Moneyville Exhibit
A Summative Evaluation Report

Prepared for

OMSI
OREGON MUSEUM OF SCIENCE AND INDUSTRY

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with the generous support of

This material is based upon work supported by the National Science Foundation under grant Number ESI-0087783. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Executive Summary

Inverness Research Associates

December 2004

From the fall of 2000 through the fall of 2004, the Oregon Museum of Science and Industry (OMSI) received funding from the National Science Foundation to create a math-based exhibit for school-aged children and their families. The end result was *Moneyville*, a colorful and inviting traveling exhibition offered in two configurations–the original full-size 6000-square-foot version and a reduced version designed to accommodate smaller venues, such as children's museums and discovery centers. Both exhibitions were designed to teach visitors about "making economic choices with the power of mathematics." OMSI staff also produced a comprehensive Teachers Guide as a support for school groups who visited *Moneyville*.

Inverness Research Associates has served as the external evaluator for *Moneyville* since the OMSI design team developed their first prototypes. Our work has included a range of activities at various stages of the project, from interviewing families around the first pre-production version of the full exhibition to following the smaller version to its first traveling venue.

OMSI had four major goals in designing *Moneyville*:

- to promote mathematics learning grounded in real-life contexts
- to encourage economic literacy
- to provide opportunities for family learning
- to create exhibits reflective of the NCTM Standards for grades K–8

According to our experiences with visitors on the floor, OMSI achieved each of these goals, some to a greater extent than others. Overall, our data indicate that OMSI has succeeded in creating an environment that attracts a wide visitor audience, especially families, and provides an opportunity for them to engage with compelling economic issues using math as a tool for exploration and understanding. Visitors to both versions of the exhibition tell us that they like *Moneyville*. They believe it not only appeals equally to children and adults but also addresses an important societal need–namely the lack of economic and mathematical literacy in our culture. Adults especially appreciate the way *Moneyville* teaches life skills that everyone needs to "succeed in life" and to function as effective citizens.

The *Moneyville* project originally received funding as a math exhibition. However, due to the topic, visitors tend to see economics as the primary focus. If they recognize the mathematics, they view it as secondary. As a result, teasing out the mathematics that visitors are using and the skills they are developing while interacting with the *Moneyville* exhibits has proven to be a challenging and complex task. OMSI's articulation of five mathematics strands: understanding numbers, measuring & comparing, finding patterns, interpreting data, and thinking & reasoning has helped pinpoint and clarify the *Moneyville* math goals. The labeling of these strands at each exhibit has helped identify the mathematics learning opportunities made available to each visitor.

One of the defining features of Moneyville, especially the larger exhibition, is the layout into five thematic areas (for example, "The Bank" or "Global Trade") and the theatrical casework that OMSI designers created to define each one. The playful and colorful nature of the set created for the exhibition is something that makes *Moneyville* particularly appealing to visitors. To provide a sense of the visual experience associated with the exhibition, we include the photo below. The full evaluation report contains a detailed analysis of the exhibition as a whole, as well as its individual components, with a particular focus on examining the mathematics learning opportunities made available to visitors of all ages.

***Moneyville 1* at OMSI–Bank Façade**

MONEYVILLE

A Summative Evaluation Report for the
Oregon Museum of Science and Industry's Traveling Exhibition

December 2004

Introduction

Overview of the External Evaluation

In the spring of 2002, the Oregon Museum of Science and Industry (OMSI) contracted Inverness Research Associates to assist with the evaluation of their *Moneyville* exhibition on money, math, and economics. Because OMSI has its own internal evaluation department, Inverness has played various but specific roles in working with this project. Our external evaluation activities have included participating in overall evaluation planning, providing technical assistance on protocol development, conducting formative evaluation on prototypes, and conducting a summative evaluation of the first iteration of both the full-size (referred to in this report as *Moneyville 1*) and smaller-size exhibitions (referred to as *Moneyville 2*).

This report serves as our final evaluation report for the *Moneyville* project as a whole, including data from our work with both versions of the exhibition. However, it focuses primarily on our findings from two periods of data collection. The first was a 3-day site visit to OMSI in August 2003 soon after the full-size exhibition opened to the public. The second was a 3-day site visit to the Museum of Discovery & Science (MODS) in Ft. Lauderdale in October 2004 to see the smaller version of the exhibition in its first traveling venue. The goals of these two site visits were somewhat different.

In Portland, our summative evaluation work over the three days had two primary purposes: 1) to document the overall visitor experience in terms of levels of engagement with the physical and conceptual notions of the exhibits, particularly keeping in mind the extent to which the exhibition met the OMSI staff's experiential and educational goals for visitors, and 2) to help inform the design of the smaller version of *Moneyville*. Since the exhibition needed to be reduced from approximately 6000 square feet to about 2000 square feet, we wanted to determine which exhibits seemed most supportive of the project goals and which appeared more "dispensable" in that regard.

In Fort Lauderdale, we once again wanted to document the overall visitor experience with the individual exhibits. However, here we focused much more attention on better understanding the kind of math learning that visitors were experiencing in *Moneyville*.

In addition, the Inverness team wanted to explore any issues that might have arisen as the exhibition traveled–particularly with respect to set-up, layout, durability, and maintenance.

The chart below provides a summary of the external evaluation activities completed at each site.

Evaluation Activities	OMSI Portland, OR	MODS Ft. Lauderdale, FL
Critical reviews of exhibits and signage	Prior to work with visitors, the team spent one half-day getting to know the navigational and conceptual aspects of each exhibit. The goal was to establish a team understanding of the exhibits and to use this knowledge to refine our conceptual framework for conducting observations and interviews.	Prior to work with visitors, the team spent about an hour becoming reacquainted with the navigational and conceptual aspects of each exhibit and becoming familiar with the layout of the smaller exhibition.
Interviews with key staff	Prior to interacting with visitors, the team spent one half day interviewing key staff members involved with the development of *Moneyville*. The purpose was to document staff perceptions of the exhibition's strengths and successes, as well as any concerns they might have about the visitor experience.	The team leader conducted a post-site visit interview with Joe Cytacki by phone. On-site, the team interviewed members of the staff (including volunteers) responsible for interacting with visitors and maintaining the exhibition.
Trackings of visitors	The team tracked and timed 40 randomly chosen visitors noting which exhibits they used and for how long. The purpose of this task was to get a sense of how visitors are flowing through the exhibition as a whole, to find out which exhibits are attracting visitors and which are not, and to document how long visitors are using each of the exhibits.	The team tracked and timed 25 randomly chosen visitors according to the same strategies used at OMSI.[1]
"Exit" interviews with visitors	The team conducted 32[2] exit interviews with randomly chosen visitors, approaching them as they were leaving the exhibition or as they appeared on the verge of leaving. These interviews helped us document what visitors thought the exhibition was about, what they thought they were learning, and their suggestions for *Moneyville 2*.	The team conducted 17 exit interviews focusing primarily on visitors' perceptions of the exhibition as a whole.
Naturalistic observations at key exhibits	OMSI staff wanted to learn about the "natural" experience of visitors, i.e., how visitors interacted with the ideas and phenomena without the intervention of an evaluator, program provider, or explainer. In order to study these natural behaviors, we stationed ourselves at key exhibits, documented conversations, and observed the behaviors of visitors.	Due to the location of the *Moneyville* exhibition at MODS, naturalistic observations were much more difficult to conduct, particularly with respect to capturing visitor dialogue.
Exhibit-specific interviews	In order to gain a deeper understanding of visitors' experiences and to confirm some of the findings from our naturalistic observations, the evaluation team conducted in-depth interviews at particular exhibits where either members of the team or OMSI staff had further questions.	We conducted exhibit-specific interviews at MODS in particular to document details about the math learning occurring at key exhibits. Between OMSI and MODS we conducted approximately 45 exhibit-specific interviews.

