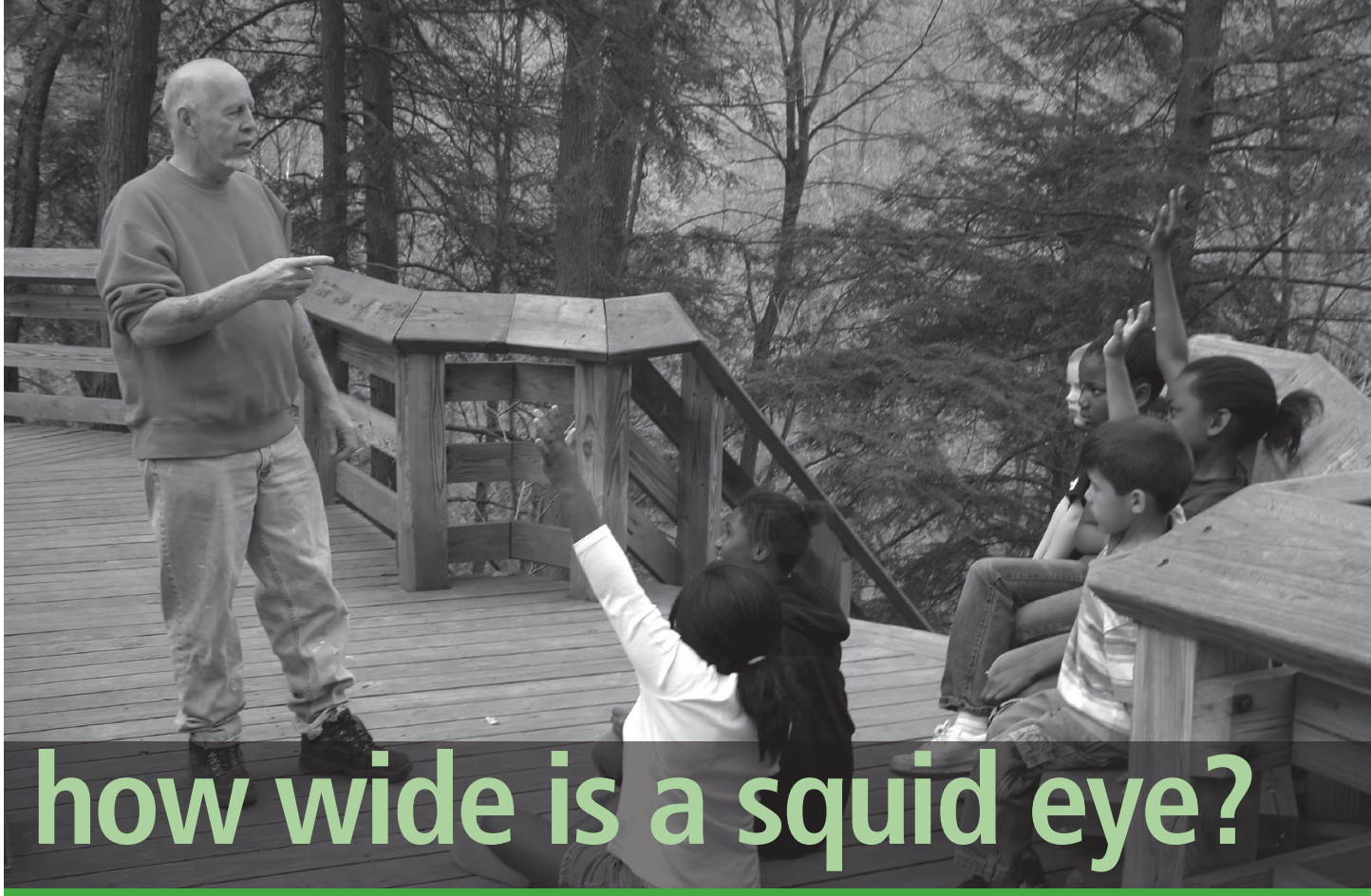

# how wide is a squid eye?

## Integrating Mathematics into Public Library Programs for the Elementary Grades

**by Marlene Kliman, Nuria Jaumot-Pascual, and Valerie Martin**

*The chart in Figure 1 (page 10) is affixed to the wall in the children's room of a public library branch in a large city. A group of 8–11-year-old children, having posted their own information on the chart, watch with excitement to see how the data set evolves as passersby contribute. Lashawnda is hoping that the next person to add a dot increases the height of the "bump" around 9, while Jamal is rooting for more dots near 5, to form two "bumps," a bimodal distribution. Maximilliano wonders if anyone with a name longer than his will post a dot, further extending the range.*

