sun causes summer in the Northern hemisphere.
   A. It is summer everywhere on Earth.
   A. The distance to the Sun has nothing to do with the reasons for seasons.
   A. It is winter everywhere on Earth.

5. In the Sun-Earth drawing along the right side of this page, which picture of the Earth best shows its size and distance from the Sun? Circle the letter of the best answer.

5. Which of the four drawings do you think best shows the shape of the Earth’s orbit around the Sun? Circle the correct letter.
Unit 2 – Why Are There Seasons?

Item 1 – Short Answer

These two pictures show the same tree on two different days at noon. Why do the Sun’s rays come in at different angles? Explain why this occurs.

Table 25. Unit 2 – Item 1 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>11</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 26. Unit 2 – Item 1 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentions intensity of light/angle of rays from Sun</td>
<td>21</td>
<td>38</td>
</tr>
<tr>
<td>Mentions location of Earth in its orbit</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Mentions seasons but NOT tilt</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Mentions Sun in a different location at noon</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Mentions tilt/angle related to seasons</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>Pictures are labeled wrong, but explanation is correct.</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
Item 2 – Short Answer

Imagine there where two Earths. One Earth is where our Earth is. The other Earth is 8000 miles closer to the Sun. Which place on these two Earths would be hotter, A or B. Explain why you think so.

Table 27. Unit 2 – Item 2 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>47</td>
<td>27</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>34</td>
<td>50</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 28. Unit 2 – Item 2 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentions intensity of light/angle of rays from Sun</td>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>Location A is negligibly closer to Sun</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Makes geographic reference.</td>
<td>16</td>
<td>11</td>
</tr>
</tbody>
</table>
Unit 2 – Why Are There Seasons?

Item 3 – Multiple Choice

Why do you think it is hotter in the United States in June than in December? Circle all that are correct.

A. Because the United States is tilted more toward the Sun in June and away from the Sun in December.
A. Because in the United States there are more hours of daylight in June than in December.
A. Because the Earth is closer to the Sun in June and farther away from the Sun in December.
A. Because the Sun gives off more heat and energy in June and less in December.
A. Because the Sun appears higher in the sky in June and its rays are more intense.
A. Because the United States is closer to the Sun in June and farther away from the Sun in December.

Table 29. Unit 2 – Item 3 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>78</td>
<td>35</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>1</td>
<td>21</td>
</tr>
</tbody>
</table>
## Unit 2 – Why Are There Seasons?

### Table 30. Unit 2 – Item 3 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because the United States is tilted more toward the Sun in June and away from the Sun in December. (Correct)</td>
<td>44</td>
<td>83</td>
</tr>
<tr>
<td>Because in the United States there are more hours of daylight in June than in December. (Correct)</td>
<td>24</td>
<td>53</td>
</tr>
<tr>
<td>Because the Earth is closer to the Sun in June and farther away from the Sun in December. (Incorrect)</td>
<td>47</td>
<td>86</td>
</tr>
<tr>
<td>Because the Sun itself gives off more heat and energy in June and less in December. (Incorrect)</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>Because the Sun appears higher in the sky in June and its rays are more intense. (Correct)</td>
<td>15</td>
<td>38</td>
</tr>
<tr>
<td>Because the United States is closer to the Sun in June and farther away from the Sun in December. (Incorrect)</td>
<td>57</td>
<td>80</td>
</tr>
</tbody>
</table>
Unit 2 – Why Are There Seasons?

Item 4 – Multiple Choice

When the Earth is closest to the Sun which of the following is true? Circle the letter of the best answer.

A. The distance to the Sun causes summer in the Northern hemisphere.
A. It is summer everywhere on Earth.
A. The distance to the Sun has nothing to do with the reasons for seasons.
A. It is winter everywhere on Earth.

Table 31. Unit 2 – Item 4 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>80</td>
<td>28</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>an</td>
<td>an</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>an</td>
<td>an</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>19</td>
<td>68</td>
</tr>
</tbody>
</table>

Table 32. Unit 2 – Item 4 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>The distance to the Sun causes summer in the Northern hemisphere. (Incorrect)</td>
<td>67</td>
<td>23</td>
</tr>
<tr>
<td>It is summer everywhere on Earth. (Incorrect)</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>The distance to the Sun has nothing to do with the reasons for seasons. (Correct)</td>
<td>19</td>
<td>69</td>
</tr>
<tr>
<td>It is winter everywhere on Earth. (Incorrect)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Unit 2 – Why Are There Seasons?

