**A STUDY OF THE EFFECTS OF SPACE TELESCOPE SCIENCE INSTITITUTE'S
PLANET IMPACT CURRICULUM:
FINAL EVALUATION REPORT**
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August 31, 2004

INTRODUCTION

Administrators and teachers continually search for supplemental materials that will
enhance instruction for teachers and promote greater learning for students. The Space
Telescope Science Institute (STScI) offers a variety of online supplementary resources
for K-16 students based on Hubble Space Telescope data and imagery. It is essential that
these curriculum materials be evaluated in a rigorous manner — especially given the
recent emphasis on scientifically based research regarding "what works" for teaching and
learning. In order to determine the effectiveness of its Planet Impact materials, STScI
requested evaluation services from Mid-Continent Research for Education and Learning
(McREL), an external, independent, and nationally recognized leader in educational
research and evaluation.

EVALUATION APPROACH AND DESIGN

The purpose of this study was to evaluate the effectiveness of STScI's supplemental
curriculum materials, Planet Impact, on eighth-grade students. McREL's summative
evaluation of the Planet Impact materials employed a quantitative methodology in order
to assess the effectiveness of the program in the eighth grade. Specifically, the evaluation
study used a quasi-experimental design with randomly assigned treatment and control
groups and pre- and post-assessments to measure the impact of the Planet Impact
materials on student learning. The evaluation was designed to address the following
questions:[1]

> 1. Did students' use of the Planet Impact materials result in an increase in
>   their understanding of the science concepts and standards embedded in
>   the materials?
> 2. How did STScI program participants who used Planet Impact materials
>   compare to non-participants on pre/post standards-based assessments?

METHOD

This study examined the effect that participating in the Planet Impact activities had on eighth-grade students' knowledge and skills related to forces and motion. The implementation period lasted five days during the end of the 2003-2004 school year. This section provides a description of the methods employed in this study, including the Planet Impact intervention, literature review, measures, procedures, settings, and participants.

<u>Intervention</u>

Teachers and students access the Planet Impact materials via STScI's Amazing Space website (http://amazing-space.stsci.edu). These materials enable students to investigate the effects of gravity on a comet's trajectory. Students do this by changing the angle of approach, the speed, and the masses of the large and small bodies. The Planet Impact lesson consists of four learning modules: (1) "What's Your Angle?" (2) "Step On It!" (3) "Pick a Comet — Any Comet," and (4) "It's a Matter of Mass." The lesson also provides an online assessment activity, "Target Practice: Hit or Miss?," as well as additional follow-up activities and opportunities for teachers to make interdisciplinary connections.

The materials are designed to help students achieve seven learning outcomes:

1. State the relationship between the mass of an object and the gravitational force it exerts on other objects.
2. Explain the relationship between the distance from a planet and the force of gravity it exerts on an object.
3. Explain how speed affects the path of a body when it is near a more massive one.
4. Explain the relationship between the mass of a body and its acceleration when it is near a more massive body.
5. Investigate how an object will be trapped by a planet's unbalanced gravitational force.
6. Apply acquired knowledge to launch a comet with the intent to hit or miss a planet.
7. Explain the significance of the crash of Shoemaker-Levy 9 on Jupiter.

Teachers can use the Planet Impact materials for whole-class instruction, small-group instruction, and individual learning. The lesson presents accommodations for classrooms with different technology equipment including those classrooms with only one computer and an overhead.

Literature Review

A brief literature review was conducted in order to gather evidence on the effectiveness of supplemental science materials and to identify studies of supplemental programs similar to Planet Impact that report effect sizes. Effect sizes from past similar studies were gathered to provide a context for interpreting the effect sizes in this study. The Educational Resources Information Center and PsychInfo databases were searched using terms such as "science + supplemental + instructional material" and "supplemental + instructional material + effect sizes." In place of the terms "supplemental" and "instructional material," synonyms including "auxillary," "complimentary," "computer-

assisted instruction," and "instructional media" were used. This brief literature review yielded few relevant studies for purposes of this study, thus indicating a need for further quantitative research on the effects of supplemental science materials on student learning.[2] Evaluators reviewed 120 studies from the search; of those, 14 were considered to be related or tangentially related to this study.[3] The most relevant studies are discussed in this report.

