SUMMARY

Students learning in the context of the environment begin to look at the world of math a little differently. Instead of thinking that math is only abstract concepts, these students learn that math skills are tools that they can use to quantify, analyze, and recognize connections among natural and socio-economic systems.

Learning in the context of their local environment fosters deeper understanding of math and enables students to more readily master crucial skills than they would in a traditional curriculum. They see how math connects to other disciplines and helps them interpret what they discover when studying economics, geography, science, and other subject areas.

EIC students also more readily remember what they learn. When they apply their emerging skills to problems that are relevant to them, students’ attitudes toward learning math improve and they begin to understand the value of math in everyday life. In the process, they become more motivated and enthusiastic about math.

Data from both the Learning and Domains Surveys indicate that teachers and administrators have found EIC-based learning to be an effective means of helping students develop their math knowledge and skills. Table 9 summarizes data obtained from the Learning and Domains Surveys on the effects of EIC on learning math skills.

Seven of the study schools conducted comparative analyses of mathematics achievement data from both EIC and traditional students. These seven schools conducted a total of seven comparative analyses of mathematics achievement using data from several different standardized tests.

Based on analysis of these data, five of the seven schools (71 percent) found that quantitative measures of achievement affirm the academic benefits of EIC-based learning for mathematics. Math was not integrated into the EIC programs at either of the two schools where achievement scores for EIC students were equal to or lower than scores for traditional students. The equal or lower scores at the schools that did not integrate math may, in fact, be additional evidence of the value of incorporating math into EIC programs. Table 10 provides a summary of the results of the comparative analyses of mathematics at these seven schools.
TABLE 9. Summary of Learning and Domains Surveys on Mathematics.

<table>
<thead>
<tr>
<th>Learning Survey Items</th>
<th>% of Educators Reporting Student Improvement</th>
<th># of Educators Responding to this Survey Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning of math</td>
<td>92%</td>
<td>137</td>
</tr>
</tbody>
</table>

Domains Survey Items

| Knowledge: content, concepts, and principles | 73% | 92 |
| Skills: processes and application to real situations | 93% | 94 |
| Retention of knowledge and skills          | 78% | 83 |
| Attitudes: engagement, enthusiasm, and interest | 89% | 94 |
| Opportunities: context and content for learning | 96% | 91 |
| Average for Math Domains Survey            | 86% | 91 |

FINDINGS

Authentic, environment-based experiences provide students with a lens through which they can connect math with all other disciplines; consequently, it becomes a more relevant and valuable subject to them. Teachers at all 40 case study schools found that employing EIC approaches is a highly effective means of making math lively, engaging, and meaningful for learners of all ages. Students learn math better when they can connect it directly to their daily lives within the context of the environment. Ninety-two percent of educators responding to the Learning Survey reported that using EIC approaches improved math learning when compared with traditional methods.

As students work through the hands-on projects common in EIC curricula, they find that math becomes a tool they can use to quantify and analyze the world around them. As these students move from conceptual understanding to meaningful application, learning reaches a critical point when suddenly math begins to make sense. As their perception of math changes, students become more committed to its study.

"They can make more sense out of their answers," commented Michael Simpson, a sixth-grade math teacher at Pennsylvania’s Huntingdon Area Middle School. For example, as they floated objects of various sizes down the river, Simpson’s students learned the meaning of water velocity and calculated average flow rates. In this real-world context, he explained, “the numbers really start to make sense to them.”

At the study schools, students’ math knowledge and skills benefited in three areas:

- improved understanding of mathematical concepts;
- better mastery and retention of math skills; and,
- valuing and becoming enthusiastic about math.

IMPROVED UNDERSTANDING OF MATHEMATICAL CONCEPTS

EIC approaches offer excellent opportunities for connecting math learning to the real world. The evidence strongly suggests that, through the hands-on experiences and problem-solving activities fostered in EIC, students begin to more fully understand abstract mathematical ideas in concrete learning situations. As a direct result, students at
**Table 10.** Summary of Comparative Analyses of Standardized Data on Student Achievement in Mathematics.