Item 5 – Multiple Choice

In the Sun-Earth drawing along the right side of this page which picture of the Earth best shows its size and distance from the Sun? Circle the letter of the best answer.

<table>
<thead>
<tr>
<th>Table 33. Unit 2 – Item 5 – Score Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
</tr>
<tr>
<td>Missing/Wrong (Score 0)</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 34. Unit 2 – Item 5 – Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C - Correct</td>
</tr>
</tbody>
</table>
Item 6 – Multiple Choice

Which of the four drawings do you think best shows the shape of the Earth’s orbit around the Sun? Circle the correct letter.

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>67</td>
<td>36</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>an</td>
<td>an</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>an</td>
<td>an</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>29</td>
<td>61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>D - Correct</td>
<td>30</td>
<td>62</td>
</tr>
</tbody>
</table>
Unit 3 – The Solar System

Items:

1. Circle True or False for each statement below.
   A. Earth is in orbit around Saturn.
   A. As a planet orbits the Sun, it takes about the same amount of time to go around the sun each time it orbits.
   A. Moons orbit around planets
   A. Everything in the Solar System orbits around the Earth.
   A. A planet close to the Sun takes less time to orbit the Sun than a planet that is far from the Sun.
   A. Some planets in the Solar System don’t orbit the Sun.

2. What description in the chart below best describes the Solar System object listed on the Left? Circle the correct descriptions.

<table>
<thead>
<tr>
<th>Solar System Object</th>
<th>Temperature</th>
<th>Size</th>
<th>Distance from Sun</th>
<th>Composition</th>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Has Atmosphere</td>
</tr>
<tr>
<td>Venus</td>
<td>Hotter than Earth</td>
<td>Colder than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Neptune</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Mars</td>
<td>Hotter than Earth</td>
<td>Colder than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Pluto</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Ceres (Asteroid)</td>
<td>Hotter than Earth</td>
<td>Colder than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
</tbody>
</table>
Unit 3 – The Solar System

3. Choose a planet or moon in the Solar System (other than Earth) that might be suitable for life. What are at least three reasons why it might be suitable for life? Explain your answer.

3. What are the different objects on the diagram? Label as many objects as you can.

3. What are at least two accurate and two inaccurate things about the diagram as a model of the Solar System? List as many as possible.

3. How would you make a more scientifically accurate model of the Solar System?
Unit 3 – The Solar System

Item 1 – Multiple Choice

Circle True or False for each statement below.
A. Earth is in orbit around Saturn. (False)
A. As a planet orbits the Sun, it takes about the same amount of time to go around the sun each time it orbits. (True)
A. Moons orbit around planets. (True)
A. Everything in the Solar System orbits around the Earth. (False)
A. A planet close to the Sun takes less time to orbit the Sun than a planet that is far from the Sun. (True)
A. Some planets in the Solar System don’t orbit the Sun. (False)

Table 37. Unit 3 – Item 1 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>44</td>
<td>60</td>
</tr>
</tbody>
</table>
# Unit 3 – The Solar System

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth is in orbit around Saturn. (False)</td>
<td>78</td>
<td>91</td>
</tr>
<tr>
<td>As a planet orbits the Sun, it takes about the same amount of time to go around the sun each time it orbits. (True)</td>
<td>74</td>
<td>83</td>
</tr>
<tr>
<td>Moons orbit around planets. (True)</td>
<td>74</td>
<td>89</td>
</tr>
<tr>
<td>Everything in the Solar System orbits around the Earth. (False)</td>
<td>81</td>
<td>92</td>
</tr>
<tr>
<td>A planet close to the Sun takes less time to orbit the Sun than a planet that is far from the Sun. (True)</td>
<td>73</td>
<td>84</td>
</tr>
<tr>
<td>Some planets in the Solar System don’t orbit the Sun. (False)</td>
<td>76</td>
<td>88</td>
</tr>
</tbody>
</table>
Unit 3 - The Solar System

Item 2 – Multiple Choice

What description in the chart below best describes the Solar System object listed on the Left? Circle the correct descriptions.