The Planet Impact materials provided teachers with opportunities to implement various instructional strategies including independent, small-group, and whole-class activities that involve online simulations, hands-on activities, and inquiry-based[4] learning. Students participating in alternative science teaching strategies, including inquiry strategies and enhanced context strategies have performed better on achievement measures than students participating in traditional instruction (Wise, 1996). According to a meta-analysis conducted by Wise (1996), inquiry strategies involve student-centered, inductive instruction that is less step by step and teacher directed than traditional instruction.

Examples include facilitated inquiry activities, guided discoveries, inductive laboratories, or indirect instruction, many of which are embedded in the Planet Impact activities. Based on 103 student achievement outcome measures, there was a mean effect size of +.28 for students participating in inquiry strategies. Enhanced context strategies involve times when teachers work with students in organizational schemes or contexts that they ordinarily would not use. The strategies in this broad category include field trips, group discussions, self-paced learning, games, or simulations. The mean effect size is +.26 from 103 student achievement measures, thus indicating that students positively benefit from participating in enhanced context strategies.

The Planet Impact supplemental materials include a computer-based instructional component. Typically, computer-based instruction involves student-centered learning materials, tutorials, games, simulations, and modeling as well as progress monitoring and additional teaching materials to expand learning. The Planet Impact computer simulations provide students with interactive, inquiry-based learning opportunities. The Planet Impact online component also includes an interactive assessment activity that allows students to test what they learn from the online simulations. The assessment activity allows students to participate in the test simulation until they arrive at the correct answer. Teachers then supplement the online component with additional classroom activities.

Three meta-analyses indicate that supplementing traditional instruction with computer-based instruction (CBI), also referred to as computer-assisted instruction (CAI), results in positive impacts on student learning (Christmann, & Badgett, 2003; Azevedo & Bernard, 1995; Hasselbring, 1984). A meta-analysis that compared the academic achievement of elementary students who received either traditional instruction or traditional instruction supplemented with computer-assisted instruction (CAI) found an overall mean effect size of +.34 based on 68 effect sizes; thus, indicating that, on average, students receiving traditional instruction supplemented with CAI attained higher academic achievement than

did 63.31 percent of those receiving only traditional instruction (Christmann & Badgett, 2003).

Research on computer-based instruction points to several conclusions: (1) when CBI and traditional instruction are compared, students receiving CBI demonstrate equal or better achievement; (2) equal or better achievement using CBI is obtained in less time; (3) the use of CBI improves students' attitudes towards the use of computers in learning situations; (4) the positive effect on learning achievement occurs regardless of the type of CBI used, the type of computer system, or the age of the students; and (5) teacher interaction proves to be effective in CBI situations (Hasselbring, 1984). Additional research reveals that computer-based instruction that provides immediate feedback about learning results in positive impacts on student achievement with a weighted mean effect size of +.80 based on 22 studies (Azevedo, & Bernard,1995). However, feedback effects on learning and retention were found to vary with CBI typology, format of unit content, and access to supplemental materials.

Measures

McREL developed two instruments to collect teacher implementation data and student outcome data for this study.

Teacher Implementation Assessment

In order to assess teachers' implementation of content materials during the study period, McREL constructed two online surveys, one for treatment teachers and one for control teachers. The survey for treatment teachers was designed to collect implementation information in order to assess the fidelity of administering the Planet Impact program.[5] The treatment teacher survey consisted of 28 items that addressed teacher background information, lesson implementation, teacher perceptions of quality and utility, and program effect on instruction and learning.

The survey for control teachers consisted of 15 items that addressed teacher background information and lesson implementation. The central purpose of the control teacher survey was to collect descriptive information about the materials and instructional practices teachers used during the study period. The findings from the control teacher survey are presented in the Results section of this report.

Student Knowledge and Skills Assessment

In order to address the evaluation questions for this study, it was necessary to use an assessment relevant to both students who used the Planet Impact materials and those who did not. As such, McREL developed a knowledge and skills pre/post assessment that aligned to both the Planet Impact science concepts and district and state standards related to forces and motion. It was McREL's judgment that a standards-based assessment would be most relevant and appropriate for measuring student learning in treatment and control classrooms.

