Math in Zoos and Aquariums: The Evolution of a Professional Development Workshop

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Abstract

With support from the Institute of Museum and Library Services, the Mathematics in Zoos and Aquariums project worked with zoo and aquarium staff members to integrate mathematical concepts into the interpretation of living collections. Over two years, the project developed three activities related to logic, measurement, and data analysis and conducted workshops with over 400 staff from 124 institutions. In refining the workshop model and conducting evaluation, we found that most staff increased their comfort with and use of math-based activities and that the goals of the participants and the size of their institutions affected implementation. Here, we describe the activities, the evolution of the workshop design, and the results of the evaluation, which used multiple methods to track participation. The workshop and the evaluation revealed patterns that have implications for introducing technical concepts into interpretive practices and for the design of effective professional development in zoos and aquariums.

Background

As stewards of living collections, zoos and aquariums have a core mission to promote conservation education: public understanding of wildlife and the conservation of the places where animals live. Conservation education is "a powerful tool for connecting people with nature" according to the International Zoo Educators Association (Mei, Qingyoung, and Ascue, 2008). Research conducted by the Association of Zoos and Aquariums showed that zoos and aquariums do, indeed, "prompt individuals to reconsider their role in environmental problems and conservation action, and to see themselves as part of the solution" (AZA, 2007).

Across the country and abroad, zoos and aquariums are evolving from an identity as exotic attractions to one of institutions that cultivate appreciation, empathy, and knowledge of living creatures. This has been accomplished through the introduction of messages, labels, exhibits, presentations, and experiences focusing on animal biology but also on social issues related to human cultural systems, for example, the impact of lost habitat, hunting and exploitation practices, and rescue and rehabilitation efforts.

In their exhibitions, zoos and aquariums often try to simulate conditions of animals in the wild as well as to relate the stories about the animals in their collections. We are familiar with how barred cages have been replaced by simulated rain forests, savannahs, and island ecosystems. More recently, technology is being introduced to these habitats to specifically

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show visitors aspects of animal behavior and to provide captivating viewing experiences (where animals are active, for example) that minimally intrude on the animals' natural behaviors. So we see artificial trees where apes can probe for honey that is placed there; heated rocks where tigers can loll closer to the visitors in winter; food that is cached in order to simulate foraging behavior in the wild, instead of keeper-scheduled feedings.

In an effort to expand the use of living collections as teaching tools for concepts of conservation, the Phoenix Zoo and TERC, with funding from the Institute for Museum and Library Services (IMLS) 21st Century Professionals Initiative, developed a collaboration based on shared goals and complementary expertise: the Math in Zoos and Aquariums Project (MiZA). To this partnership, the Phoenix Zoo brought extensive experience and commitment to pursuing the goals of conservation education in a zoo context as well as an understanding of the dynamics of that context for conducting educational programs. TERC provided decades of experience developing mathematics activities for learners from kindergarten through adults and supporting these with professional development for teachers. Together the two institutions, in designing a staff development project, began with the assumption that mathematical explorations could support visitor engagement with ideas of conservation. Here, we describe the design decisions that were taken along the way, and the effects of the project on zoo and aquarium staff and institutions.

The scientific work of zoos and aquariums involves very interesting applications of mathematics and science by keepers, curators, medical staff, nutritionists, and conservationists in their respective jobs. The outcome of their work results in many critical decisions about husbandry practices and population management. For school age children with their families and in school groups, the settings of zoos and aquariums provide a very motivating context in which to highlight technical work and demonstrate how mathematics is applied in the real world. By focusing on mathematical patterns and relationships among quantitative measurements that conservationists study, we believe zoos and aquariums can help visitors understand how natural systems interrelate and how conservation practices can have an impact.

We proposed that the best way to pursue these explorations was to work with zoo and aquarium educators who could introduce interpretive innovations in their individual institutions. While the ultimate goal of our work is to influence visitor learning, understanding, and empathy in the service of conservation, in this project, we focused on professional development as leverage for this goal rather than visitor learning *per se*. While each educator we worked with could impact a large number of visitors, we first had to have an impact on them.

Considering interpretive staff as mediators of visitor learning is an important step in understanding visitors' experiences. However, conservation education research hasn't given us extensive insights into effective ways for staff to engage visitors. It has tended to focus on general visitor knowledge about animals and their habitats, endangered species and disappearing habitat, affective responses, and conservation actions visitors may or may not consider (Luebke and Grajal 2008**).** Few if any studies specify particular pedagogical approaches to conservation education, although recent projects like the Brookfield Zoo's Teen

Inquiry Project are looking at inquiry-based interpretive experiences to help visitors think about engaging in conservation behavior **(**Maes, Murphy and Kutska, 2008).

We began with the expectation that carrying out mathematical reasoning about animal identification and behavior can support people's understanding and caring about animals. We wanted to design activities that promoted curiosity and interest among members of the public and invited them to take part in simulated conservation work. We believed that involvement in these activities could lead to concern and empathy about animals and even, in turn, lead to further interest in the math and science of animals.

Of course, before visitors connect with specific concepts that may lead to understanding and caring, interpretive staff needs to be exposed to the ideas. When our project began in 2005, there weren't many professional development opportunities of this sort in the field. Most of the professional development offered to staff within and across institutions concerned conservation projects and husbandry but focused on animals rather than on implications for interpretation for visitors. Educational workshops for staff were mostly programmatic: how to partner with schools and community groups; what materials to provide school groups; organizing teen programs, and so on.