<table>
<thead>
<tr>
<th>School Name</th>
<th>Effect of EIC</th>
<th>After Implementing EIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dowling Elementary</strong></td>
<td><strong>Math</strong></td>
<td>Median math comprehension scores on CAT (California Achievement Test) rose 16 percentile points for low achievers, 13 percentile points for middle achievers, and 7 percentile points for high achievers (over a 2 year period). Tracked 1995-97.</td>
</tr>
<tr>
<td><strong>Hotchkiss Elementary</strong></td>
<td><strong>Math</strong></td>
<td>4th-, 5th-, and 6th-grade EIC students averaged a 15.5% year-to-year gain in TAAS (Texas Assessment of Academic Skills) passing rates as they moved from one grade to the next. Tracked 1995-97.</td>
</tr>
<tr>
<td><strong>Park Forest Elementary</strong></td>
<td><strong>Math</strong></td>
<td>20% more 5th-grade students scored in the top and high middle ranks, on PSSA (Pennsylvania State System of Assessment), than similar schools designated by the Pennsylvania Department of Education. Tracked 1995.</td>
</tr>
<tr>
<td><strong>Chariton Middle</strong></td>
<td><strong>Math</strong></td>
<td>45% of 7th-grade students scored at least one grade above and 17% scored at least three grades above national grade equivalent student populations on the ITBS (Iowa Test of Basic Skills). Tracked 1995-96.</td>
</tr>
<tr>
<td><strong>Huntingdon Area Middle</strong></td>
<td><strong>Math</strong></td>
<td>The school ranked 1st of 66 schools for students scoring in high and high-middle quartiles, on PSSA, in their assessment region. Tracked 1996-97.</td>
</tr>
<tr>
<td><strong>Radnor Middle</strong></td>
<td><strong>Math</strong></td>
<td>The students &quot;performed on par with the control students at Radnor&quot; in math. Math is not integrated into this program. Tracked 1990-92.</td>
</tr>
<tr>
<td><strong>Tahoma High</strong></td>
<td><strong>Math</strong></td>
<td>11th-grade students, who had been in the program in 9th and 10th grades, averaged 3.1% lower on CFAS (Curriculum Frameworks Assessment System) in math than other Tahoma 11th graders. Math is not integrated into this program. Tracked 1995-96.</td>
</tr>
</tbody>
</table>

**Notes:** Appendix C presents descriptions of the assessments. Appendix D provides notes on program history and participating populations.

the study schools gain deeper math knowledge than their peers in traditional classes. Seventy-three percent of respondents to the Domains Survey reported that EIC students improved their understanding of math concepts and content beyond students in traditional math classes.

Although quantitative measures are not a primary data source for this study, where such statistics were available they corroborated other evidence of improved math achievement. At Minnesota's Dowling Elementary School, for example, principal Jeffrey Raison compared the math performance of his students before and after implementation of an environment-based curriculum. Raison found that, after introduction of the EIC program, median scores in math comprehension rose, over a two year period: 16 percentile points for low achievers; 13 percentile points for middle achievers; and, 7 percentile points for high achievers.

The integrated and interdisciplinary character of EIC programs also gives students the opportunity to connect their math studies with other disciplines. They begin to see the relationships between a variety of subject areas. For example, when students combine...
math studies with an analysis of a community opinion survey, they learn more than statistics; they begin to understand the socio-economic significance of the data they have gathered.

In Dallas, principal Judy Zimny conducted a comparative analysis of her Hotchkiss Elementary students and detected an average of 15.5 percent year-to-year improvement in the Texas Assessment of Academic Skills (TAAS) passing rates of EIC students at three different grade levels. She credited the integrated, interdisciplinary nature of the school's environment-based program with these considerable gains.

When students explore school grounds, natural areas, their neighborhoods and the community at large, they encounter opportunities to employ a diversity of math skills. Elementary students determining the average number of cicadas in their schoolyard study plots, seventh graders calculating the board feet of lumber in the woods behind their campus, high school students conducting a complex statistical analysis of the population dynamics of deer in their county—all these students are developing their emerging math skills in authentic settings. Ninety-six percent of educators responding to the Domains Survey reported that EIC approaches offered students greater opportunities to learn math in a real-world context than traditional curricula.

"I can see it in my other classes; I see the eyes glaze over," said Vince Vergis, who teaches math in both traditional and EIC settings at Florida's Taylor County High. "I guarantee that the comprehension, as a whole, with the EIC group is much better because of their hands-on experiences. In my mind there's no doubt. The [EIC] kids understand more concrete concepts. They're able to apply their understanding and take it to a higher level.

"This year we used geometry to do measurements at the Econfina River," Vergis continued. "Consequently, the students know the formulas; they've seen it and measured it and been there with it. Now, when I ask them questions either verbally or on a test they can give me answers that I'm sure none of my other classes [outside the EIC program] could have answered. I feel they've grasped the concepts better."

Huntingdon's Simpson also attributes gains in math learning directly to the EIC program. Previously, he noted, "math was always taught in isolation." Now, because of the broader learning opportunities afforded by the EIC approach, "students are interpreting; they're writing about it, they even go back and recalculate because they are more likely to realize when they don't get the right answer," Simpson said. "I don't get nonsense answers on math tests anymore."

"I guarantee that the comprehension, as a whole, with the EIC group is much better because of their hands-on experiences."

**Better Mastery and Retention of Math Skills**

EIC approaches help students master math skills and transform these abilities into tools they can use in the process of discovery. When students have the chance to apply their understanding of math to interdisciplinary, hands-on projects it helps them learn these skills more effectively. Additionally, they are more likely than students in traditional curricula to see how they can apply these math skills in other settings.