*As children reflect on the growing patterns of responses, their afterschool group leader, Markeshia, guides them to consider sampling: If we collect 100 more responses from this library, do you think the overall shape of the data will remain the same? What if we collect responses from a library branch across town? from a different part of the U.S.? from another country?*

*Each week, children in Markeshia's group explore a "question of the week." Sometimes children choose the question; sometimes Markeshia selects a question to mesh with a theme she wants children to explore. Whatever the topic, she*

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**NURIA JAUMOT-PASCUAL**, senior research associate at TERC, leads informal math workshops, professional development programs, and webinars in English and Spanish. She has worked for more than 20 years as a teacher and staff developer in Spain, Central America, and the U.S. She is currently a doctoral student in education at the University of Georgia.

**VALERIE MARTIN**, senior web and graphic designer at TERC, specializes in conveying math and science concepts in a clear and visually appealing manner. On the Mixing in Math projects, she ensures that web and print resources are accessible and engaging to a wide range of readers, whatever their math background.

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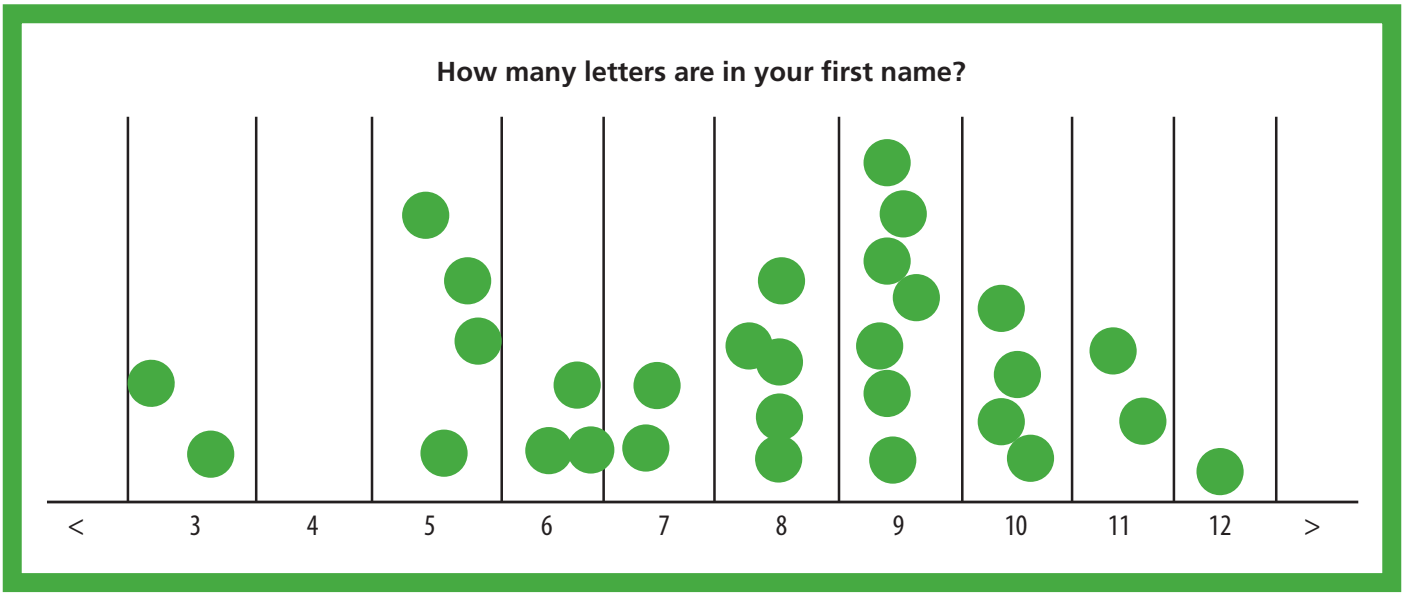



**Figure 1. Math off the Shelf Activity**

*always embeds data analysis, guided by resources that show her how she can infuse math into her work with children.*

Although public library programs for the elementary grades offer explorations in a wide range of topics, scenes like this one, in which mathematics plays a role, are all too rare: Mathematics offerings are typically limited to homework help (Char & Foote, 2009; U.S. Department of Education, 2003). However, when informal educators incorporate mathematics into their project-based offerings, children stand to gain. Participating in out-of-school activities that embed mathematics in authentic ways bolsters children's skill development, appreciation of the relevance of mathematics, and mathematics attitudes (Guberman, 2004; Harris Interactive, 2011; Nasir, Hand, & Taylor, 2008).