<table>
<thead>
<tr>
<th>Solar System Object</th>
<th>Temperature than Earth</th>
<th>Size than Earth</th>
<th>Distance from Sun than Earth</th>
<th>Composition</th>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Ice</td>
</tr>
<tr>
<td>Venus</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Neptune</td>
<td>Hotter than Earth</td>
<td>Smaller than Earth</td>
<td>Farther to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Ice</td>
</tr>
<tr>
<td>Mars</td>
<td>Hotter than Earth</td>
<td>Bigger than Earth</td>
<td>Farther to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Pluto</td>
<td>Hotter than Earth</td>
<td>Smaller than Earth</td>
<td>Farther to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
<tr>
<td>Ceres (Asteroid)</td>
<td>Hotter than Earth</td>
<td>Smaller than Earth</td>
<td>Closer to the Sun than Earth</td>
<td>Mostly Gas</td>
<td>Mostly Rock</td>
</tr>
</tbody>
</table>
## Unit 3 – The Solar System

### Table 39. Unit 3 – Item 2 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>49</td>
<td>43</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>20</td>
<td>44</td>
</tr>
</tbody>
</table>

### Table 40. Unit 3 – Item 2 – Jupiter Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Size</td>
<td>83</td>
<td>91</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>84</td>
<td>91</td>
</tr>
<tr>
<td>Composition</td>
<td>55</td>
<td>71</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>39</td>
<td>64</td>
</tr>
</tbody>
</table>
## Unit 3 – The Solar System

### Table 41. Unit 3 – Item 2 – Venus Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td>Size</td>
<td>66</td>
<td>72</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>66</td>
<td>84</td>
</tr>
<tr>
<td>Composition</td>
<td>41</td>
<td>58</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>39</td>
<td>64</td>
</tr>
</tbody>
</table>

### Table 42. Unit 3 – Item 2 – Neptune Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>79</td>
<td>85</td>
</tr>
<tr>
<td>Size</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>79</td>
<td>89</td>
</tr>
<tr>
<td>Composition</td>
<td>30</td>
<td>44</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>36</td>
<td>53</td>
</tr>
</tbody>
</table>

### Table 43. Unit 3 – Item 2 – Mars Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Size</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>62</td>
<td>77</td>
</tr>
<tr>
<td>Composition</td>
<td>52</td>
<td>73</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>48</td>
<td>74</td>
</tr>
</tbody>
</table>
Table 44. Unit 3 – Item 2 – Pluto Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>84</td>
<td>92</td>
</tr>
<tr>
<td>Size</td>
<td>81</td>
<td>92</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>83</td>
<td>65</td>
</tr>
<tr>
<td>Composition</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>63</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 45. Unit 3 – Item 2 – Ceres Responses

<table>
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<tr>
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<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
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<td>81</td>
</tr>
<tr>
<td>Size</td>
<td>62</td>
<td>83</td>
</tr>
<tr>
<td>Distance from Sun</td>
<td>61</td>
<td>75</td>
</tr>
<tr>
<td>Composition</td>
<td>59</td>
<td>87</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>72</td>
<td>92</td>
</tr>
</tbody>
</table>
## Unit 3 – The Solar System

### Table 46. Unit 3 – Item 2 – Temperature Responses

<table>
<thead>
<tr>
<th>Object</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Venus</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td>Neptune</td>
<td>79</td>
<td>85</td>
</tr>
<tr>
<td>Mars</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Pluto</td>
<td>84</td>
<td>92</td>
</tr>
<tr>
<td>Ceres</td>
<td>51</td>
<td>84</td>
</tr>
</tbody>
</table>
## Unit 3 – The Solar System

### Table 47. Unit 3 – Item 2 – Size Responses

<table>
<thead>
<tr>
<th>Object</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>83</td>
<td>91</td>
</tr>
<tr>
<td>Venus</td>
<td>66</td>
<td>72</td>
</tr>
<tr>
<td>Neptune</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>Mars</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>Pluto</td>
<td>81</td>
<td>92</td>
</tr>
<tr>
<td>Ceres</td>
<td>62</td>
<td>83</td>
</tr>
</tbody>
</table>

### Table 48. Unit 3 – Item 2 – Distance from Sun Responses

<table>
<thead>
<tr>
<th>Object</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
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<tbody>
<tr>
<td>Jupiter</td>
<td>84</td>
<td>91</td>
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<tr>
<td>Venus</td>
<td>66</td>
<td>84</td>
</tr>
<tr>
<td>Neptune</td>
<td>79</td>
<td>89</td>
</tr>
<tr>
<td>Mars</td>
<td>62</td>
<td>77</td>
</tr>
<tr>
<td>Pluto</td>
<td>83</td>
<td>65</td>
</tr>
<tr>
<td>Ceres</td>
<td>61</td>
<td>75</td>
</tr>
</tbody>
</table>
## Table 49. Unit 3 – Item 2 – Composition Responses