McREL began its assessment development process by first identifying the National Science Education Standards embedded in the Planet Impact materials. McREL also completed a state and district standards alignment to the Planet Impact materials. Second, McREL reviewed national and state assessment documents (i.e., NAEP, TIMSS, and state assessments in which the study took place) for any pertinent assessment items. Third, McREL reviewed and adapted assessment items from the Planet Impact materials. Fourth, after a quality assurance review by internal staff members, McREL submitted the assessment for external review to university professors at Massachusetts Institute of Technology and Wichita State University to ensure content and construct validity. Based on reviewer feedback, McREL made revisions to the assessment.

Next, McREL pilot-tested the assessment with a small number of eighth-grade students in a school proximate to McREL. During the pilot test, students participated in the Planet Impact activities, took the assessment, and provided feedback on the instrument regarding any words or phrases that were unclear or confusing. McREL used this feedback to make further modifications to the instrument. Finally, staff at STScI reviewed and provided feedback on the validity of the assessment, which led to further modification of the assessment. The final assessment, which provides the basis for the findings in this report, consisted of 23 items: 12 multiple choice items, 2 true or false items, 7 ordering items, and 2 short essay items.[6] The assessment took 35-40 minutes to complete.

Procedures

<u>Study Orientation</u>

Treatment and control teachers participated in a 90-minute orientation session. During this time, McREL oriented teachers to the study design, the online teacher surveys, and the student assessment. Treatment teachers also participated in a review of the Planet Impact materials.

<u>Test Administration and Scoring</u>

During the study orientation, McREL reviewed the administration and scoring processes for the student assessment. Teachers administered the student assessment before and after the five-day implementation period. Each teacher was responsible for scoring the pretests and posttests for their students based on the answer sheets provided by McREL. Teachers were given explicit directions, written and verbal, regarding the scoring of tests. Despite this instruction, teachers had a high error rate in scoring the tests. As a result, McREL rescored all of the tests to ensure accuracy. The highest possible score on the student assessment was 36.

Settings

The evaluation study took place in two schools in one urban school district located in an Eastern coastal city. This school district consists of a low socioeconomic, low-achieving, and high-minority student population. Neither school received Title 1 funding during the 2003-2004 school year; however at least 50 percent of students in both schools qualified for free or reduced-price lunch.

Schools were chosen in order to enhance the generalizability of the findings from this study so that the findings are applicable to the types of students and settings most likely to use Planet Impact materials. Based on experience, STScI staff believed that teachers' access to technology and comfort with using technology in the classroom were paramount in the successful implementation of the Planet Impact materials. Therefore, schools were considered for selection based on their support of technology integration and their existing technology infrastructure. Additionally, it was important to ensure that no other major supplemental science initiatives similar to Planet Impact were being implemented in the classrooms.

Schools also were considered for selection based on the number of eighth-grade students, the percentage of students who passed the 2002-2003 state student assessment in science, the percentage of highly qualified eighth-grade teachers, the percentage of students qualifying for free- or reduced-price lunch, and the percentage of minority students. Table 1 presents this information for both the treatment and the control school. Once qualifying schools were identified, a treatment and control school were randomly selected by the toss of a coin.

Table 1.

Treatment and Control School Characteristics

Characteristics	Treatment School	Control School
Number of eighth-grade students, 2003-2004	330	240
Percentage passing 2002-2003 state science assessment	82%	85%
Percentage of highly qualified eighth-grade teachers	100%	100%
Percentage of students who qualified for free or reduced-price lunch	60%	50%
Percentage of minority students	70%	44%

Participants

<u>Teachers</u>

Three treatment teachers and three control teachers agreed to participate in the study and signed an informed consent form. Participant teachers received hard copies and CD-ROMs of the Planet Impact materials prior to the study. Control teachers were able to access the Planet Impact materials online after the study. All teachers and the site coordinator received a small stipend for their contributions to the study.