Creating this new kind of professional development workshop required both the Phoenix Zoo and TERC to expand their expertise; this collaborative learning is a large part of what made the project so powerful. Phoenix Zoo staff explained the complex aspects of the conservation education mission and exposed TERC staff to the variety of approaches currently being used. They also explained the everyday ways in which programs are carried out on trails and in classrooms, who the zoo audiences are, and the ways different departments interface. TERC staff members introduced a broader definition of math, including topics that went far beyond numbers and calculations, and effective ways of engaging adults in mathematical reasoning. The math incorporated in our workshops included logic, sorting and classifying, data collection and analysis, and measurement, only a few of which were mathematical topics that immediately came to mind for Phoenix Zoo staff – or for our workshop participants. Together, we developed workshops that used mathematical reasoning as a way for staff to help the public "see" animals in new ways, develop a deeper appreciation for them, and consider conservation issues that might affect them.

The perspectives underlying MiZA were based on a previous project that, among other things, provided a proof of concept for the effectiveness of professional development through collaboration among math educators and informal educators. The Math Momentum in Science Centers (MMSC) project was a collaboration funded by the National Science Foundation among TERC, the Association of Science and Technology Centers and 13 science centers and aquariums around the country (Need NSF Grant # etc. here). From 2003 to 2006, MMSC developed a series of one-day workshops on data, measurement and algebra in order for the core group of science centers and aquariums to capitalize on the math in their environments. These 13 centers not only hosted the workshops but also developed their own math-related projects to further extend their mission of inquiry into the nature and content of science (Bell, Mokros, Nemirovsky, Rubin and Wright, 2006).

We agreed that what worked in science centers could also work in the context of living collections, that is, the principles upon which the MMSC workshops were designed could be generalized across institutions to include zoos and more aquariums. The MiZA project gave us an opportunity to build on some of the lessons of the MMSC project, as described below under Workshop and Activity Format. Based on the MMSC experiences, we asked ourselves questions like these as we designed and the MiZA workshops: "What activities could expand staff's confidence in their own mathematical thinking and help them understand how to integrate conservation practices and math? How could a staff development workshop empower participants to make the activities/projects their own and take the next steps that make sense for them and their institution?" Below, we first describe how the workshop materials and activity formats evolved as we understood the route to our goals more extensively. We then discuss the results of the project evaluation that examined the impact of the project on the workshop participants and some of the factors that influenced those results.

Project Goals and Structure

The MiZA project's primary goal was to design, implement and evaluate professional development for zoo and aquarium educators that explored how mathematical reasoning could be an effective tool to enhance visitors' conservation education. The goal of the workshop was to educate staff about the connections between math and conservation education that they could then use themselves to enhance their institution's programming.

We began by adapting a professional development model based on several assumptions that derived from the experience of TERC's math educators and from experiences all of us had had in teacher professional development. The primary principles of this model were:

- The workshop structure should support participants first as math learners, then as math "facilitators." This approach gives participants a deeper understanding of mathematical content, as well as an appreciation of the challenges involved in mathematical reasoning. In order to achieve participants' abilities to use math and to see its relationship to the work of the institution, we would need to address their confidence and knowledge levels. In MiZA workshops, participants did each activity themselves before discussing how they might adapt it for their own context.
- Workshop activities should be presented in a way that reflects as much as possible the context in which they will be implemented. In MiZA workshops, data and measurement activities were introduced in the zoo and aquarium context, so that participants were thinking from the start how these math topics might be useful in their own institutions.
- Workshops should be designed to explicitly help participants implement in their own ways what they've experienced in the workshop. In MiZA workshops, we made clear at the beginning of the workshop that participants should be thinking all along about how these experiences could fit into their home institutions. We then provided supports throughout the workshop – discussion and planning time – so that participants could begin to anticipate the opportunities and challenges that awaited them.

We planned for the dissemination of the work through an on line Workshop Leader Guide, that includes activity pages and materials for leading a workshop. Those materials are available at: http://www.phoenixzoo.org/educators/miza.html.

The Workshop and Activity Format - The MiZA workshop for zoo and aquarium staff was offered 21 times in cities across the US and Canada[1] reaching over 400 staff members in 124 institutions. Although we attempted to create a workshop that would be applicable for all sites, it was obvious from the beginning that each workshop would be different from others in significant ways. Each workshop setting was unique, from hotel rooms to classrooms overlooking animal enclosures, poolside to artificial jungle-side. We had to organize some activities according to what animals the institution had in its collections. The categories of participants attending the workshops varied by site as well. All the following were represented among participants: educational staff, curatorial staff, volunteers, teachers, and management. Since the site hosting the workshop invited people from nearby facilities, we never knew who the guest list might include until we got there. We originally wanted to host teams of two or three people from each institution, but it became clear that for many institutions, especially small ones, this was more staff than they could spare for the day. Even the time frames varied from site to site; although we had originally planned for a one-day format, we developed 2-hour and half-day formats to meet particular sites' needs.

Within that variability, the workshops shared the following general structure; details of each part appear below:

- The workshop began with an introduction, a description of mathematical thinking, and an icebreaker data game
- For each of the three math activities (described below) in the workshop, the following sequence of events occurred:
- Participants played the game/did the activity themselves, in order to have the experience of being a mathematics user.
- The whole group discussed their experiences doing the activity, the mathematical content and how they thought such an activity might fit into their institutional context.
- Small teams briefly considered how to implement the activity in their setting, including filling out a planning guide
- Final discussion included teams choosing one of the three activities to implement and considering in more detail how to follow these plans when they returned to their place of work. Each team filled out a final planning form and handed it in to the workshop leaders. Follow up by MiZA staff, designed to support participants as well as collect information about how they were using the ideas, was discussed.