[1] For *Moneyville 2*, we chose to do fewer visitor trackings in order to conduct more exhibit-specific interviews.
[2] Of the 32 interviews, 16 were people we had tracked. Interviews included 15 adults (8 females, 7 males), 1 teenager, 10 girls and 6 boys.

Visitor Demographics

At OMSI, our work took place during the summer. Therefore, most of the visitors we observed were part of family groups, a significant portion of whom were out-of-town visitors on vacation. We also encountered a few summer camp groups who had come to OMSI for the day, and these groups offered a view into how the school group population might interact with the exhibition. There were also a few adult couples who came through the exhibition. In terms of ethnicity, the visitors were mostly Caucasian.

OMSI Visitors Tracked (n=40): Demographics by Age/Gender

	Female	Male
Children	10	12
Adults	11	7

OMSI Visitors Tracked: Demographics by Age/Ethnicity

	Af. Am.	Asian	Caucasian	Hispanic
Children	0	3	18	0
Adults	0	0	19	0

At MODS, we observed a range of groups on our first day (Friday), including school groups, church and Girl Scout groups, as well as the general public. On the second day we observed primarily the general public; on both days visitors were ethnically diverse.

MODS Visitors Tracked (n=25): Demographics by Age/Gender

	Female	Male
Children	10	7
Adults	5	3

MODS Visitors Tracked: Demographics by Age/Ethnicity

	Af. Am.	Asian	Caucasian	Hispanic
Children	4	0	10	4
Adults	0	0	6	1

This Report

This report represents findings from studies of the visitor experience in both *Moneyville 1* and *Moneyville 2*. It has been written for the leaders of the *Moneyville* project at OMSI to use both internally and externally, as they see fit. The remainder of the report is organized into three sections:

- Comparing the Two Versions of *Moneyville*
- Findings Related to Project Goals
- Overall Lessons Learned

The first section examines similarities and differences in content, visitor flow, and durability across the two versions of the exhibition. The second section, Findings Related to Project Goals, considers in detail each of the four stated goals as laid out in the original proposal. The report ends with a section on Overall Lessons Learned.

We include as appendices: 1) a detailed analysis of the mathematics learning that occurs at five key exhibits, 2) brief descriptions of individual exhibits, 3) the layout of *Moneyville 1* in Portland, Oregon, and 4) the layout of *Moneyville 2* in Ft. Lauderdale, Florida.

Two Versions of *MONEYVILLE*–Similarities and Differences

Overview

In this section of the report, we discuss the similarities and differences between the two versions of *Moneyville*, the larger 6,000-square-foot version and the smaller 2,000-square-foot version.[3] As noted in our introduction, we observed the large version at OMSI in August 2003 and the small version at the Museum of Discovery and Science in Fort Lauderdale, Florida, in October 2004.

Originally, we planned to observe the two versions of *Moneyville* in the same venue (OMSI), evaluating each version with more or less the same audience and in the same physical context. In this way, we believed making distinctions between the two could be more clean and rigorous because we could eliminate some of the variables inevitably involved in a traveling venue. However, due to various logistical and scheduling factors, we did not have the opportunity to conduct our study in this way and, therefore, evaluated *Moneyville 2* at its first traveling venue.

Below we highlight our findings about what these two versions have in common and what distinguishes them from one another.

Visitor Response to *Moneyville*

We want to say first and foremost that overall, according to what we saw and heard in Portland as well as Ft. Lauderdale, visitors are quite positive about both versions of *Moneyville*. They find both versions of the exhibition inviting and like the playful way that it looks: "...like Dr. Seuss-ville!" and "…like a pop-up book." *Moneyville*'s appeal spans a wide age group, from toddlers to grandparents and ages in between.

Visitors to *Moneyville* also think that the topic of money and economic literacy is a relevant and important one–something that they can relate to as part of their daily life. For example, we regularly saw people pulling out bills and coins of their own to compare and investigate. Because money is also something that everyone feels they know at least something about, *Moneyville* helps reduce the intimidation that visitors sometimes confront in more science-based exhibits. They can readily make connections to their own experiences. For example, we heard things like, "We just went to Volcano National Monument–the Indians used obsidian to trade for things" and "I give my son a handful of change and ask, 'How much do I have?'"

[3] Please see the appendix to this report for floor layout maps of each of the two versions.

Some visitors also appreciate what they perceive as the "objective" or "value-free" aspect of *Moneyville*. As one woman at OMSI told us: "I like that this is not controversial; I like science, facts. The last [temporary exhibition] on disease...that was really dark. Here, I haven't had to say 'some people believe this, some that.'" Overall, many people we talked to expressed the notion that money is simply part of real life and that most people could benefit from knowing more about it. They appreciate OMSI's attempt to fill this need via the creation of *Moneyville*.

We also want to preface all of our findings by noting that, in spite of the physical differences between the two versions we studied, the visitor experience was actually more similar than different–particularly with respect to the overall messages that visitors were taking away and the extent to which they encountered mathematics as they investigated money and economics concepts.

Physical Differences between *Moneyville 1* and *2*

Although it requires only one-third the space of the original version, *Moneyville 2* includes approximately two-thirds of the individual exhibits contained in *Moneyville 1*. Below is a list of the exhibits that appear in the 6000-sq.-ft. version, organized by thematic area. The exhibits that appear in bold type are also in *Moneyville 2*.