Informal educators, from afterschool providers to librarians, care deeply about children's mathematical success, but they often are math-avoidant themselves and thus shy away from doing mathematics with children (Gasbara & Johnson, 2008; Intel, 2009). Like many adults, they lack confidence and comfort with mathematics, and they view mathematics as being devoid of context. In everyday life, adults estimate, measure, and navigate, but they don't think of these activities as mathematics and do not share strategies with children (Esmonde et al., 2013; Lange & Meaney, 2011). Even as awareness of science as a cultural and social activity is growing, adults of all backgrounds often view mathematics as a context-free topic consisting of facts and algorithms (Allexsaht-Snider, 2006; Martin, 2009a, 2009b).

To provide informal educators in library settings with an alternative vision of mathematics, the authors, based at TERC, a STEM education nonprofit, initiated Math off the Shelf (MotS) with funding from the National Science Foundation. MotS involved two phases: resource development and dissemination with evaluation. In the first phase, we worked with library-based informal educators (LBIEs, including children's librarians and library-based afterschool educators) to create interdisciplinary mathematics resources tailored specifically to their needs. In the second phase, we made the resources available to a wider group of LBIEs and investigated results: Did access to these resources lead LBIEs to make any changes in their practices? in the way they interacted with children? in their own views of mathematics?

In this paper, we describe resource characteristics and key findings. We chose to focus on LBIEs because families are increasingly relying on public libraries as free, safe places for children in the absence of other out-of-school care (Newman & Celano, 2006; Public Agenda, 2006). Given the wide range of informal educators based in libraries, our findings suggest that informal educators can integrate mathematics into their offerings if they have access to resources that readily mesh with their own program goals and formats.

## Designing Math Resources: What Works in the Library?

For the first two years of MotS, we worked with several dozen LBIEs in four regions in the northeastern U.S. (Queens, New York, and locations in Connecticut, Massachusetts, and Westchester County, New York) to create interdisciplinary mathematics resources. The majority of our LBIE partners were based in urban areas with significant low-income Latino/a or African-American populations. As community-based informal educators, LBIEs know their audience well: They craft programs to fit the interests and needs of the local

population; they are familiar with formats and themes that draw in neighborhood crowds; and they build strong rapport with the community. Thus, we sought to develop ways for them to infuse mathematics into what they already do successfully and confidently, rather than create a separate, standalone mathematics program.

## Design Process

We employed an interactive and iterative design process. First, we solicited from LBIEs upcoming programming themes, such as animals or healthy snacks, and special events, such as Earth Day or Chinese New Year. We also asked them about their needs when no programs are available; for example, they need games children can play quietly by themselves. Next, we developed activities designed to be embedded in these existing contexts and themes. After our LBIE partners chose among the activities, implemented their choices, and gave feedback, we revised and then invited a wider group to try the activities. Our process continued until we had a varied bank of about 200 well-vetted activities in English and Spanish, including dozens each of crafts, projects to last an hour or more, games, and short activities designed to fill 5–10 minutes. Many of the activities are appropriate for the full elementary grade range, with suggestions for increasing or reducing challenge; others are geared for particular grade levels. For example, the activity that introduced this article could be made simpler for younger children by using a yes-or-no question such as "Did you eat fruit today?"

Throughout the process, we spent hundreds of hours communicating with LBIEs in person, by phone, and by e-mail to better understand their realities, the opportunities and constraints in their varied library settings, their goals and joys in work-