Introduction and Ice Breaker - We knew that setting the stage would be important for reaching participants with our ideas. We designed the introductory materials to give participants an idea of the workshop's purpose and a math icebreaker so that participants could find out a bit about one another. In pilot workshops, however, we noticed that workshop participants were often puzzled about why we were focusing on math. They weren't generally aware of the pressing educational agendas of schools or of the fact that "math" actually includes much more than number facts. We added to our introduction segments on 1) the National Council of Teachers of Mathematics curriculum and professional development standards; 2) data on how US students fare on standardized tests; and 3) developmental progressions describing how children's ideas about data and measurement grow, which served as a way for participants to consider which activities would be appropriate for which audiences.

We customized the icebreaker to include some data analysis concepts in the context of participants' experiences. We asked participants to line up according to the following question: How long have you worked in your current institution? We discussed this distribution then asked everyone to line up according to a different question: How long have you worked in the informal education field? Of course, the order changed in interesting ways – and the ensuing discussion revealed some data concepts that we would revisit later.

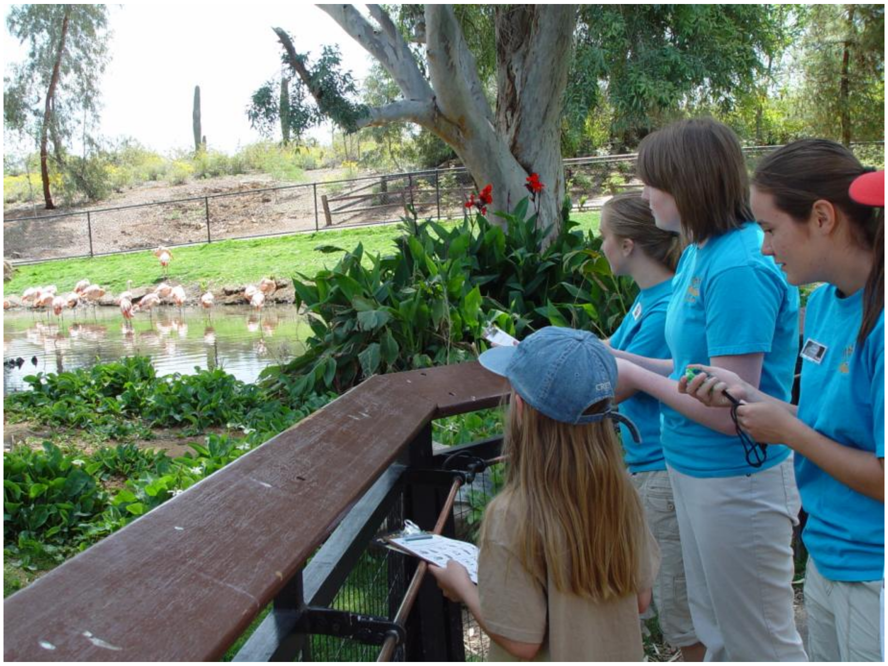
Math Activities - The next part of the workshop consisted of work on three math activities. As described above, in each case, the participants first played the games themselves, then discussed as a group how they might implement such an activity in their own institutions, then met in smaller groups to do more focused planning about implementation. The following are descriptions of the three activities, including their connections with conservation issues.

Guess My Animal. Guess My Animal is a logic game like "20 questions" that involves categorizing data. The goal is for visitors to be able to sort and categorize data of any type through numerical reasoning and logic (e.g.. using greater than and less than judgments, formulating questions based on data categories, and eliminating data that do not fit certain criteria). This activity originated at the New England Aquarium, where it was done with penguin species. We then tried it out the Phoenix Zoo, using data about individual goats rather than species. We found that it was important to provide templates so that each institution could customize the game by creating a deck with animals from its own collection or region. Creators of the game can include many different kinds of facts, including those related to species status. A deck of endangered amphibian cards and a deck of penguin cards that indicate their survival status (originally developed at the New England Aquarium) are available through the Henry Doorly Zoo.
(http://www.omahazoo.com/index.php?p=education&s=educatorscorner&u=resources)

One of the advantages institutions saw in this activity was its potential to promote awareness of conservation issues in their area. Conservation connections can happen as visitors develop emotional connections by using personal information about individual animals and develop empathy for un-charismatic animals by learning about their species (Myers and Saunders, 2002). Visitors may also make connections to issues around conservation by discussing how scientists use these types of data to monitor the health of populations of ecosystems: for example, keeping track of the numbers and types of migratory birds moving through southern Arizona is important to monitor the quality of the habitat.

Be an Animal Scientist. Be an Animal Scientist is based on a data analysis activity developed by the New England Aquarium and TERC in which students collected data on penguin behavior. Be an Animal Scientist gives visitors the opportunity to become scientists by observing and recording behavior of animals. They observe an actual animal exhibit and/or do a fun and interesting kinesthetic activity designed to familiarize students with animal behaviors involving simulations. One of the mathematical goals is for visitors to understand how to collect, record, and interpret observational data using columns and rows as well as use compiled data to create a bar graph. The facilitator leads a discussion about what people noticed and what variables in the environment may have influenced the animals' behavior patterns.

This activity can be contextualized to an institution's collection and can build stronger connections to the observed animals by helping participants see them as unique individuals. It can also help participants see the links between a species and the environment it lives in by relating its behaviors to it environment. As we found in piloting the activity around flamingo observations, children could begin to see relationships between feeding and location, aggression and feeding, activity levels and time of day. This kind of participation can help children understand the work of field biologists.