Individual *Moneyville* Exhibits by Area

DOLLARS AND SENSE	GLOBAL TRADE
Balancing Your Budget	*Money from Around the World*
Get Real	***From Around the World***
Inflation Station	***Material World***
The Real Cost of Credit	*The Shirt Off Your Back*
The Better Buy	*The Shipping Dock*
THE MONEY FACTORY	THE BANK
Money Factory Entry	***Million Dollars***
Making Money (Rubbing Station)	*Money on the Move*
Face Value	***Make a Million***
Anti-Counterfeiting Lab	***Kids Bank Teller Window***
How Money is Made (videos)	***Kids Bank Puzzles***
History of Money	
Money Mysteries	TO MARKET, TO MARKET
Moneyworks Park	***Stock Market***
Barterville	***Lemonade Stand***
	Quick Change
	Kids Market

The following points summarize the key physical differences between the two *Moneyville* versions:

- *Moneyville 1* contains 28 individual components; *Moneyville 2* has 17.
- *Moneyville 1* has more physical scaffolding and casework that contributes to the "city" feel of the exhibition (such as the Bank front, the Money Factory façade, etc.) and helps to visually mark the five thematic areas.[4]
- The layout of *Moneyville 1* was organized according to the five thematic areas of the exhibition, and related components for each area were clumped in the same vicinity. In *Moneyville 2*, as it was arranged at MODS, components that were together in *Moneyville 1* were dispersed throughout the whole gallery.
- At OMSI, *Moneyville 1* was located in its own gallery with no other competing exhibits in proximity. At MODS, in addition to the *Moneyville 2* exhibits, there were five OMSI Brain Teaser exhibits in the gallery. Visitors moved freely back and forth between the Brain Teasers and the *Moneyville* exhibits. In addition, the exhibition was located immediately adjacent to a simulator ride that was very popular among children and teenagers.

Visitor Flow and "Holding Power" in *Moneyville 1* and *2*

Visitor Time Spent in *Moneyville*

	Moneyville 1 (n=40)	*Moneyville 2* (n=25)
Average time in exhibition (minutes)	24.63	10.13
Shortest time in exhibition (minutes)	7.00	0.10
Longest time in exhibition (minutes)	59.85	29.00

- As the table above shows, across our 40 trackings in *Moneyville 1*, the average length of time spent in the exhibition as a whole was nearly 25 minutes. The shortest stay we observed was 7 minutes and the longest was just under an hour. Indeed, the majority of visitors remained more than half an hour. On average, the visitors we observed spent about 20% of their time negotiating their way through the exhibition, selecting an exhibit, or waiting (i.e., they spent that amount of time not engaged with or focused on a particular exhibit).

[4] Again, the five thematic areas are: The Money Factory; The Bank; To Market, To Market; Dollars and Sense; and Global Trade.

Across our 25 trackings in *Moneyville 2*, the average length of time spent in the exhibition as a whole was just over ten minutes–less than half the time of the larger exhibition. The shortest stay we observed was less than a minute and the longest was 29 minutes.

Our sense is that the comparative sizes of the two exhibition versions only partially explain this difference. From what we observed, it appears there were more competing exhibits and attractions to distract visitors in Ft. Lauderdale than there were in Portland. Also, at OMSI, with the exhibition located in its own hall, the atmosphere was much more conducive to concentration, for example, the dominant sounds were the musical riff associated with the "Stock Market" exhibit going through another cycle and the sounds of clinking change at "Make a Million." At MODS, on the other hand, a loud air pressure exhibit and other noise from neighboring galleries largely drowned out the sounds of *Moneyville*. As a result, visitors to *Moneyville 1* at OMSI were perhaps more likely to give the exhibits attention than at MODS, thereby contributing to differences in hold times.

- As with any large exhibition, some exhibits attract more visitors than others. We analyzed our tracking data to get a sense of which *Moneyville* exhibits visitors were drawn to most. In *Moneyville 1* there were eight exhibits with which visitors interacted in 50% or more of our trackings. In the following table we compare the percentage of our tracked visitors who stopped at these same exhibits in *Moneyville 2*.

Popular Exhibits

	Moneyville 1 (n=40)	*Moneyville 2* (n=25)
Money Factory (entry)	50%	N/A
Making Money–Rubbing Station	62.5%	8%
Making Money–Videos	50%	N/A
History of Money–Money Mysteries	62.5%	36%
Faking Money–Real or Counterfeit	50%	52% (for all sides of Faking Money)
Faking Money–Glowing Threads	52.5%	0%
Money on the Move	57.5%	N/A
Kids Market	50%	24%

- Note that some other seemingly popular exhibits (with long hold times) do <u>not</u> appear on this list, for example, Face Value (25% of the visitors in *Moneyville 1* and 36% in *Moneyville 2*, used this exhibit). This trend appears to be a function of its location (in *Moneyville 1*) and the long hold time (and, therefore, wait time) of the exhibit.

- *Moneyville* has a number of components with relatively long hold times compared with many other exhibits we have evaluated–sometimes up to 10 minutes. Below is a list of individual exhibits in *Moneyville 1* whose average hold times were longer than 2 minutes, with comparative hold times in *Moneyville 2*:

Exhibits with Hold Times Over 2 Minutes

	Moneyville 1 (Avg. hold time in minutes)	*Moneyville 2* (Avg. hold time in minutes)
Quick Change	3.74	1.30
Face Value	3.59	3.78
Crane and Ship Dock	3.57	N/A
Stock Market	3.50	6.12
Material World	3.26	1.03
Better Buy	3.08	N/A
Money Factory–Videos	2.85	N/A
Moneyville Demonstration	2.80	N/A
Kids Market	2.70	1.05
Money Factory–Rubbing Station	2.69	0.06
Money on the Move	2.69	N/A
Make a Million	2.08	2.78

According to the tracking data, for a few exhibits the hold times were even longer for *Moneyville 2* than for *Moneyville 1*–Face Value, Stock Market, and Make a Million. The differences for Face Value are quite small. But the differences for the other two might be explained by the fact that these two exhibits were located towards the back of the hall, away from some of the competing noise. They were some of the few places in *Moneyville 2* where visitors could truly settle in and interact with an exhibit in a deeper way.