<table>
<thead>
<tr>
<th>Object</th>
<th>Pretest Percent Correct</th>
<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>55</td>
<td>71</td>
</tr>
<tr>
<td>Venus</td>
<td>41</td>
<td>58</td>
</tr>
<tr>
<td>Neptune</td>
<td>30</td>
<td>44</td>
</tr>
<tr>
<td>Mars</td>
<td>52</td>
<td>73</td>
</tr>
<tr>
<td>Pluto</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Ceres</td>
<td>59</td>
<td>87</td>
</tr>
</tbody>
</table>

## Table 50. Unit 3 – Item 2 – Atmosphere Responses

<table>
<thead>
<tr>
<th>Object</th>
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<th>Posttest Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>39</td>
<td>64</td>
</tr>
<tr>
<td>Venus</td>
<td>39</td>
<td>64</td>
</tr>
<tr>
<td>Neptune</td>
<td>36</td>
<td>53</td>
</tr>
<tr>
<td>Mars</td>
<td>48</td>
<td>74</td>
</tr>
<tr>
<td>Pluto</td>
<td>63</td>
<td>74</td>
</tr>
<tr>
<td>Ceres</td>
<td>72</td>
<td>92</td>
</tr>
</tbody>
</table>
Unit 3 – The Solar System

Item 3 – Short Answer

Choose a planet or moon in the Solar System (other Than Earth) that might be suitable for life. What are at least three reasons why it might be suitable for life? Explain your answer.

Table 51. Unit 3 – Item 3 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>17</td>
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<tr>
<td>Insufficient Information (Score 2)</td>
<td>25</td>
<td>27</td>
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<tr>
<td>Partial Understanding (Score 3)</td>
<td>35</td>
<td>37</td>
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<tr>
<td>Complete Understanding (Score 4)</td>
<td>10</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 52. Unit 3 – Item 3 – Responses – Planets/Moons

<table>
<thead>
<tr>
<th>Planet Chosen</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>Earth</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mercury</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Saturn</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Europa</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Earth’s Moon</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Venus</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Uranus</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Titan</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other Moons</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Jupiter</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Neptune</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pluto</td>
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<td>3</td>
</tr>
</tbody>
</table>
## Table 53. Unit 3 – Item 3 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>27</td>
<td>53</td>
</tr>
<tr>
<td>Water</td>
<td>34</td>
<td>47</td>
</tr>
<tr>
<td>Rocky Surface</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>Temperature</td>
<td>34</td>
<td>46</td>
</tr>
</tbody>
</table>
Unit 3 – The Solar System

Item 4 – Short Answer

What are the different objects on the diagram? Label as many objects as you can.

Table 54. Unit 3 – Item 4 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>12</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 55. Unit 3 – Item 4 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent Labeled</th>
<th>Posttest Percent Labeled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>74</td>
<td>70</td>
</tr>
<tr>
<td>Earth</td>
<td>59</td>
<td>72</td>
</tr>
<tr>
<td>Jupiter</td>
<td>56</td>
<td>71</td>
</tr>
<tr>
<td>Neptune</td>
<td>44</td>
<td>62</td>
</tr>
<tr>
<td>Mercury</td>
<td>51</td>
<td>67</td>
</tr>
<tr>
<td>Mars</td>
<td>49</td>
<td>65</td>
</tr>
<tr>
<td>Saturn</td>
<td>64</td>
<td>77</td>
</tr>
<tr>
<td>Pluto</td>
<td>69</td>
<td>79</td>
</tr>
<tr>
<td>Venus</td>
<td>48</td>
<td>67</td>
</tr>
<tr>
<td>Asteroid Belt</td>
<td>20</td>
<td>43</td>
</tr>
<tr>
<td>Uranus</td>
<td>40</td>
<td>59</td>
</tr>
</tbody>
</table>
Unit 3 – The Solar System

Item 5 – Short Answer

What are at least two accurate and two inaccurate things about the diagram as a model of the Solar System? List as many as possible.

Table 56. Unit 3 – Item 5 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
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</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
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<tr>
<td>Partial Understanding (Score 3)</td>
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<td>2</td>
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<tr>
<td>Complete Understanding (Score 4)</td>
<td>37</td>
<td>57</td>
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</tbody>
</table>
Unit 3 – The Solar System

Item 6 - Short Answer

How would you make a more scientifically accurate model of the Solar System?