Finders/Keepers. Finders/Keepers is a measurement activity that involves aquatic species and exemplifies how linear measurement is used in fish management. To play the game, each group needs a fishing pole (a dowel rod with a magnet), a data sheet, and a fishing chart. Players use their poles to collect paper fish (which have paper clips that the magnet can grab) from a pre-stocked "pond". They measure each one and record its length on the data sheet. They then check the fishing chart to determine if the fish is a "keeper" and whether it is endangered or not.

In most states, fish and wildlife departments monitor the health of fish and set fishing regulations to make sure that over-fishing doesn't occur. Conservation of fish depends on having a good breeding stock. Sometimes, when fish are declared threatened or endangered, they cannot be fished at all. In other cases, fish and game regulators set either minimum sizes for a keeper, or "slot limits", which means that they allow fishing only within a certain size range. Fish in this range are known as 'keepers." Fish that are juveniles are not keepers, and often fish that are large and good breeders are not keepers. Population sustainability is a central feature of conservation work that becomes vivid for children. Mathematical and practical issues of how to measure animals that are odd shapes or are squirming, dangerous, or too large to weigh also arise.

The Evolution of the Workshop model - MiZA included time for the project team to pilot both the activities and the workshop format. As we tried things out, got feedback from the workshop participants, and discussed our own observations of what worked and what didn't, we encountered a variety of design issues related to both the content and the format of the workshop. Below, we describe several of these issues and how we took them into account.

Adapting the Activities to Individual Sites. Even after we settled on the three main activities of the workshop, we found that we needed to extend them in response to the different contexts participants worked in.

We created several levels of the **Guess My Animal** game to engage visitors with varying degrees of familiarity with logic. We discovered in the course of the workshops that Guess My Animal cards can be made accessible even to pre-reading children, who can play the game by just asking questions about visual characteristics of the animals rather than data that is recorded in text. The simplest text-based version of Guess My Animal, where cards represent individual animals, is accessible to children as young as second grade. Playing the game with animal species rather than individuals required somewhat more sophistication. But these young visitors are invariably accompanied by several older family members, who needed something more complex to hold their attention. For that reason, we created a more difficult game, Guess My Rule, which requires player to guess the <u>rule</u> the "chooser" is using rather than the <u>animal</u> by asking a series of questions about individual cards. For example, the chooser might be using the rule "has white fur." Other participants ask questions about individual cards -- "Does this card fit your rule?" – in order to figure out the chooser's rule. We developed a version of the game that involved two rules and extended the educational nature of the activity even further

The **Be an Animal Scientist** game also became more multi-faceted as we had more workshops. We customized the activity based on the animals in each workshop site, so we observed diving beetles, gorillas, and wolves along with penguins and flamingos in several locations. As our audience grew to include institutions with plant rather than animal species, we helped them design a "Plant" scientist activity that required participants to observe the state of plants (e.g. fraction of leaves that have turned red so far) rather than the actions of animals. Some of the participating institutions had already done animal behavior observation activities (often by scientists as well as visitors) and were able to share with the group how these activities could lead to increased interest in conservation.

When we first introduced the **Finders' Keepers** activity, we customized the fish guides for each site. Sometimes this was a problem. For example, while we were planning the Bronx Zoo workshop, we discovered that all fish caught in the Bronx River had to be released immediately, which made the activity of measuring a fish to determine whether or not it was a "keeper" unnecessary. In that case, we shared the Bronx River regulations sheet with the group then did the activity using information from another part of New York State! In the subsequent workshops, we used Texas fishing regulations as much as possible because customizing was difficult.

Adding Questions about Math, Science and Conservation. All participants were interested in how they could connect the activities with math, science and conservation. They had different reasons for each of these categories. Participants wanted to know how to talk about the **mathematics** embedded within each of the activities; since many of them had just significantly expanded their notion of math, they couldn't necessarily describe the math content of what they proposed to do. In terms of **science**, participants wanted to be able to recognize and talk about the places in their settings where the kind of math they were learning might be used by curatorial and scientific staff. The **conservation** connections were particularly important, since most zoos and aquariums could most easily justify spending time on a new activity if it were clear that it supported conservation education.

We created a separate information sheet for each activity detailing its math, science and conservation connections. This was an excellent resource for workshop leaders, as well as for workshop participants to take home with them to share what they had learned with other staff (see: http://www.phoenixzoo.org/educators/miza.html).

Including Planning Time. Successful professional development workshops with *teachers* include time for the participants to think realistically about how they would go back to their schools and actually implement what they learned (Loucks-Horsley, Stiles, Mundry, and Love, 2009). They allow planning time for participants to review the realities of who has to be informed about what's going on, what kind of scheduling needs to happen, how parents might need to be involved, who will buy, collect, and store the materials in the building, and so forth. If teachers think ahead about potential obstacles, they can be better prepared for them.

Based on these staff development models, we decided to include planning time in the workshop even though we didn't originally know what the range of planning issues might be for this kind of professional staff. We began by scheduling one block of time at the end of the workshop for participants to create an implementation plan, choosing among the three activities they had experienced. However, it was difficult for participants to remember enough detail about each activity to make a plan without spending some time reviewing the activities. We therefore began to schedule planning time in three sections, one after each activity. These three planning times served both as time for the team from an institution to consider how they might implement the activity and as time for them to come to a final decision about which implementation plan to submit at the end of the workshop. Multiple blocks of planning time seemed to work better for people because they could focus on one activity at a time and gradually build an image of introducing mathematics into their interpretive programs.

When participants left the workshop, their group handed in a planning sheet that specified the activity they planned to implement, some details of its implementation and what challenges they thought they might encounter in the process. These documents formed the backbone of the follow up that workshop leaders provided (see below).