- Related to the flow patterns of the exhibition, and the popularity of many of the exhibits, we think there is an issue about availability of the individual components and, correspondingly, to the concepts they convey. Particularly in *Moneyville 1*, we noted on several occasions that visitors came in and saw that many of the key exhibits were in use; in this sense, our trackings only partly reflect real interest in the exhibitions. That is, if a given visitor is moving through the hall when many of the exhibits he or she is attracted to are in use, there is no way to "see" or record that interest. We think this happened in particular at the Lemonade Stand in *Moneyville 1* and at Face Value in both versions.[5]

[5] According to the Chicago Museum of Science and Industry's 1995 exhibit design guidelines for contractors, item 1.2.3e states: "In order to prevent long lines at popular exhibits with typical interaction times greater than 90 seconds, duplicate exhibits should be installed whenever possible." As Inverness Research suggested to OMSI staff in an earlier memo, this might be something to consider for *Moneyville*, given the number of individual exhibits with hold times greater than two minutes.

Overall Thoughts about the Flow and Navigation of the Exhibition

- Our sense is that people were staying for relatively long periods of time in *Moneyville 1* not because they had difficulty figuring out what to do, but rather because they were presented with a variety of exhibits that they found interesting and engaging. When they finished with one exhibit, they wanted to experience another, to the point that some of the visitors we tracked left the gallery only to return later in the day and stay for another significant block of time.

- As we noted above, we speculate that there are several reasons for the difference in overall length of visit between *Moneyville 1* and *Moneyville 2*. In *Moneyville 2* there were five Brain Teaser exhibits placed within the same gallery, and about half the visitors we tracked spent some time at those exhibits for an average of almost five minutes. Second, the very dynamic (and loud) air pressure exhibit in the adjacent gallery drew a lot of children away from *Moneyville 2*. Third, *Moneyville 2* is a smaller exhibit and there is less to do there.

- We heard few comments from visitors about the "city-ness" of *Moneyville*. While we did not ask people about the city metaphor explicitly, we think that, because money is so much a part of peoples' everyday lives and so obviously inter-twined with the activities presented in the exhibition, perhaps the city façade faded to the background for visitors or was subliminal. In *Moneyville 2*, the theater-like city setting was even more reduced than in the larger version; however, visitors still came away with many of the same big ideas for the exhibition as in *Moneyville 1*.

Durability and Maintenance

Moneyville includes a range of *types* of exhibits: from computer-based interactives, to role playing activities, to wooden puzzles, to opportunities for artistic expression with standard art materials (crayons and paper). Some of these exhibits appear to be quite durable and were working well when we observed them at OMSI as well as at MODS (e.g., the Making Money rubbing station, the Quick Change and Lemonade Stand computer interactives, and the Million Bucks Cube). Other exhibits were less durable or had important pieces missing; we note these issues below:

- Balancing Your Budget continues not to work as well as intended. This has been the case since we observed visitors using the earliest prototypes. The balancing mechanism worked intermittently at best in both of the museums, and visitors had a quite difficult time actually being able to make it reach a balanced position.

As one little boy explained, "I'm trying to balance these blocks, but they don't balance. It always tips." In a discussion with MODS exhibits staff, we were told that they had to modify the exhibit: "We put that Plexiglas case on the moneybag because kids thought real money was in there…they would tear into it!"

- Also in Balance Your Budget, the blocks were chipped and worn, and looked to us to be "tired." MODS staff suggested, "The different (Balancing Your Budget) blocks could have been tethered–we find those blocks everywhere [else in the museum] and they start breaking."

- Both in the Kids Market and especially in the Kids Bank, the plastic coins provided are critical to conveying the idea of the exhibits. At OMSI, these coins were plentiful. However, at MODS, there were very few coins available for the buying and selling activities. Dimes especially were in short supply. Another instance of missing pieces occurred at the Kids Bank where, throughout our visit, one of the puzzles was missing all of its pieces. In an interview with exhibit staff at MODS, we were told that this is an ongoing issue with this exhibition–that the coins and puzzle pieces are found in other areas of the museum, and that it takes constant monitoring to replace them.

- Aside from the issues alluded to above around specific exhibits, our overall sense is that the majority of exhibits contained in *Moneyville 2* are working well, traveling successfully, and proving to withstand months of regular visitor use–and occasional abuse.

Findings Related to Project Goals

Background

In their original proposal submitted to the National Science Foundation, OMSI staff articulated four specific goals for their completed *Moneyville* exhibition:

1. *to provide engaging experiences based on real-life contexts in which visitors use math concepts and skills and gain an increased awareness of the importance of math in daily life*
2. *to present basic economics concepts in ways designed to increase visitors' economic literacy and empower them to make more informed economic decisions*
3. *to promote family learning about math and economics*
4. *to help K - 8 teachers and students meet math curriculum goals by creating exhibits and ancillary materials based on national math standards*

In this section, we discuss each goal individually–listing strategies that the OMSI development team used to achieve these goals, addressing questions that the OMSI staff was interested in, and providing evaluation data indicating the extent to which the *Moneyville* project has accomplished the given goal.

GOAL #1: *To provide engaging experiences based on real-life contexts in which visitors use math concepts and skills and gain an increased awareness of the importance of math in daily life*

> *I liked that one where you start with doubling a penny and keep going like that everyday. You get to a $1 million in less than a month! That was a real ah-hah for me!*
>
> –13-year-old girl

According to OMSI staff, their strategies for achieving this first goal began with the playful design and immersive urban environment. Through simulation games and opportunities for role-playing in contexts that paralleled daily life (bank, market, shops, etc.), they attempted to embed mathematics in activities that were based on real-life experiences. The OMSI staff selected five math strands to focus on, common threads that are woven across the exhibition, based on the NCTM Standards for grades K–8 (see Goal #4 for more detail). They also developed "Math at Work" labels for each exhibit to assist adult visitors in recognizing these strands. Some of the questions that the OMSI staff hoped the evaluation team could help them answer included the following:

Were the activities engaging?
Do visitors recognize the relationship of exhibit activities to real-life experiences?
Do visitors use math concepts and skills in the activities?
Do visitors gain an awareness of the importance of math in daily life?
What factors contributed to these findings?

- For the most part, visitors are clearly finding the *Moneyville* activities engaging and reflective of real-life experiences. However, the extent to which they recognize and make use of mathematical concepts and strategies varies a great deal from visitor to visitor, and from exhibit to exhibit. In the eyes of most visitors, this exhibition is simply and solely about money and economics. The explicit connection to mathematics is not one that they readily make. And while we did observe visitors using a number of math concepts and skills as they interacted with the individual activities, much of the math that visitors use as they make their way through the exhibition is so deeply embedded that it seems to occur at an almost subconscious level. As a result, only rarely do visitors see math as the salient part of their experience. Because of the complexities connected to teasing out the mathematics that visitors use and engage with in *Moneyville*, we have devoted a separate section to this topic in Appendix A.