Table 57. Unit 3 – Item 6 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
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<td>24</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>32</td>
<td>37</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>17</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 58. Unit 3 – Item 6 – Responses

<table>
<thead>
<tr>
<th>Category</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Size</td>
<td>26</td>
<td>31</td>
</tr>
<tr>
<td>Orbit</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Spacing/Distance</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Scale</td>
<td>8</td>
<td>15</td>
</tr>
</tbody>
</table>
Unit 4 – Beyond The Solar System

Items

1. Why is detecting planets around other starts difficult? Explain at least two reasons.

1. What is the order of things from smallest to largest? Fill in the blanks below with the following

   The Universe
   The Sun
   The Milky Way Galaxy
   The Solar System
   The Earth

3. Which is true?
   A. There are galaxies in the Solar System.
   A. There are more galaxies than stars.
   A. There are more than a billion galaxies.
   A. No galaxies can be viewed as a whole through a telescope.

3. What stars can we see with the unaided eye in the night sky?
   A. Stars in our Solar System
   A. Most of the stars in the galaxy.
   A. Most of the stars in the Universe.
   A. A small portion of the stars in the galaxy.

3. Which is the best description of how stars are arranged in the Universe?
   A. They occur in clumps called galaxies that are many different sizes and shapes.
   A. They are spread out fairly evenly throughout the Universe.
   A. There is no apparent order to the arrangement of stars in the Universe.
   A. They occur in clumps called galaxies, which are all about the same size and shape.

3. How have astronomers explored the stars beyond our solar system? Circle all the are true.
   A. By studying our own Sun and comparing it to other stars.
   A. By sending astronauts to other stars.
   A. By sending spacecraft to fly by other stars.
   A. By studying the light that comes to Earth from stars.
Unit 4 – Beyond The Solar System

Item 1 – Short Answer

Why is detecting planets around other stars difficult? Explain at least two reasons.

Table 59. Unit 4 – Item 1 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
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<td>Missing/Wrong (Score 0)</td>
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<td>6</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>47</td>
<td>42</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>18</td>
<td>38</td>
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<tr>
<td>Complete Understanding (Score 4)</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 60. Unit 4 – Item 1 – Responses

<table>
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<th>Posttest Percent</th>
</tr>
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<tbody>
<tr>
<td>Distance</td>
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<td>42</td>
</tr>
<tr>
<td>Size</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Light</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Telescope</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Unit 4 – Beyond The Solar System

Item 2 – Short Answer

What is the order of things from smallest to largest? Fill in the blanks below with the following:

- The Universe
- The Sun
- The Milky Way Galaxy
- The Solar System
- The Earth

Table 61. Unit 4 – Item 2 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
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<td>0</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
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<tr>
<td>Insufficient Information (Score 2)</td>
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<td>NA</td>
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<tr>
<td>Complete Understanding (Score 4)</td>
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<td>79</td>
</tr>
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</table>
### Table 62. Unit 4 – Item 2 – Percent Choosing Categories

<table>
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<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smallest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universe</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sun</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Milky Way</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Solar System</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Earth</td>
<td><strong>90</strong></td>
<td><strong>98</strong></td>
</tr>
<tr>
<td><strong>Second</strong></td>
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<td></td>
</tr>
<tr>
<td>Universe</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sun</strong></td>
<td><strong>78</strong></td>
<td><strong>95</strong></td>
</tr>
<tr>
<td>Milky Way</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Solar System</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Earth</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Third</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universe</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Sun</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Milky Way</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td><strong>Solar System</strong></td>
<td><strong>57</strong></td>
<td><strong>81</strong></td>
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<tr>
<td>Earth</td>
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<td>0</td>
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<tr>
<td><strong>Fourth</strong></td>
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<td></td>
</tr>
<tr>
<td>Universe</td>
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</tr>
<tr>
<td>Sun</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Milky Way</strong></td>
<td><strong>54</strong></td>
<td><strong>81</strong></td>
</tr>
<tr>
<td>Solar System</td>
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<td>15</td>
</tr>
<tr>
<td>Earth</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Largest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universe</td>
<td><strong>87</strong></td>
<td><strong>96</strong></td>
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<td>Sun</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Milky Way</td>
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<td>Earth</td>
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### Table 63. Unit 4 – Item 2 – Percent Choosing Correct Responses Pre/Post

<table>
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<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
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<tr>
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<tr>
<td>Second</td>
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</tr>
<tr>
<td>Third</td>
<td><strong>56 / 81</strong></td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td><strong>54 / 81</strong></td>
<td></td>
</tr>
<tr>
<td>Largest</td>
<td><strong>87 / 96</strong></td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sun</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milky Way</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unit 4 – Beyond The Solar System

Item 3 – Multiple Choice

Which is true?