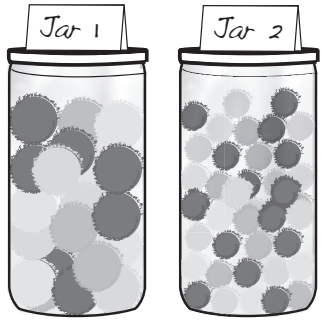
**Table 1. Typical Children's Public Library Characteristics**

| LIBRARY CHARACTERISTIC | COMMON? | CORRESPONDING MotS CHARACTERISTIC |
|---|---|---|
| Setting allows for substantial noise, movement, mess; provides separate activity space | No | Provides a resource bank; LBIEs choose what fits their setting |
| Books are available | Yes | Includes activities that make use of library resources |
| Setting serves as a public space; substantial foot traffic | Yes | Capitalizes on public audience with data-collection activities and museum-type displays |
| Programs, boards, and displays follow a monthly or seasonal theme | Varies | Offers activities that can be readily customized to a theme (e.g., animals, weather, planets) |
| Participants may walk away mid-activity, leaving the program or building | Yes | Provides guidance on drawing out the mathematics mid-activity, rather than only at wrap-up |
| Drop-in attendance: number, age, and abilities of participants not known in advance | Yes | Includes information on selecting and adapting for different needs, abilities, ages, and audiences |
| Children present when program or adult supervision is unavailable | Yes | Offers activities children can do without adult facilitation |
| Informal educators have paid time for professional development | Varies | Designed to be accessible without training |
| Informal educators have autonomy in designing programs | Yes | Resources are accessible and visually appealing to draw in math-avoidant adults |
| Informal educators comfortable leading mathematics activities | No | Draws on adults' everyday math skills by focusing on content that arises from authentic situations (e.g., measuring to create a poster) |

ing with children, and their reasons for choosing to use particular resources. Table 1 summarizes characteristics common to their settings and ways that we shaped MotS resources to accommodate their needs.

## Example Activities

The resource bank includes a broad variety of activities. Some are appropriate for almost any type of out-of-school program, including crafts projects and games children can play quietly. Others are designed to capitalize on unique aspects of most library settings. Often LBIEs customized activities to fit local interests and needs.




| Estimate | | Explanation |
|---|---|---|
| Jar 1 | Jar 2 | |
| 40 | 200 | Well, jar 2 has smaller pieces so it has more than jar 1 |
| 113 | 850 | Because 1 big one = about 5 small ones |
| 100 | 1000 | I did length x width then I x'ed that by height |

**Figure 2. Estimation Strategies Recorded at a Public Library**

### *Library as Venue for Gathering Public Opinions*

As the opening anecdote on name length illustrates, libraries can be an ideal venue for collecting and displaying data from a wide range of passersby. LBIEs have used the MotS data-collection activity "Quick Questions" (http://mixinginmath.terc.edu/activities/quickquestions.php) to explore community data on everything from languages spoken at home to favorite vegetables to opinions about changes to local bus service. LBIEs choose the question to match children's interests, address a timely community issue, or align with a monthly or summer reading theme.

### *Library as Forum for Exchanging Problem-Solving Strategies*

Patrons of all ages bring different opinions, experiences, and backgrounds to the library; they also bring a variety of mathematical strategies. Museum-type displays, in which patrons are confronted with a puzzle or problem and asked to record their solution strategies, provide a way for children to share ideas with and learn from many others. In one such activity, children and other library patrons share strategies for estimating. LBIEs place two identical jars out in a public area. They fill one jar with large objects, such as beads, pasta shells, or pompoms, and another with identical smaller ones. Next to the jars is a sheet on which passersby record the number of objects they estimate to be in each and, most importantly, how they made their estimates (Figure 2). As with Quick Questions, this activity, Mystery Jars (http://mixinginmath.terc.edu/activities/mysteryjars.php) can be readily adapted to different themes. For instance, LBIEs have used large and small beads to launch an arts-and-crafts monthly theme and bottle caps of two sizes in honor of Earth Day.

### *Children's Books as Mathematical Springboards*

Mathematics is inherent in many aspects of children's books: shapes and sizes in picture book illustrations, dimensions of fairy tale giants of phenomenal proportions, and quantities and measurements in record books. In one activity, Size Riddles (http://mixinginmath.terc.edu/activities/sizeriddles.php), children make sense of measurements while exploring nonfiction books about animals, plants, people, or anything that comes in different sizes. For instance, one LBIE focused the activity on sea creatures in order to align with her summer-long ocean theme. Children perused non-fiction books to find intriguing facts about the size of sea creatures; then they used the facts in riddles, accompanied by string or ribbon that they measured and cut to represent the size (Figure 3).