Sharing Experiences. We also considered how much time to set aside for people to share their plans. There were two opposing considerations here: being able to hear other people's thoughts on a particular issue is often the best way to engage in problem-solving and imaginative thinking. On the other hand, too much sharing in a workshop can be enervating, especially if participants come from circumstances with different opportunities and challenges (e.g. teachers and informal science educators).

Our workshop guide gives the leader flexibility in including an appropriate amount of discussion. Places where it was possible to have a discussion are 1) at the beginning, where individual institutions attending the workshop could describe how they already used math; 2) time after doing each activity to talk about the math it contained; 3) time after each activity and planning time to share emerging plans; 4) time at the end of the workshop to talk about the choice their team had made about an activity to implement.

Including Follow Up and Technical Assistance. What seems possible in a workshop often seems less so when the realities of a workplace reassert themselves. In order to increase the probability that participants would actually follow through on the plans they made at the workshop, we contacted participants about the status of the plans they had outlined two months after the workshop. We intended these calls to be offers of assistance in addition to reminders. Sometimes participants had questions about the math or details of the activity that had hindered their implementation, and our phone call offered them an opportunity to clarify these plans. In many cases, we had the feeling that they would never have initiated the call, but were happy to have the help in moving forward.

Evaluation

The MiZA evaluation was designed according to a Logic Model, as specified by IMLS, and focused on participants' experiences in the workshop as well as on implementation and institutional adoption. Measures assessed participants' levels of confidence and knowledge, whether any increases were retained over time, how implementation progressed, and whether and how individual and institutional factors influenced implementation.

Garibay Group conducted the summative evaluation of the project, working closely with the project staff throughout as we made course corrections and adjustments. The primary goals of the summative evaluation were to determine the degree to which MiZA achieved its stated outcomes of influencing participants' practices and determining what factors played a role in changing their practice. The three main anticipated outcomes that guided the project and evaluation were:

1. Confidence: Workshop participants will increase their confidence in their ability to incorporate math into their interpretive activities
2. Implementation: Workshop participants will successfully adapt one of the workshop math activities to work with their own collections.
3. Connections: Workshop participants will see connections among the math activities, science and conservation.

These goals came from our original Logic Model. As the project evolved we realized just how much participant activities were determined by the context of their institutions. Thus, the project increasingly looked at the role of institutional factors on activity implementation. The structures of different institutions led to different processes of integrating new ideas; other institutional factors either facilitated or became barriers to the adoption of the math activities. This two-tiered analysis contributed to the development of the professional development model described below. Full details of the analysis may be found in Garibay and Kies (2008).

Below we briefly describe the evaluation methods, then discuss the evaluation results in three sections: Short term results, Long term results and Factors that influenced the results (including institutional contexts).

Evaluation Methodology - The evaluation used a mixed methods approach (Green and Caracelli, 2002; Johnson and Turner, 2002), including both quantitative and qualitative data. Specific methods included surveys, phone interviews, debriefing data from follow-up calls between MiZA staff and participants, and workshop observations.[2]

Short Term Results - How did the workshop affect participants' math knowledge and confidence? Rating their level of knowledge, confidence, and understanding both before and immediately after the MiZA workshop, respondents, overall, showed statistically significant increases in reported understanding of how to use math to interpret living collections at their institutions.

According to pre- and post-workshop ratings, the workshop positively impacted participants' understanding and confidence in implementing math at their institutions regardless of their self-reported level of comfort with math. Those with low math comfort as well as those with higher levels of comfort with math showed statistically significant gains in their understanding of how to use math to interpret living collections and in their confidence to do so.

Data also indicated that the MiZA workshop successfully provided participants with concrete, easy-to-incorporate math concepts, creative new ways to think about math, and a variety of tools, strategies, and ideas about math activities that could be easily adapted to different audiences and settings. After coding open-ended responses to the question of what participants learned from the workshop, the following clusters emerged:

- Gained ideas for incorporating math concepts/activities into a range of programming and for different potential audiences (N=111).
- Expanded concepts about what math is and how it can be applied (N=47).
- Found that math concepts are easy to incorporate (N=24).
- Gained ideas about math activities that are animal-specific (N=20).

How did MiZA workshop participants implement activities? Because the workshop successfully provided participants with the supports described above, over 60% of the participants were able to implement one or more activities.

While the majority of participating organizations implemented activities, however, participants identified several challenges in the process, including: a) difficulty motivating other staff members; b) time involved in preparing/adapting activities; c) finding ways to integrate an activity into an already full program; d) uncertainty about how to adapt an activity for a specific age group. For those who did not implement activities, the reasons most often cited were: a) not having enough time (70%), b) having a curriculum in place and being unable to add anything new to it (17%), and c) that the activities did not fit with their organization's goals (17%).

The frequency with which participants implemented activities varied. The activities most often implemented included "Be an Animal Scientist" (45%) and "Guess My Animal" (38%). The Finders Keepers activity was implemented by only 17% of participating organizations. The most prominent reason cited for choosing to use one activity over another was that an activity fit well with (and could easily be integrated into) existing programming.

One goal of the MiZA project was to have participating institutions develop activities for casual visitors as a primary target audience. Piloting at the Phoenix Zoo showed that the activities worked well at stations along the trails. While many participating organizations successfully implemented activities, however, the goal of targeting casual visitors was significantly less successful. MiZA activities were primarily implemented with formal groups, with equal percentages of institutions (44%) conducting activities with school groups and out-of-school structured groups such as summer camps. An average of 12% of participating institutions indicated that they had implemented activities with family visitors

Reasons why activities were implemented less often with casual visitors varied, but included that: a) the majority of institutions had many more programs aimed at formal groups; b) implementation with casual visitors was perceived as more challenging due to necessary coordination with other departments (e.g., visitor services, curatorial); c) a perception existed that activities took too long to successfully conduct with casual visitors; d) participants felt that casual visitors would not be interested in math-based activities; and e) participants believed that the activities themselves were more appropriate for organized groups (especially children).