Of the six teachers, three held a bachelor's degree and three had earned a master's degree. Three of the participating teachers had been teaching eighth-grade science five years or less and three had taught for five years or more. When asked how often teachers integrate technology into their instruction during the school year, two teachers reported weekly, three teachers reported monthly, and one teacher reported quarterly. Overall, these teacher characteristics were evenly distributed across treatment and control groups. All of the teachers participating in the study reported that they felt comfortable or very comfortable integrating technology into their instruction. Five teachers indicated that they were very comfortable using inquiry-based, hands-on activities.[7]

Students

The final sample consisted of 310 eighth-grade students: 179 students in the treatment group and 131 students in the control group. Means comparisons of assessment pretest scores using independent samples t tests were conducted to determine if participant and control groups differed significantly prior to the study. The analyses revealed no significant differences on initial assessment performance between treatment and control groups when equal variances were not assumed, $t (1, 307) = .82, p = .41$, thus indicating that these two groups demonstrated comparable knowledge of forces and motion before the study.

RESULTS

The evaluation questions for this study focus on (1) student performance in Planet Impact classrooms and (2) student performance comparisons for students who participated in the Planet Impact activities and those who did not. This section presents the results of these evaluation questions based on the student pre/post assessment and the teacher online surveys.

Teacher Implementation

In order to better understand how teachers taught the concepts of forces and motion (either using the Planet Impact materials or traditional materials), implementation data were collected from teachers via an online survey. In the control setting, this information provided a description of the way in which teachers traditionally teach these concepts using materials, activities, and instructional strategies. The implementation data collected from the treatment group of teachers provided information regarding the fidelity of implementing the program. It is important to mention that because the teacher sample sizes were small, these data are not sufficient to generalize findings to the population of

teachers from which the samples were drawn. Nevertheless, the implementation data provide insights for the interpretation of the findings from the student outcome data.

Implementation in Control Classrooms

On average, students in control classrooms received 125 minutes of instructional time on forces and motion during the five-day study period. Control teachers indicated that they used a wide variety of instructional materials and strategies to teach forces and motion. For example, one teacher indicated using worksheets, overhead transparencies, textbooks, film, computers, online activities, and a real-life, hands-on activity. Other control teachers reported using inquiry activities, lecture and demonstration, experiments, and typed notes. One control teacher indicated a great deal of confidence in students' learning, and explained: "Students were able to apply the information [they learned] through fun and interactive experiments." Control teachers facilitated lessons that provided students with opportunities to work individually, in small groups, and with the whole class.

Implementation in Treatment Classrooms

On average, students in treatment classrooms received 201 minutes of instructional time on the lessons during the study period. All teachers agreed that the amount of time that they spent implementing Planet Impact was an appropriate amount of time. Treatment teachers indicated that students participated in the Planet Impact activities in small groups, as a whole class, and as individuals.

Whereas control teachers could use a wide variety of instructional materials, the materials used by treatment teachers were determined by the scope of the Planet Impact materials. Yet, through the various Planet Impact activities, treatment teachers were able to implement a variety of instructional practices that included online activities and simulations as well as hands-on, inquiry-based activities. Teachers were given implementation guidelines that delineated which activities should be implemented during the study and which were optional. Although only one teacher indicated completing all of the required activities, the average treatment teacher reported completing 92 percent of the required Planet Impact activities; only one teacher omitted the misconception section, the inquiry activity "A Comet Hits Jupiter," and the student assessment activities. Finally, the average teacher reported completing the majority (53%) of the Planet Impact optional activities. Thus, fidelity of Planet Impact implementation appeared high.

Although it may be preferable for each student to individually access a computer, the Planet Impact teacher guide provides instructional variations based on technology availability, ranging from a classroom with one computer and an overhead projector to a student computer lab. As a result of technology limitations during the time of the study, treatment teachers indicated some level of technical difficulty in implementing the Planet Impact activities. In response to the question, "Did you have to modify your use of the Planet Impact materials because of technology limitations?" one teacher indicated that students had to "double up" on functioning computers. Another teacher indicated that the

class was "limited" to three computers. It is important to note, however, that the Planet Impact instructional materials account for technology variations such as those experienced by treatment teachers during the study.

Although McREL's alignment of the Planet Impact materials with state standards and district objectives indicated that it was appropriate to implement the materials in eighth grade, treatment teachers indicated that the Planet Impact materials seemed below grade level. One teacher explained, "I think the content is geared more for the sixth grade level than eighth grade." Another teacher, when asked what would make Planet Impact more useful and effective, replied, "Implement the lessons with students in grades six or lower." One teacher simply indicated that "the computer activities were not very challenging for the students."