- While visitors do not always recognize the mathematics that they are doing or using, it is clearly present throughout the exhibition. Visitors can practice counting and making coin equivalencies in the banking and market areas. They have an opportunity to recognize patterns and trends in a variety of contexts from Making Money to the Stock Market. They can estimate and make predictions at exhibits like the Real Cost of Credit and Lemonade Stand and Inflation Station. They practice their cashier skills at Quick Change. Visitors can work with large numbers as they contemplate the power of exponential growth and compound interest in exhibits like Making a Million or at the Million Buck Cube. All of these exhibits involve important mathematical ideas. Still, across both versions of the exhibition, the opportunities for visitors to deeply consider mathematical ideas or wrestle with difficult concepts are few and far between. Instead, economics and money serves as the leading edge in most activities and the mathematics remain fairly hidden, albeit valuable.

- The role of the computer interface as a tool for enhancing mathematical understanding is also a bit tricky. Clearly, having the computer make calculations and graph data enables visitors to focus on the ideas in a way that they could not and would not otherwise. However, if the computer does all the work without additional visitor interaction or input, then there is the risk of it actually short-circuiting some of the thinking that visitors might engage in. For example, in Lemonade Stand, school-age visitors could not make sense of the profit and loss graphs because they were not clear about where the graphs were

coming from–they had not truly encountered the mathematics used to create them. Some visitors told us that they would like to be able to do more math in the exhibit. As one teenage girl put it, "There needs to be more that you can figure out and less facts, less to just look at or they tell you what you're supposed to notice."

In our judgment, OMSI developers generally underestimated the mathematics that some visitors might have been willing to grapple with, with respect to solving problems themselves and making their own conjectures, perhaps to ensure that others were not put off or intimidated.

- We think there are several exhibits that could be considered to be "teaching exhibits." By this we mean exhibits whose potential is best revealed when they are used by a knowledgeable explainer or teacher to clarify complex math ideas not available to the average visitor. Examples include: Kids Market, Kids Bank, Get Real, Million Buck Cube, Lemonade Stand, Make a Million, Stock Market, and Quick Change. We have generally seen parents and older siblings playing this role, museum staff much less so. However, these are exhibits around which floor staff, as well as visiting teachers, could potentially be trained in order for them to be better used to their full potential.

GOAL #2: *To present basic economics concepts in ways designed to increase visitors' economic literacy and empower them to make more informed economic decisions*

> *As far as importance in life, this topic is more important than anything else in the museum. If my boys just learned well the ideas in the lemonade exhibit, that would be good.*
>
> –home-school father of two boys, 7 and 9 years old

In terms of discipline-based content, the strength of both versions of the *Moneyville* exhibition resides here. Early on, OMSI staff chose to use Beverly Serrell's strategy of focusing on one "big idea"[6]–in this case, "*understanding and making economic choices with the power of math*." They made repeated use of the "choices" vocabulary in copy panels and tried to model Serrell's "invitation" in exhibit copy to cue visitors to the main idea. In addition, the five thematic areas are organized according to basic economics concepts as defined by NCEE Economics Standards. Within each thematic area, the intention was to present similar and related economics topics at different conceptual levels and in contexts related to daily life. For example, in To Market, To Market, young visitors can role-play buying and selling the Kids Market; older school-age visitors can practice the cashier skills associated with buying and selling at Quick Change; and still older

[6] Beverly Serrell, *Exhibit Labels: An Interpretive Approach* (Walnut Creek: Altamira Press, 1996)

visitors can buy and sell stock at the "Stock Market." Overall, the OMSI staff had questions about the extent to which visitors would:

- recognize and understand the "big idea" of *Moneyville*
- find the economics concepts accessible
- gain an understanding of basic economic concepts

- Across both versions of the exhibition, there are many opportunities for visitors to engage with activities explicitly focused on developing economic literacy. The activities provide a context for applying mathematical ideas. For example, visitors encounter concepts such as how compound interest can be to their benefit (Make a Million) or to their detriment (Real Cost of Credit). Below are some of the things we heard from visitors that reflect some of the economics messages they gleaned from the exhibitions.

  – At Balancing Your Budget, a 7th-grade girl talked extensively about choices:
    "I need housing, transportation, groceries, and education. (My kids will not be stupid.) I have everything I need, except for vacation and eating out. The point is, if you do too many fun things, you won't have enough money left over for what you need."
  – A second-grader said, "I learned that there's different money for every country."
  – At the Stock Market an 8-year-old boy tells us: "The first time I played, I didn't get that you need to sell the stock, too. So I just kept buying. But when you sell your stock that's really how you make your money."
  – An adult female said: "This is all about money and the economy–from local through global."
  – A teenage boy at Get Real, "This helps me practice for survival out there. I thought a high-paying job would be good, but it's not that simple. With the high pay comes bigger expenses."

  These quotes help illustrate the kinds of economics learnings and insights that visitors of all ages experience while interacting with both versions of the *Moneyville* exhibition.

- Visitors have the opportunity to enhance their own economic literacy in nearly every interactive: the Making Money video shows how money is made, counterfeiting and more detail about how money is uniquely identified is explored in Faking It, and the practical aspects of economic literacy are explored in Get Real and Real Cost of Credit. The international side of economics and import/export concepts are accessible in the Global Trade part of *Moneyville*.

- Visitors are picking up strong messages about the importance of spending and saving wisely and about the consequences of making various choices.

  – Man at Cost of Credit: "This is to deter kids from getting credit cards–that's good because I think [credit cards] are evil."
  – Mother of three middle-school kids: "This exhibit[ion] is about money and what it's used for. [Get Real] is the most useful thing I've ever seen for slightly older kids. Their dad is out of work."
  – Girl, 8 years old: "It's about money and how you should save it."

- When we asked children about what they had learned in the exhibition, most of their answers related to economic literacy rather than learning about mathematics or the power of math as a tool. We heard things like: "I never knew how they made money" or "The counterfeiting one [was new]…how they do that."

- We asked school-age visitors if what they were doing in *Moneyville* was the same or different as what they were doing in school; they answered that it was more or less the same and used economic concepts in their examples. "We just studied the stock market…." "We learned about this [history of money] in school." However, a number of children pointed out that it was a little different, and, when they did so, their examples were more directly related to math. For example, an 11-year-old boy at the Quick Change exhibit said, "We do a lot with money in school, but this is more fun–and more challenging." Another little girl said, "This is really different from what we do at my school. All we do with numbers is add, subtract, multiply, and divide." This is an indication to us that *Moneyville* has the potential of and sometimes succeeds in providing opportunities for contextualized mathematics learning that young visitors are not experiencing in school.