In the end, the majority of institutions reported that they were very likely (52%) or somewhat likely (42%) to continue implementing MiZA activities.

How did the MiZA experience impact participants professionally? In addition to how activities were used and whether they were adapted, the evaluation looked at the influence of the experience on participants' practices and professional approaches.

The project had a positive impact on participants' understanding and confidence regardless of their self-reported math comfort. Even those participants who initially reported low levels of math comfort showed statistically significant gains in their understanding of how to use math to interpret living collections. The project also influenced participants' own practice, with 80% reporting that implementing activities had a positive impact on their abilities to integrate math concepts and ideas into their work.

MiZA training had an impact on participants at several levels. It increased participants' comfort with math; their understanding of and ability to use math to communicate conservation issues; and their confidence in using math to help interpret living collections.

Long Term Results - How did participation in a MiZA workshop affect participants' long term math comfort and knowledge? MiZA's influence on participants' comfort continued beyond the workshop timeframe. When reflecting on their perceived level of math comfort after participating in MiZA some six to twelve months after the workshops, 11% moved from "Not very comfortable" and "Somewhat comfortable" to "Comfortable" and "Very comfortable," a statistically significant change.

Participants listed a wide range of ideas or skills gained from participating in MiZA. Twenty-two percent said the most significant idea they took from the project was that MiZA changed their previous perceptions of what constituted math, providing new ways of approaching the issue of math implementation in their programming. The majority of respondents said that participating in MiZA increased their understanding of math, data, measurement, and logic, with nearly 30% mentioning learning more about specific content, such as data collection, measurement, and using ethograms. Slightly more respondents—though not a statistically significant amount—believed their understanding of data, measurement, and logic specifically increased more than their understanding of math in general.

How did MiZA workshops affect participants' awareness of connections between math and conservation? A large majority of respondents agreed that participating in MiZA increased their understanding of how conservation and math relate. Respondents also reported a positive impact on their abilities to incorporate math in communicating conservation issues. Ratings of their abilities before and after involvement in MiZA showed a statistically significant shift from responses of "Not at all equipped" and "Not very equipped" to Somewhat," "Adequately," and "Very equipped."

In terms of the activities themselves, the majority of respondents (72%) said they found implementing activities "useful" (34%), "very useful" (17%), or "somewhat useful" (21%) in communicating conservation messages. 23% of participants were "not sure" how incorporating math affected the conservation message.

How did MiZA workshops help participants engage target audiences? Participants reported that MiZA increased their understanding of the role that math could play with each of their target audiences. The level of impact, however, differed significantly for each type of audience. Participants best understood the role math can play with school groups, followed by other organized groups, and least with casual visitors. These differences may be related to a lower number of organizations that implemented activities with casual visitors.

The majority (80%) of participants said implementing activities had a positive influence on engaging their audiences more deeply. Thirty-six percent said implementation had a "moderate influence," 27% cited a "significant influence," and 17% who saw "some influence" (17%, however, were not sure, while 3% believed no influence existed.)

When asked directly how implementing math-based activities affected visitors' engagement with their *programs* versus *exhibits*, respondents showed statistically significant differences between these two applications. A significantly higher percentage of participants (63%) reported that implementing math-based activities had a "moderate" or "significant" influence on programs compared to exhibits (37%). This greater influence in perceived engagement may relate to the fact that significantly fewer institutions have implemented activities in the broad exhibition setting for casual visitors.

How did attending a MiZA workshop impact participants' work over time? The majority of respondents (82%) indicated that implementing activities at their organization positively impacted their abilities to integrate math concepts and ideas into their own work. However, while MiZA positively influenced participants on various levels, most of the participation was from Education department staff and in most cases did not affect the overall organization.

Eighty per cent of participants stated that participating in MiZA was professionally valuable experience while nearly one fifth (18%) indicated that their involvement in the math project was only "Somewhat valuable" professionally. Those who implemented activities, however, rated the overall value of participating in MiZA higher than those who did not implement activities.

How did attending a MiZA workshop influence participants' expectations for involvement in future projects? The majority of respondents (87%) indicated they would, if given the opportunity, be likely to participate in future projects focused on using math to help communicate conservation messages. Those who had implemented activities were more likely to predict that they would participate in future projects that focused on using math to communicate conservation messages than those who did not implement activities.