In sum, both treatment and control group teachers used a variety of instructional materials and learning strategies. Control teachers spent somewhat less time teaching forces and motion than treatment teachers during the study period; this variation will be explored further in analyzing student assessment results. Treatment teachers demonstrated a high level of implementation fidelity during the study, despite their perceptions that the materials were not age appropriate and despite the instructional adjustments they had to make due to limited access to computers during the time of the study.

Student Performance Results

This study sought to answer two primary evaluation questions:

1. Did students' use of the Planet Impact materials result in an increase in their understanding of the science concepts and standards embedded in the materials?
2. How did STScI program participants who used Planet Impact materials compare to non-participants on pre/post standards-based assessments?

The Planet Impact student data, combined with implementation data from the teacher surveys, were intended to provide the information necessary to answer these questions. As noted earlier, students were assessed twice: before and after the intervention. This pre/post design allows evaluators to estimate the change in students' knowledge due to the Planet Impact materials.

In order to appropriately address the evaluation questions related to student performance, evaluators conducted various analyses, including descriptive and inferential statistical analyses and effect-size estimations.[8] Because a central interest of this study was to determine whether differences in student performance occurred for students in participant and control groups, univariate analyses of covariance (ANCOVA) were conducted. The analyses presented in this section reveal whether students in treatment and control groups experienced significant differences in performance related to forces and motion at the end of the study period.

<u>Treatment and Control Average Learning Gains</u>

In order to address the first evaluation question (#1) and to examine the differences in student learning from pretest to posttest, a paired-samples t test was conducted. Table 2 presents mean scores, standard deviations, and pretest-to-posttest mean differences as well as t test results and effect size estimations[9] for both treatment and control groups. As shown in Table 2, the results indicate that the treatment group showed significant improvement over the study period. The average treatment student score on the assessment activity before using the Planet Impact materials was 17.13 (of a possible 36). After the intervention, the average student's score was 19.56. The difference between this average pre- and post-score was highly statistically significant (p<.001). Moreover, calculations indicate a moderate effect size for the treatment of +.35. Effect sizes can be translated into percentile points for ease of interpretation. In this case, the treatment group effect size reflects an average learning gain of 13 to 14 percentile points on a standardized test. Based on this information, it may be interpreted that students' use of Planet Impact materials resulted in an increase in their understanding of the science concepts and standards embedded in the materials.

Table 2.

Paired Samples t Tests for Treatment and Control Students

	n	Pretest	Posttest	Pre-Post Mean Difference	t value	df	p level	ES (Cohen's d)
Treatment Group	179	17.13 (6.21)[a]	19.56 (7.79)	2.43	5.48	178	.000	.35
Control Group	131	16.64 (4.40)	17.37 (5.45)	.73	1.83	130	.069	.15

[a] Standard deviations are shown in parentheses.

A similar analysis was performed on the control group data. The results indicate that, while there was a difference in the mean pre and post score, this difference was not statistically significant (p=.069). The average control student's score before the intervention was 16.64, while the average control student's score after the intervention was 17.37. Finally, the effect size for the control condition was a modest +.15, which would translate to an average student learning gain of 6 percentile points on a standardized test.

<u>Treatment and Control Group Differences</u>

To answer the second evaluation question (#2), which inquires if the performance of treatment and control students differed on the student knowledge and skills assessment, evaluators conducted univariate analyses of covariance (ANCOVA). Therefore, this analysis determined if student performance on the posttest differed as a result of

assignment to either the treatment group or the control group when using students' pretest scores as a covariate. In using the pretest score as a covariate, evaluators controlled for students' performance on the assessment at the beginning of the study.

Results indicate a significant difference between treatment and control groups on the posttest when controlling for pretest performance, $F(1, 307) = 8.70$, $p = .003$, thus suggesting that the treatment students had overall higher levels of performance on the posttest assessment compared to control students. The effect size of $+.34$ is moderate and indicates that the average student's performance in the treatment group would be 13 percentile points higher than the average student's performance in the control group on a standardized test.

As reported previously, treatment teachers spent an average of 201 minutes of instruction on forces and motion during the study period, whereas control teachers spent an average of 125 minutes. Given this discrepancy, evaluators sought to understand if the amount of time teachers instructed students on forces and motion explained the difference between treatment and control group performance. Therefore, evaluators conducted an ANCOVA to examine posttest differences between treatment and control students with instructional time as a covariate to adjust for differences in instructional time.