- Our sense is that visitors are definitely getting the message that *Moneyville* is about making economic choices and the trade-offs involved with such decisions–saving versus spending, helping a friend versus paying off your credit card this month, driving a nice car versus taking public transportation. As one seven-year-old girl explained to us:

  > *"It's so kids can see how hard it is to choose and to see how much money their parents are actually spending just to get them things, like something to eat."*

  However, as visitors make these choices in the exhibition, there are places where the power of mathematics as a decision-making tool could be made more

apparent. For example, in Balancing Your Budget, if the scale were more sensitive and the blocks more carefully calibrated with respect to their respective sizes and weights, this relationship might become clearer. In both versions of this exhibit, visitors guess at the comparative weights of the blocks and often must place nearly all of them on one side of the scale before making it tip to "over budget."

- Ultimately, very few visitors we interviewed internalized both halves of *Moneyville*'s "big idea." For the majority, *Moneyville* was a mathematics exhibition only to the extent that visitors need math skills to interpret economic messages and make economic decisions. Given the target age and topic of the exhibit, we still feel that there are missed opportunities in *Moneyville* when it comes to making mathematics vivid and powerful in its own right for visitors.

GOAL #3: *To promote family learning about math and economics*

> *We've been talking about so many important things there, things like budgets and 18% credit cards and the stock market–things that I don't think we'd be talking about otherwise. I think it's terrific.*
>
> –grandmother with 12-year-old grandson

Moneyville is designed to appeal not only to a wide range of ages but also to families who might interact with the exhibits as a group. Some of the strategies that OMSI staff used to encourage family learning include grouping activities for different age groups within each thematic area (for example, Kids Market and Stock Market are located side-by-side in *Moneyville 1*) and designing multi-user activities and activities that encourage group interactions. OMSI also worked with the "family friendly" criteria laid out in the PISEC (Philadelphia/Camden Informal Science Education Collaborative) report on family learning in museums[7] and attempted to apply these to individual *Moneyville* exhibits as well as to the exhibition as a whole. The PISEC criteria are as follows:

Multi-sided:	family can cluster around exhibit
Multi-user:	interaction allows for several sets of hands (or bodies)
Accessible:	comfortably used by children and adults
Multi-outcome:	observation and interaction are sufficiently complex to foster group discussion
Multi-modal:	appeals to different learning styles and levels of knowledge
Readable:	text is arranged in easily-understood segments
Relevant:	provides cognitive links to visitors' existing knowledge and experience

[7] Minda Borun et al., *Family Learning in Museums: The PISEC Perspective* (Philadelphia: PISEC/The Franklin Institute, 1998)

Finally, OMSI developers attempted to set activities in contexts related to visitors' lives, making it more likely they would make some sort of personal connection to the content.

- In our trackings as well as exhibit-focused observations and interviews, we documented many examples of "family learning," or at least of family interaction and engagement. Parents and grandparents were having their children slow down and look closely at exhibits; the children listened and responded to parents reading the labels: "hey, let's look at this; let's play this; let's see what this is about." The parents seem to be able, in this exhibition, to focus their children's attention and to help them see things that they might not on their own.

- As examples, at Lemonade Stand, we saw older kids and adults showing the younger ones how to look at the variables involved in running their business. We heard one little girl, who had recently sold lemonade on their corner, say to her mother: "You know what? I need to start charging more money for my lemonade!" At Quick Change, we heard older siblings helping younger siblings think about how to make change: "Remember, you want to make sure that the change and what they're buying add up to the money they're giving you." At Stock Market, we observed a grandfather and grandson working together to develop their portfolio. And at Balancing Your Budget, we heard multiple discussions comparing the cube sizes, weights, their effect when placed on the scale, and the extent to which they reflect the budget of the visiting family. Based on our observations we can safely say that the range and quantity of opportunities that *Moneyville* presents for family learning is one of the greatest strengths of this exhibition.

- We observed that some of the exhibit components provided the opportunity for parents to become aware of their child's skill level. For example, a mother of a 2nd grade daughter using Quick Change said: "I can see I'll need to spend more time helping her with subtracting."

- Both the physical and intellectual structures in this exhibition seem, overall, to encourage family interactions and inter-generation learning. Not only does the topic of economics seem to be inherently interesting to visitors of many ages, but also the clustering of exhibits within different areas provides visitors of a range of ages something to do.

  For example, in the Making Money thematic area, we saw young children engaged at the Rubbing Station while parents and older children watched the videos about making money. And at individual components, such as the 3-sided Faking Money station, the children became excited about seeing the money close-up, while the parents read the labels and explained what the kids were seeing.

A similar phenomenon occurred in the Shipping Dock area, where older children and adults could take a more careful look at Material World, Better Buy, and the view finders while little children played within view. Finally, in both the Kids Bank and the Kids Market, some parents felt compelled to role-play along with their children in the activities of the market.

- We noted that some young children and parents of younger children felt this was "for older kids" while those "older kids" and some adults we interviewed thought it was for younger children. One nine-year-old girl said, "these exhibits are for everybody." There are two messages here. The first is that when designers are trying to appeal to such a broad audience, visitors are going to encounter exhibits that are too young for them, too old for them, and just right. The second is that *Moneyville* is actually targeting grades K–8, so that the 9-year-old is right in the center of the age bracket, and from her vantage point, the exhibition is probably for "everybody."

- Further opportunities for family learning might be possible if the design of the exhibition incorporated customized seating that would accommodate multiple users. For example, most of the computer interactives (Make a Million, Get Real, Lemonade Stand, and Quick Change) had only one and sometimes two stools in front of them. As a result, when families tried to use the exhibits, they were jockeying for a seat, sitting on each other's laps, kneeling, or standing.

  Perhaps some sort of seating that does not preclude wheelchair accessibility, while also providing a comfortable place for multiple family members, could be included. This would also help at the Making Money videos in *Moneyville 1*– several times we saw people wanting to watch together, but only one could sit while the other had to stand. We wonder if some sort of mini-theater seating with multiple benches would make a difference here.

- Although we don't have specific data on this for *Moneyville*, we have seen in exhibitions like this–where children stay for a long time–that having a lot of seating for adults is key to the duration of a family's stay, and perhaps to their ultimate usage of more of the exhibits. The built-in seats at the Shipping Dock exhibit in *Moneyville 1* seem to work well, as they include seats of multiple heights and are positioned so that adults can observe their children while sitting down.