A. There are galaxies in the Solar System.
A. There are more galaxies than stars.
A. There are more than a billion galaxies.
A. No galaxies can be viewed as a whole through a telescope.

Table 64. Unit 4 – Item 3 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
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<td>5</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>73</td>
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</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
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<td>55</td>
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</tbody>
</table>

Table 65. Unit 4 – Item 3 – Responses

<table>
<thead>
<tr>
<th>Answer</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are galaxies in the Solar System. (Incorrect)</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>There are more galaxies than stars. (Incorrect)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>There are more than a billion galaxies. (Correct)</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>No galaxies can be viewed as a whole through a telescope. (Incorrect)</td>
<td>41</td>
<td>22</td>
</tr>
</tbody>
</table>
Unit 4 – Beyond The Solar System

Item 4 – Multiple Choice

What stars can we see with the unaided eye in the night sky?
A. Stars in our Solar System
A. Most of the stars in the galaxy.
A. Most of the stars in the Universe.
A. A small portion of the stars in the galaxy.

Table 66. Unit 4 – Item 4 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
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<td>1</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>49</td>
<td>35</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>51</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 67. Unit 4 – Item 4 – Responses Chosen

<table>
<thead>
<tr>
<th>Answer</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stars in our Solar System. (Incorrect)</td>
<td>32</td>
<td>18</td>
</tr>
<tr>
<td>Most of the stars in the galaxy. (Incorrect)</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Most of the stars in the universe. (Incorrect)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>A small portion of the stars in the galaxy. (Correct)</td>
<td>52</td>
<td>63</td>
</tr>
</tbody>
</table>
Unit 4 – Beyond the Solar System

Item 5 – Multiple Choice

Which is the best description of how stars are arranged in the Universe?

A. They occur in clumps called galaxies that are many different sizes and shapes.
A. They are spread out fairly evenly throughout the Universe.
A. There is no apparent order to the arrangement of stars in the Universe.
D. They occur in clumps called galaxies, which are all about the same size and shape.

Table 68. Unit 4 – Item 5 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>70</td>
<td>41</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>29</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 69. Unit 4 – Item 5 – Responses

<table>
<thead>
<tr>
<th>Answer</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>They occur in clumps called galaxies that are many different sizes and shapes. (Correct)</td>
<td>30</td>
<td>55</td>
</tr>
<tr>
<td>They are spread out fairly evenly throughout the universe. (Incorrect)</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>There is no apparent order to the arrangement of stars in the Universe. (Incorrect)</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>They occur in clumps called galaxies, which are all about the same size and shape. (Incorrect)</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>
Unit 4 – Beyond The Solar System

Item 6 – Multiple Choice

How have astronomers explored the stars beyond our solar system? Circle all that are true.

A. By studying our own Sun and comparing it to other stars.
B. By sending astronauts to other stars.
C. By sending spacecraft to fly by other stars.
D. By studying the light that comes to Earth from stars.

Table 70. Unit 4 – Item 6 – Score Frequencies

<table>
<thead>
<tr>
<th>Score</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing/Wrong (Score 0)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Inaccurate Information (Score 1)</td>
<td>60</td>
<td>44</td>
</tr>
<tr>
<td>Insufficient Information (Score 2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Partial Understanding (Score 3)</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Complete Understanding (Score 4)</td>
<td>20</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 71. Unit 4 – Item 6 – Responses – Percent of Students that Chose Correctly

<table>
<thead>
<tr>
<th>Answer</th>
<th>Pretest Percent</th>
<th>Posttest Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>By studying our own Sun and comparing it to other stars. (True)</td>
<td>59</td>
<td>68</td>
</tr>
<tr>
<td>By sending astronauts to other stars. (False)</td>
<td>80</td>
<td>89</td>
</tr>
<tr>
<td>By sending spacecraft to fly by other stars. (False)</td>
<td>47</td>
<td>61</td>
</tr>
<tr>
<td>By studying the light that comes to Earth from stars. (True)</td>
<td>60</td>
<td>71</td>
</tr>
</tbody>
</table>