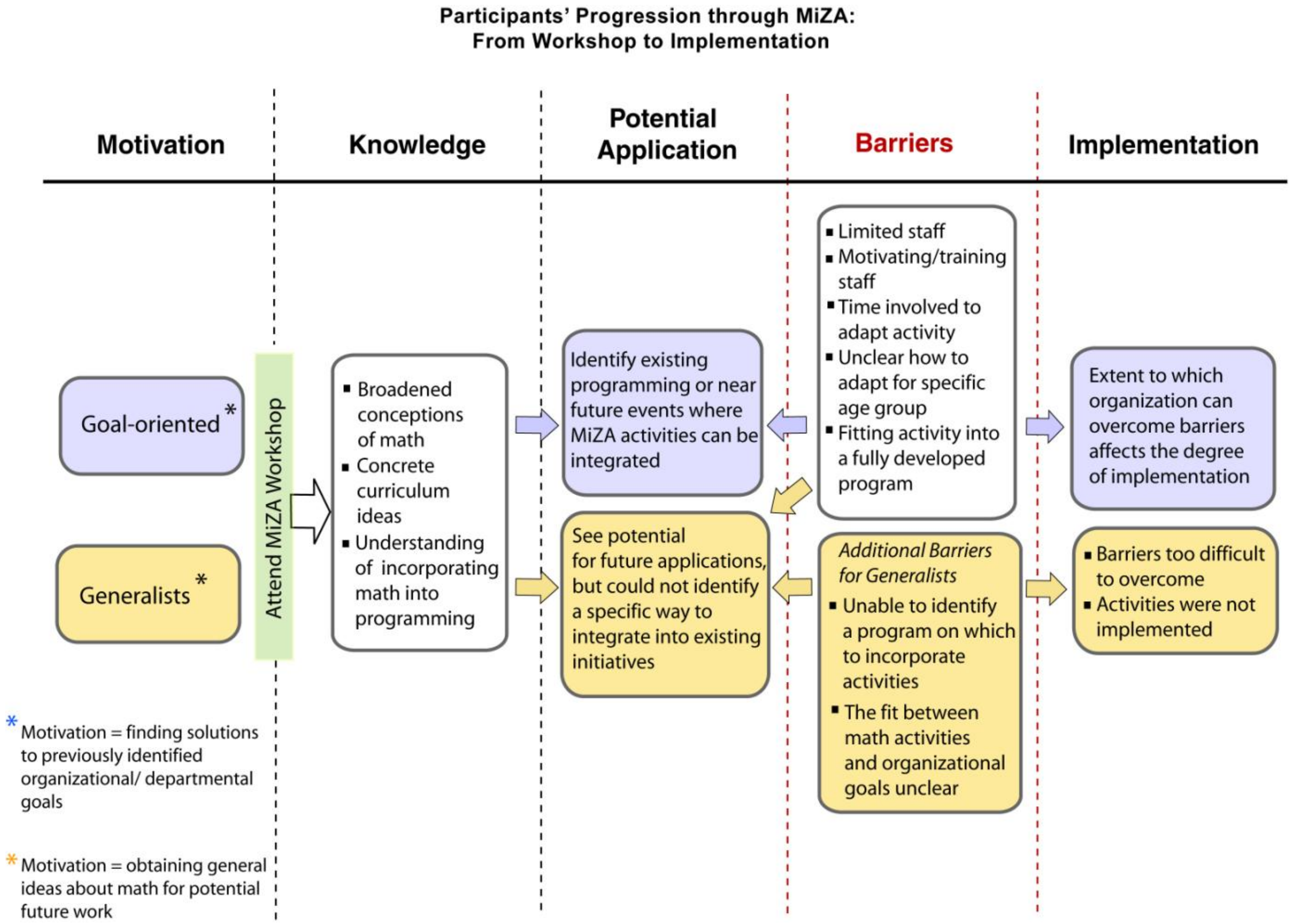
Those who reported higher comfort with math after participating in the workshop were also more likely than those less comfortable with math to foresee participating in future math-focused projects that would help communicate conservation messages.

How likely were MiZA workshop participants to recommend MiZA to their colleagues? A high percentage (85%) of participants stated that they would likely recommend the MiZA initiative to a colleague. Again, those who implemented activities in their organization were significantly more likely to recommend the workshop compared to their colleagues who failed to implement any MiZA activities.

Factors That Influenced the Outcomes - The factors that influenced the project outcomes existed on different levels, from the individual to the institutional. The surveys, interviews, and plans collected from the participants allowed the evaluator to categorize their motivations, to track how much participants felt they benefitted, and how they planned to use the activities. By comparing outcomes across types of institutions, the overall pattern of adoption processes was identified.

How participants progressed through the process of implementing MiZA activities: At the individual level, data indicated that those individuals attending the workshop with a specific program goal in mind, and who were able to discern how MiZA math activities fit into their overall department and/or institution, more successfully implemented an activity after the workshop. In addition, when participants could quickly adapt an activity (i.e., without significant time spent to customize it) they were more likely to implement it. Interestingly, those who had more general motivations for attending, such as wanting to explore the possibility of this kind of approach, were less likely to implement. Such an outcome is consistent with an activity theory framework (Davydov, 1999) which predicts that someone's mental goal will influence the meaning they make of a learning activity or event. It will determine, in fact, which mental tools they apply to a situation.

When seen from the perspective of barriers that participants identified as obstacles to carrying out the new practices, we saw that the "generalists" has less success, overall. All participants had institutional barriers in common but there were additional ones for the generalists, as seen in Figure 1.



Factors that influenced implementation: In order to be implemented successfully, a MiZA-related activity had to go through several "hurdles." Several of these had to do with the speed and ease with which staff could implement the activities. **While** all participants showed gains in knowledge as a result of attending the MiZA workshop, being able to identify specific existing or near-future initiatives where MiZA activities could be incorporated proved critical to actually implementing activities—and, in essence, putting that new knowledge into practice. For those participants who could not identify a specific program or initiative into which to integrate MiZA activities, this issue sometimes became too significant a barrier to overcome. Similarly, implementing an activity was difficult for people who could not see a fit between the MiZA activities and their institutions' goals.