- After completing our work with both the *Moneyville 1* and *Moneyville 2* exhibitions, our evaluation team used the PISEC criteria to create a "family learning" composite rating for each of the individual *Moneyville* exhibits as well as the five thematic areas. Each of the PISEC criteria served as an indicator for

the composite. The individual indicators were scored by members of our evaluation team, then summed, and averaged. These sums provided the basis for the overall family learning ratings. The ratings are based on a 5-point scale where 1 is "not at all reflective of PISEC criteria" and 5 is "highly reflective of PISEC criteria." The results are shown in the table below (note exhibits in bold are those contained in both *Moneyville 1* and *Moneyville 2*).

Family Learning Ratings by Area and Exhibit

DOLLARS AND SENSE	**4**	**GLOBAL TRADE**	**5**
Balancing Your Budget	4	*Money from Around the World*	4
Get Real	4	***From Around the World***	4
Inflation Station	4	***Material World***	5
The Real Cost of Credit	3	*The Shirt Off Your Back*	4
The Better Buy	3	*The Shipping Dock*	4
MONEY FACTORY	**4**	**THE BANK**	**4**
Money Factory Entry	3	***Million Dollars***	5
Making Money (Rubbing Station)	4	*Money on the Move*	3
Face Value	3	***Make a Million***	4
Anti-Counterfeiting Lab	4	***Kids Bank Teller Window***	4
How Money is Made (videos)	3	***Kids Bank Puzzles***	3
History of Money	4		
Money Mysteries	4	**TO MARKET, TO MARKET**	**5**
Moneyworks Park	3	***Stock Market***	5
Barterville	4	***Lemonade Stand***	4
		Quick Change	4
		Kids Market	5

Overall, the PISEC composite ratings are further evidence for the success of the *Moneyville* exhibition in providing valuable learning opportunities for family groups.

GOAL #4: *To help K-8 teachers and students meet math curriculum goals by creating exhibits and ancillary materials based on national math standards*

> *A lot of it is a little over my son's head, but I'm a 3rd grade teacher and there's some really good stuff here that I could do with my students.*
>
> –mother of a toddler

OMSI staff used the math standards developed by the National Council of Teachers of Mathematics (NCTM) as the basis for selecting their mathematics strands. Through the use of "Math at Work" labels, they helped K–8 teachers recognize the strands associated

with each exhibit. In addition, the Teachers' Guide produced for *Moneyville* contains an overview document that makes even more readily apparent the mathematics contained in the exhibition and the extent to which it can help teachers and students meet larger curricular goals. Below is a list of the ten NCTM Standards for grades K–8 and the five *Moneyville* math strands that resulted from OMSI staff's synthesis of these ideas for the purposes of the exhibition.

Due to the design of the external evaluation, the Inverness Research team collected much less data related specifically to this goal than we did for the other three. For example, we did not conduct teacher interviews, and–although we did observe and interact with some school groups–we did not have the opportunity to work in great depth with them. However, we did review the *Moneyville* Teachers Guide for content and usefulness and found it to be of very high quality. In addition, our team has a strong working knowledge of the NCTM Standards, and we have used the standards as an overlay for analyzing all of the exhibits that comprised *Moneyville* at various stages of the external evaluation.

NCTM Standards	***Moneyville* Math Strands**
Numbers & Operations	Understanding Numbers
Algebra	Finding Patterns
Geometry	
Measurement	Measuring & Comparing
Data Analysis & Probability	Interpreting Data
Problem Solving	Thinking & Reasoning
Reasoning & Proof	
Connections	
Communication	
Representation	

The first five NCTM Standards describe goals with respect to mathematical content. The second five present process goals. Together, the ten standards represent the basic skills and understanding that NCTM believes students need as effective citizens of the 21st century. OMSI's strands are primarily a distilled version of four NCTM content standards (Geometry is omitted) and two NCTM process standards (Problem Solving and Reasoning & Proof). OMSI chose to de-emphasize the Algebra standard but includes it with the Finding Patterns strand. Perhaps most importantly, the entire exhibit is highly reflective of the NCTM Connections standard–which calls for connecting mathematics to other related curricular areas.

The table below lists the exhibits contained in *Moneyville* and the math strands that OMSI associates with each one. An examination of the distribution of the strands across the exhibits indicates that the Money Factory was the area of the exhibition where OMSI staff anticipated the least mathematics would occur; our observational data confirms

this expectation. The majority of exhibits were designed to incorporate multiple math strands. The only exhibit that involved four strands was Kids Market, and, according to what we observed, these strands are generally only accessible to the young visitor who has an adult companion with whom they are working closely. About 40% of the exhibits involve three strands and another 20% involve two. It is worth noting that, according to OMSI designers, the Finding Patterns strand is represented in almost one-third of the exhibits, Thinking & Reasoning in about 60%, Understanding Numbers in about 40%, Measuring & Comparing in about 25%, and Interpreting Data in about 25%. More than one-fifth of all the exhibits did not have any math strands associated with them.

INDIVIDUAL *MONEYVILLE* EXHIBITS AND THEIR MATH STRANDS

Exhibits	*FP**	*TR*	*UN*	*MC*	*ID*
Making Money	x				
Face Value					
Anti-Counterfeiting Lab		x			
Barterville		x			
History of Money					
Money Mysteries					
Moneyworks Park					
How Money is Made					
Million Dollars		x	x	x	
Money on the Move					
Make a Million		x	x	x	
Kids Bank (incl. puzzles)		x	x	x	
Stock Market		x	x		x
Lemonade Stand		x	x		x
Quick Change	x		x		
Kids Market	x	x	x	x	
Balancing Your Budget	x	x		x	
Get Real		x	x		
Inflation Station	x		x		x
The Real Cost of Credit	x				x
The Better Buy	x	x	x		
Money from Around the World		x		x	x
From Around the World		x			
Material World		x		x	x
The Shirt Off Your Back		x			x
The Shipping Dock	x	x			

*FP=Finding Patterns, TR=Thinking & Reasoning, UN=Understanding Numbers, MC=Measuring & Comparing, and ID=Interpreting Data

In our final analysis, we feel that the vast majority (four out of five) of the *Moneyville* math strands are indeed grounded in and reflective of the NCTM Standards. The fifth,

Thinking & Reasoning, has proven more problematic for us. Thinking & Reasoning appears to combine the NCTM Standards for Problem Solving and Reasoning & Proof. However, the way it has been applied to some *Moneyville* exhibits relates to these standards quite loosely. For example, in Anti-Counterfeiting Lab and From Around the World, visitors clearly have an opportunity to think and reason as they examine currency or piece together facts to answer the questions at hand. However, this sort of thinking and reasoning is generally not the kind of rigorous and analytic thinking and reasoning associated with the two NCTM Standards upon which the math strand is based. Our sense is that because of the colloquial meaning of Thinking & Reasoning, it became a bit of a "catch all" math strand.