## What Changed When the Resources Were Distributed Widely?

Once we finalized the resources, we made them available for free access on a public website: http://mixinginmath.terc.edu. For evaluation purposes, we selected eight primarily low-income cities and regions across the U.S. In each, a library administrator sent out an e-mail encouraging LBIEs to review the website and use any activities they wished. Use was voluntary; in most cases, administrators had no supervisory role over LBIEs and did not track or follow up on use.

### Survey Process

In each of the next three years, an external evaluator who had not been involved in the resource development sent an annual electronic survey to LBIEs in the eight regions with the help of their library administrators. LBIEs were asked to fill out the complete survey if they had learned of MotS resources at least four months previously. Survey items addressed incorporation of mathematics into work with children, math-related attitudes and beliefs, reasons for including mathematics in

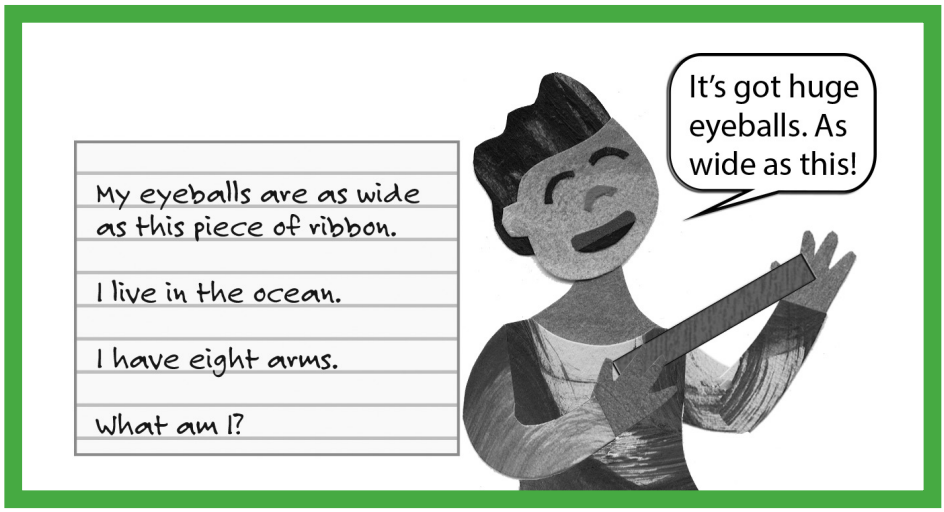



**Figure 3. A Size Riddle**

programs, and perceptions of benefits to children. The evaluator had already gathered baseline data on a subset of these issues through an electronic survey near the start of the project.

Each year, respondents noted how much time had passed since they were initially exposed to MotS resources. Other survey questions asked about respondents' professional roles—children's librarian, library-based afterschool educator, and others—and about the extent of their use of the resources, where we found a range from those who used them daily to those who never used them. Survey questions varied to some extent from year to year, so annual comparisons are not always possible. Below we cite the year in which the data were reported. All data are drawn from corresponding evaluation reports (Char & Foote, 2009; Char & Berube, 2010; Char & Clark, 2011). The response rate each year was just over 50 percent, with 67 respondents at baseline, 28 in 2009, 83 in 2010, and 148 in 2011.

As one LBIE said in response to an open-ended survey question, "Prior to MotS I didn't think about the role of mathematics in the library, as my personal experience using mathematics wasn't strong or positive."

## Survey Findings

### *Frequency and Nature of LBIE Mathematics Offerings*

At baseline, approximately 10 percent of LBIEs surveyed had *ever* used mathematics with children in *any* context (Char & Foote, 2009). As one LBIE said in response to an open-ended survey question, "Prior to MotS I didn't think about the role of mathematics in the library, as my personal experience using mathematics wasn't strong or positive" (quoted in Char & Clark, 2011).

In annual surveys, the vast majority of LBIEs reported that, because of MotS resources, they were now using mathematics regularly in a wide range of contexts, with the total amount of mathematics integration skyrocketing. For instance, in 2010, 74 percent reported integrating mathematics into crafts programs at least monthly, 28 percent doing so at least weekly, and 3 percent daily; 40 percent incorporated mathematics into story times and book clubs at least monthly and 21 percent at least weekly (Char & Berube, 2010).

### *Talk about Mathematics*

At baseline, talk about mathematics apart from homework was minimal: Only 11 percent of LBIEs surveyed in 2009 reported *ever* discussing mathematics in everyday life with children; 5 percent said they felt able to explain how mathematics for the elementary grades aligned with the library's mission (Char & Foote, 2009).