In addition to having general success with an activity, it was important that the activity be incorporated into a program in which staff was already invested. For this reason, one-time special events or short-term programming were typically *not* optimal choices. Additionally, staff had to be able to quickly assess ways to adjust an activity and efficiently make revisions in order to consider it as a permanent component of their offerings. The finding that participants who implemented activities were more likely to predict that they would participate in future projects using math for conservation messages aligns with well-documented research in the professional development literature. That literature indicates that having opportunities to actually use and practice knowledge and skills learned after trainings is essential in changing practice (see, for example, Ingvarson, Meiers and Beavis, 2005).

Another predictable finding was that some individuals reported that they could have used more help and guidance in revising their implementation strategies than was provided for in the project plan. Interviews revealed that some individuals went through a lot of "trial and error" and would have liked supportive feedback to make the effort worthwhile. This need for support raises a practical issue for projects with national reach that touch large numbers of participants.

Institutional factors that influenced implementation. From the interview data, features of the participating institutions themselves emerged as having an impact on the project outcomes (see Figure 2). Interestingly, by categorizing where the successful adopters worked, we found that small and large institutions afforded different advantages for adopting the new practices, with staff from both types being able to implement activities, but for different reasons. The size of the institution affects the specialization of staff, numbers of programs, and communication among staff members. In a small institution, staff need to be generalists and have the ability to impact programs and share new practices with the relatively few other staff members with whom they work. At larger institutions, staff tends to be more specialized, but often have more time to introduce new ideas and to design special programs to accommodate them. Literature about factors influencing change focuses more on formal educational institutions (e.g., Senge, Carlton-McCabe, Lucas, Smith, Dutton and Kleiner, 2000). The ways in which new practices are adopted in informal learning settings has not yet been studied in detail.

Organizational Factors Influencing Implementation

	Small Institutions	*Large Institutions*
Staff	Small number of staff.	Large number of staff. ✔
Time	Staff often responsible for broad range of programming, limiting available staff time for enchancements/new initiatives.	Individual staff members' responsibilities are more specialized, often translating to more time available for new initiatives/ enchancements. ✔
Programming	Fewer programs offered, which canlimit options for where activities can be implemented.	Broad range of programming; more options available where activities can be implemented. ✔
Possibilities for integrating activities	An individual staff member is involved in most programming offered, thereby increasing the possibilities that activities can be integrated into various programs. ✔	Individual staff members are more specialized in what programmatic area or audiences they are responsible for. Therefore, an individual staff member has a limited scope of programs (or audiences) where they can incorporate activities.
Communication	Staff size makes it easier to share ideas and integrate activity content into programmatic areas. ✔	Difficult to efficiently share ideas among staff members. In largest institutions, no mechanism exists for this because of specialization in a programmatic area.

✔ ***Indicates instances in which one type of institution has an advantage.***

Conclusions, Implications and Future Work

Specific evaluation findings of the MiZA project as well as an understanding of the evolution of the workshop design can be useful in informing the design of future professional development initiatives in zoos and aquariums, since they illustrate “process” issues that influence outcomes.

For example, several aspects of MiZA’s workshop structure contributed to its success. The most critical were: a) providing a set of activities that participants could take and readily adapt for their institution’s needs, and b) putting structures in place to encourage and support participants in actually implementing activities.

Helping participants identify and link activities to existing programming, addressing organizational structure issues, and including staff-driven evaluation of visitors’ experiences to help participants reflect on their “practices” can strengthen professional development initiatives at zoos and aquariums. Figuring out ongoing support for the incorporation of new educational practices is also something to consider in the future.

Keeping in mind that variation among sites is a fact of life, training needs to be adaptable, particularly if the model is revised to serve a broader range of departments. This project identified the ways in which flexibility needs to be considered and incorporated in professional development for zoo and aquarium staff. Some findings, particularly the need for providing a set of activities that participants could take and readily adapt for their institution’s needs and putting structures in place to encourage and support participants in actually implementing activities align with well-documented research in the professional development literature.

Longer-term changes in interpretive practices were not addressed in the MiZA project but would be valuable to examine as staff tackle issues of conservation education and what that implies about institutional mission. We believe that one route to helping the public understand the work of the institutions and of conservators in general is to engage them with the underlying scientific work and the tools used by zoo and aquarium professionals, tools such as measurement, pattern analysis, inference, and computation.

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Notes

1. AZA Western Regional Meeting, Vancouver; AZA Western Regional Meeting, Denver; AZA Eastern Regional Meeting, Jacksonville; Blank Park Zoo; Bronx Zoo; Dolphin Quest; Fort Worth Zoo; Grouse Mountain Refuge for Endangered Wildlife, Vancouver; Lincoln Park Zoo; Monterey Bay Aquarium; National Aquarium; New England Aquarium;

Henry Doorly Zoo; Oregon Zoo; Phoenix Zoo; Pittsburgh Zoo and PPG Aquarium; Saint Louis Zoological Park; Tennessee Aquarium; Toronto Zoo; Woodland Park Zoo.

2. *Paper surveys* were used at the beginning and end of workshops to assess both immediate outcomes from the MiZA workshops and intermediate outcomes resulting from participants' involvement in the MiZA project. *On-line surveys* were administered to participants toward the end of their involvement in the project to assess longer-term outcomes. *In-depth interviews* were the primary qualitative method used in this study. The interviews also provided opportunities to gain insight into the varied organizational contexts in which MiZA activities were implemented and the ways in which such contexts influenced outcome at a particular institution.

Throughout the project, MiZA staff followed up with participants via *phone calls* with workshop participants to provide them support and assistance.. These calls were also used to track progress, identify barriers, and document any unanticipated issues that emerged. A database was established to track project activity and organizations implementing activities. *Workshop observations* by the evaluator were also incorporated into the summative study, allowing the evaluator to examine firsthand the various components of the workshop.

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