Students in EIC programs gain application skills as they use math to quantify characteristics of soil samples, analyze stream flow parameters, determine changes in employment patterns in the lumber industry, or estimate the number of cord grass plants to order for a re-vegetation project.
First-hand experiences in applying math to authentic problems helps these students understand math skills more thoroughly than their traditional peers. Ninety-two percent of educators responding to the Domains Survey reported that EIC students improved their math skills when compared to students in typical education programs.

"It was more meaningful because they did the work themselves and had ownership in the project. They retained the math concepts better."

Tenth graders at Minnesota's Little Falls High, for example, applied their knowledge of statistics to analyze their observations of the Mississippi River. Using their graphing and statistical skills, these students began to see unusual patterns in their water quality data. Further analysis uncovered a significant variation in water chemistry during the year, which in turn, triggered even deeper mathematical analysis. Ultimately, this led to the discovery of a waste-runoff problem occurring upstream from their study site.

Not only do EIC students develop stronger math skills, but they also better remember the math they learn and bring that knowledge back to the classroom. Seventy-eight percent of respondents to the Domains Survey reported that retention of math knowledge improved after implementation of environment-based instructional approaches.

While studying the life cycle of native salmon populations, Washington's Bagley Elementary students "were able to grasp the concepts of probability and measurement better than when I presented it in regular classroom instruction," said Gloria Able. "It was more meaningful because they did the work themselves and had ownership in the project." More importantly, she said, "they retained the math concepts better."

Many other case study schools also documented significant improvement in students' long-term retention of math skills after adopting EIC methods. At California's Open Charter School, for example, teachers compared the year-to-year achievement of students and found increased scores on annual math inventories. These results applied to students at all ability levels.

Judy Utovich, a fourth/fifth-grade teacher at Open Charter, monitored students who were taught math skills using traditional approaches and compared that to teaching math skills with EIC approaches. "When I gave the inventory at the start of this year," she said, "just looking at various math skills, every one of our students from last year scored 80 percent or above on the inventory."

Utovich discovered that eight months after teaching percentage skills in an ecosystem project, students recalled both their understanding of the concepts and the activity that provided the context for learning. In contrast, she found that most students taught with traditional methods could not, when tested six months later, remember those same skills.

Significantly, Utovich noted, these improvements happened regardless of students' ability levels or learning styles. "These are everywhere from gifted students to limited English learners," she said. "There's really quite a span in the group I monitored."

Middle and high school teachers observed effects similar to what Utovich found. At Kentucky's Jackson County Middle School, Kim Flynn, a seventh-grade math teacher reported, "When I taught the kids math skills like measuring, in the classroom, they forgot it and couldn't make use of it. When the students had a chance to use these skills on our nature trail, they not only learned better but could apply and remember their math skills longer."

As EIC students see the connections between math and their surroundings, they begin to apply mathematics in new, inventive ways, pushing beyond the benchmarks of traditional curricula to acquire and apply advanced math skills.
Valuing and Becoming Enthusiastic about Math

Learning in the context of the environment helps students recognize the practical value of math for quantifying and understanding the world around them, and perceive the importance of learning what can otherwise appear to be irrelevant mathematical material. When this occurs, their attitudes about math change from merely tolerating it to wanting to learn more. “They’ll say, ‘We need to know this in order to solve the problem,’” said Carol Dungen, a fourth-grade teacher at Maryland’s Hollywood Elementary. “Now, when they learn something in math, they see the use in it, there’s a reason why they’re doing it, not just because the teacher said to do it.”

Eighty-nine percent of educators responding to the Domains Survey reported that students’ attitudes toward learning math improved when compared to their traditional counterparts. “They know they’re going to do something besides read in a textbook and maybe learn something and then a week later not remember it,” Dungen concluded.

Educators at middle and high school levels observed similar improvements in students’ attitudes. At Oregon’s Waldo Middle School, for example, seventh-grade math teacher Mike Reams noticed students beginning to understand why studying math is important. “When the kids see a connection between what they do in the classroom and what they might see out there in the real world, their motivation changes,” Reams said. “They actually see some purpose in learning, rather than just coming in and memorizing this and memorizing that. They see some reason why it might be valuable to know math.” Teaching math in the context of a project like endangered species, “just gives kids a connection to something real, something that seems to make sense to them... something other than just the book and the page and the teacher lecturing in front of them for 50 minutes,” Reams explained.

Students appear to place a higher value on math when they sense that their work has potential significance beyond the classroom. “I wanted my project to have some kind of relevance to the community,” said Sherri, a sophomore at California’s Piner High School. “I was applying the math that I had learned, it mattered, and not just to me and my personal development. So, I wanted to be as accurate as I possibly could.”

In addition, students begin to perceive the real value of the math skills they are acquiring. “These kids are learning things that are going to set them up for life,” commented Clyde Cusick, principal at Florida’s Taylor County High. Studying in the environment makes math “relevant and alive to them.”