After exposure to MotS resources, LBIEs noted a variety of ways in which they wove mathematics into their daily conversations with children: 61 percent reported infusing mathematics into the questions they asked children as they chatted with them; 32 percent now used mathematical language in their library orientations; and 59 percent found occasion to discuss the role of mathematics in everyday life with children at least monthly—with 31 percent doing so weekly and 9 percent daily (Char & Berube, 2010; Char & Clark, 2011). Fifty percent felt confident in their ability to explain how mathematics for the elementary grades aligned with the library mission, a tenfold increase compared to baseline (Char & Clark, 2011; Char & Foote, 2009). These mathematics interactions built on LBIEs' everyday knowledge of, for example, taking a measurement, reading a simple graph, and estimating a quantity. The MotS resources helped LBIEs to see the relevance of their knowledge to their work with children.

### *Why LBIEs Incorporated Mathematics*

When asked to rank factors that contributed to these changes in practice, each year the LBIEs' top two reasons were their own commitment to offer mathematics to children and children's interest and demand (Char & Berube, 2010; Char & Clark, 2011). The LBIEs made their choices autonomously: Only 8 percent noted that pressure from a supervisor or

library director was a factor in decisions to begin and sustain use of mathematics in their offerings (Char & Clark, 2011).

LBIEs attributed their newfound mathematics commitment to MotS resources, with 90 percent maintaining that they developed a much more positive attitude toward mathematics, 88 percent coming to believe that all librarians should learn more about integrating mathematics into programming for children, and 60 percent noting that including more mathematics is now a strong priority for their libraries (Char & Clark, 2011). As one respondent put it, "I now consider mathematics to be a part of the offerings a library can have" (quoted in Char & Clark, 2011).

The MotS resources not only offered a new vision of mathematics for the library but also gave LBIEs a way to realize this vision. No matter their setting, programming themes, and circumstances, they reported that they found activities in the resource bank that enabled them to integrate mathematics into their existing practices. Furthermore, each year, about 50 percent went beyond MOTS resources and, for the first time, created their own mathematics activities (Char & Berube, 2010; Char & Clark, 2011; Char & Foote, 2009).

The MotS resources not only offered a new vision of mathematics for the library but also gave LBIEs a way to realize this vision.

### *Lasting Changes*

These results were sustained over the three years of surveys, with mathematics becoming integral to LBIEs' programs. For instance, each year, about 90 percent stated that continuing to include mathematics in offerings for the elementary grades was a strong priority, and just over 50 percent reported regularly discussing the role of mathematics in everyday life with children (Char & Berube, 2010; Char & Clark, 2011; Char & Foote, 2009). These results are particularly striking given that the evaluation took place during and immediately following the recession of 2008, with libraries undergoing budget cuts and consequently reducing staff time and programs. Nevertheless, the changes continued over time, lasting well beyond the initial flurry of excitement that can accompany a new educational method or set of resources.

The perception of lasting change is echoed by state and regional library leaders interviewed by the MotS evaluators. One said, "I saw libraries that may have started a bit hesitant at mathematics really open up because the activities made them confident that they could do them with their children" (quoted in Char & Clark, 2011). Another added:

> What the project did was make that connection that "I can do what I'm doing regularly, select intentionally books that have a good foundation to talk about math, and have activities that are related." That was a change in their behavior and they're [now] making a conscious effort (quoted in Char & Clark, 2011).

### *Effect on Children*

To assess the effect on children, evaluators surveyed 34 LBIEs expressly tasked with homework help and with academic enrichment when homework help is not needed. These LBIEs had the option of using MotS resources as a component of their academic enrichment. Unlike children's librarians, for whom interactions with children comprise only a portion of their daily jobs (with cataloging, reference, collection management, and other tasks consuming much of their time), these LBIEs spend their working hours with children and are thus poised to observe the mathematical growth of individual children over time. Their perceptions of changes in children's attitudes toward mathematics are summarized in Table 3 (next page).

## Why Choose Mathematics?

Each out-of-school environment—afterschool program, summer camp, childcare center, or library—has unique affordances and constraints; each is staffed by informal educators with their own traditions, professional practices, and values. LBIEs enjoy a wealth of books, opportunities to offer public programs, and a great deal of autonomy. They must contend with limitations in the degree of mess, movement, and noise they can accommodate and in the extent to which they are available to supervise children. When offered mathematics resources expressly tailored to these realities, LBIEs made substantial and long-term changes: They began to weave mathematics into many areas of their practice, regularly shared their everyday mathematics knowledge with children, and came to view mathematics as integral to their work and to children's engagement and learning. They particularly valued the fact that they could integrate mathematics into their existing areas of strength and expertise, drawing on the themes, projects, and ways of interacting with children they had developed over time to address local interests and needs.