Results indicate that when adjusting for instructional time, there were differences between treatment and control students on the posttest assessment, $F(1, 307) = 3.46$, $p = .06$. This reveals that when the amount of instructional time is held constant and does not vary, student performance in treatment and control groups did differ—with the p value approaching significance. Put another way, the greater performance levels demonstrated by the treatment group may be partially explained by the greater amount of instructional time to which that group was exposed. In light of this adjusted difference, the learning gains demonstrated between treatment and control groups reflect a moderate effect size of $+.20$, which would translate to an eight percentile-point learning gain for treatment students over control students.

Limitations of Study

There are limitations of this evaluation study that readers should take into account when interpreting the study's results. Foremost, this study did not employ a true experimental design with randomly assigned treatment and control students. Instead, random assignment occurred at the school level. As a result, other factors such as teacher- and school-related factors may have played a role in student performance. In addition, the sample was limited to only two schools with high minority populations and students with low socioeconomic status.

Therefore, caution is warranted in generalizing study results to the general population. Additionally, a larger sample size would greatly increase the power of the study to detect significant differences in learning; however, the budget precluded increasing the total sample size. Furthermore, because of test preparation and testing schedules, the study

could not be implemented until the end of the school year—a time when students and teachers may have been slightly disengaged or less open to new classroom activities.

CONCLUSION

The central purpose of this evaluation study was to measure the effectiveness of STScI's Planet Impact supplemental program on student learning in science, specifically forces and motion. In order to gauge the effectiveness of the Planet Impact materials, information was collected on teachers' implementation in both the treatment and control conditions, and on students' performance before and after the intervention. Treatment teachers demonstrated a high level of implementation fidelity during the study period, using 92 percent of the required materials and 53 percent of the optional materials. Both treatment and control teachers focused on forces and motion for a five-day period and used a variety of instructional strategies.

During the project period, treatment students using the Planet Impact materials demonstrated significant learning gains from pretest to posttest with a moderate effect size ($d = +.35$), whereas the learning gains demonstrated by control students were not significant. The effect size for students participating in Planet Impact is consistent with the small-to-moderate effect sizes reported by Wise (1996) in his meta-analysis of students participating in inquiry strategies ($d = +.28$) and enhanced context strategies, such as simulations, games, and self-paced learning ($d = +.26$).

Comparisons between treatment and control groups suggest that treatment students had overall higher levels of performance on the posttest assessment. The effect size of $+.34$ indicates that the average student's performance in the treatment group would be 13 percentile points higher than the average student's performance in the control group on a standardized test. Overall, the results of this study reveal that eighth-grade students experienced significant learning gains from using the Planet Impact materials.

FOOT NOTES

[1] The evaluation plan included a third question to examine differences between three groups of participants: those who used the Planet Impact materials and received training, those who used the materials without training, and those who used traditional materials to teach forces and motion. This third question was eliminated as a result of design changes made during the site recruitment process.

[2] There were several reasons for determining that many studies were not relevant to this review. Reasons for excluding studies were that they didn't include measures of student achievement, the sample involved only subgroups of students (e.g., special education, ESL, low-achieving), the sample was international, the study was not research or evaluation, or the intervention was too dissimilar to Planet Impact.

[3] These include only five studies related to science and several studies related to computer-based or computer-assisted instruction across various content areas.

[4] Inquiry-based learning involves asking a simple question, completing an investigation, answering the question, and presenting the results to others.

[5] Originally, both a teacher log and survey were planned for the study based on an implementation period of three weeks. Because the implementation period was only five days, these two instruments were combined into one online survey.

[6] The assessment—as completed by students—consisted of 24 items; however, one multiple choice item was omitted in analysis because of a revision error.

[7] One teacher did not respond to this item.

[8] An effect size is a unit of measurement that expresses the increase or decrease in achievement of students in the treatment group. Effect sizes are expressed in standard deviation units. For example, an effect size of 1.0 indicates that that the mean score in the treatment group was 1.0 standard deviation higher than the mean score in the control group.

[9] Effect sizes were estimated using Cohen's d formula in which the mean pretest score is subtracted from the mean posttest score and then divided by the pooled standard deviation for the pretest and posttest.

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