Perhaps, like many informal educators, the LBIEs in our study felt strongly all along that children should succeed at mathematics. However, it was not until they encountered resources that honored and built on features of the library setting and on their own unique talents as informal educators that they saw themselves as capable of helping to realize that success.

**Table 3. Perceptions of Changes in Children Due to Experience with MotS Resources, 2011**

| BECAUSE OF MY USE OF MotS RESOURCES, CHILDREN IN MY LIBRARY... | PERCENT (*N* = 34) |
|---|---|
| Have gained confidence in mathematics | 78% |
| See mathematics as relevant to everyday life | 70% |
| Have developed mathematics skills | 69% |
| Have gained enthusiasm for mathematics | 67% |
| Can better explain their mathematics ideas | 59% |

*Source:* Char & Clark, 2011

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## References

Allexsaht-Snider, M. (2006). Urban parents' perspectives on children's mathematics learning and issues of equity in mathematics education. *Mathematical Thinking and Learning,* 8(3), 187–195.

Char, C., & Berube, S. (2010). *Evaluation report for MATHEMATICS OFF THE SHELF year 3.* Montpelier, VT: Char Associates. Retrieved from http://mixinginmath.terc.edu/aboutMiM/researchReports.cfm

Char, C., & Clark, L. (2011). *Summative evaluation report for MATHEMATICS OFF THE SHELF year 4.* Montpelier VT: Char Associates. Retrieved from http://mixinginmath.terc.edu/aboutMiM/researchReports.cfm

Char, C., & Foote, M. (2009). Evaluation report for MATHEMATICS OFF THE SHELF year 2. Montpelier, VT: Char Associates. Retrieved from http://mixinginmath.terc.edu/aboutMiM/researchReports.cfm

Esmonde, I., Blair, K., Goldman, S., Martin, L., Jimenez, O., & Pea, R. (2013). Math I am: What we learn from stories that people tell about mathematics in their lives. In B. Bevan, P. Bell, R. Stevens, & A. Razfar (Eds.), LOST opportunities: Learning in out-of-school time (pp. 7–27). New York, NY: Springer.

Gasbarra, P., & Johnson, J. (2008). *Out before the game begins: Hispanic leaders talk about what's needed to bring more Hispanic youngsters into science, technology and math professions.* Retrieved from http://www.publicagenda.org/citizen/researchstudies/education

Guberman, S. (2004). Out-of-school activities and arithmetical achievements. *Journal for Research in Mathematics Education, 35*(2), 117–150.

Harris Interactive. (2011). *STEM perceptions: Student and parent study.* Retrieved from http://www.microsoft.com/en-us/news/presskits/citizenship/docs/STEMPerceptionsReport.pdf

Intel. (2009). Parents more comfortable talking drugs than science. Retrieved from http://www.intel.com/pressroom/archive/releases/2009/20091021edu.htm

Lange, T., & Meaney, T. (2011). I actually started to scream: Emotional and mathematical trauma from doing school mathematics homework. *Educational Studies in Mathematics, 77*(1), 35–51.

Martin, D. (2009a). Researching race in mathematics education. *Teachers College Record, 111*(2), 295–338.

Martin, D. (Ed.). (2009b). *Mathematics teaching, learning, and liberation in the lives of black children.* New York, NY: Routledge.

Nasir, N., Hand, V., & Taylor, E. (2008) Culture and mathematics in school: Boundaries between "cultural" and "domain" knowledge in the mathematics classroom and beyond. *Review of Research in Education, 32*(1), 187–240.

Neuman, S. B., & Celano, D. (2006). The knowledge gap: Implications of leveling the playing field for low-income and middle-income children. *Reading Research Quarterly, 41,* 176–201.

Public Agenda. (2006). *Long overdue: A fresh look at public and leadership attitudes about libraries in the 21st century.* New York, NY: Author.

U.S. Department of Education. (2003). *When schools stay open late: The national evaluation of the 21st-Century Community Learning Centers program, first year findings.* Washington, DC: Author.