Lessons Learned

In proposing *Moneyville*, OMSI took on an ambitious project. The development team wanted to create an exhibition full of rich opportunities for visitors to interact with mathematics–a subject that traditionally has been at least intimidating and, in some cases, a major academic barrier for American adults and school children alike. And to bring this topic into a museum setting where people pay to have fun and relax in a social manner, creating exhibits that enable visitors to interact with mathematics in a non-threatening and seemingly non-academic way, was a tall order. The use of money and economics to invite people into this subject proved to be a creative and successful approach–*Moneyville* has proven to be a physically and conceptually attractive exhibition. And overall, the visitors we encountered in both *Moneyville 1* and *Moneyville 2* said that they had enjoyed themselves and left with positive feelings about the experience.

As we conclude our work with *Moneyville* and reflect on how the larger field might benefit from OMSI's efforts in developing this exhibition, we offer some broad lessons learned. We have organized this discussion according to four domains: topical relevance, math learning, family learning, and overall engagement.

- Topical Relevance: Overall, museum visitors of all ages very much appreciated the concepts presented in *Moneyville.* Money and economics are important and relevant subjects for children as well as adults in their daily lives. Parents especially want their children to understand the basics of personal finance. Moreover, the values of saving, using credit wisely, and budgeting that the exhibition reinforces are consistent with those of the adult visitors we encountered in the course of our evaluation work. One adult leader of a church group who visited *Moneyville* in Ft. Lauderdale said: "This exhibit is teaching them about their future and what to do to survive."

- Math Learning: The OMSI developers made a decision to embed the mathematics of their exhibit in compelling applications–to the point that visitors were often doing math without realizing it. We understand the logic behind this choice and recognize that it may be an effective strategy for getting reluctant visitors to interact with a difficult subject. Still, we need to point out that something very valuable may be lost when the mathematics is not made compelling for its own sake. If visitors do not recognize that they are doing mathematics, then there is little opportunity to influence their attitudes about math or their perceptions of the discipline. It becomes impossible for them to leave the exhibition thinking, "Hey, that was fun, and I was doing math." The truth is that the math can be robust in its own right

and highly attractive to visitors. In Ft. Lauderdale, we observed a very memorable example of this when a church group came to visit the museum, as the following vignette describes:

> While the youngsters and a few of their chaperones interacted with the *Moneyville* exhibits, a group of six adults explored the OMSI Brain Teasers. One involves the numbers 1 to 11–the task is to organize them such that one number is in the center of a circle formed by the other ten numbers and every 3-way sum adds up to the same amount. The adults worked on this puzzle for at least 20 minutes–making conjectures, debating about strategies, and ultimately coming up with a method that they thought might work for other puzzles. It was arguably the richest mathematical discussion we encountered on our Florida site visit. And it was entirely by accident.

For us, the lesson is that when the context provides the hook for the mathematics, there needs to be an opportunity for making meaning–that is, for making the idea explicit so that visitors who are interested can recognize and experience the math more deeply. As an example, the concept of compound interest appears in multiple places in both versions of *Moneyville*, but rarely do visitors have an opportunity to consider how the concept really works and why the money grows. We realize that providing such opportunities is quite a challenge, albeit a worthy one.

- Family learning: The topic of money and economics is an unusual one for a science museum. However, unlike many other exhibitions found in science museums, visiting adults bring considerable working knowledge of the topic at hand in *Moneyville*. This adult expertise and prior experience encourages strong family interactions that might not happen were the topic more specialized. It follows that opportunities for family learning are frequent in *Moneyville 1* and *Moneyville 2*, occurring throughout the exhibition.

  Still, if family learning is truly a priority for an exhibition, then putting extra effort into designing creative seating options is also a must. A family of four, for example, will be hard pressed to effectively share a computer screen with a single stool and have a high quality experience. Instead, seating needs to encourage and support the kind of group interaction that the exhibition is trying to achieve. Unfortunately, with respect to family learning, seating remains an issue in both versions of *Moneyville*, but especially *Moneyville 2*. As a result, visitors probably do not spend as much time as they might with seating that invites two or more visitors to work together. We did see telling examples of visitors doing their best to work together–an adult was sitting on her partner's lap in order to use Make A Million–and a young visitor climbed up onto the Lemonade Stand façade in order to participate in the activity with his sister and parents. In our experience, this is an example of one of those

seemingly small details that can have a sizeable impact on the visitor experience.

- Overall Engagement at *Moneyville 1* and *Moneyville 2*: Although visitors to both versions of the exhibitions were able to take away similar overarching messages, the data suggest that *Moneyville 2* is not as strong as *Moneyville 1* in terms of hold times and overall engagement with the exhibits. As mentioned earlier in this report, there are several factors that likely contributed to this phenomenon (and which OMSI staff have little control over). In particular, the layout in the gallery led to the dispersing of exhibits that were intended to be closer together, as did the inclusion of non-*Moneyville* exhibits in the same gallery.[8] The message here is simply a reminder of what a difference location and layout can make, particularly when visitors are being presented with ideas and activities that require their focused attention for more than a few seconds. Creating an environment that is conducive to concentration makes all the difference in a content-rich exhibition–something to consider as *Moneyville* continues to travel.

We look forward to encountering *Moneyville* in the months and years ahead as we conduct work with our other museum-based projects. While not without issue, OMSI has succeeded in creating a fun and memorable experience for the visiting public, particularly families. Even if the mathematics is not as apparent as it might be, the overriding *Moneyville* message is clear and it is a powerful one: economic choices can have big impacts on the quality of your life, and mathematics is one of the tools that you need to make those choices.

[8] This lesson suggests that when the exhibition travels, that literature intended for renting museums include a strong recommendation to keep certain components together whenever possible.

Appendices

Appendix A–Analysis of Mathematics Learning

Appendix B–Exhibit Descriptions

Appendix C–Layout of *Moneyville 1* in Portland, Oregon (Summer 2003)

Appendix D–Layout of *Moneyville 2* in Ft. Lauderdale, Florida (Fall 2004)

APPENDIX A – Analysis of Mathematics Learning

Design of the Math-Focused Work

The developers of *Moneyville* crafted a framework for considering mathematics in the exhibition which goes beyond the five strands. It includes perceptions of mathematics as a discipline, for example, the idea that "mathematics is more than arithmetic." The *Moneyville* developers also wanted visitors to see math as useful and embedded in many everyday activities. They want visitors to see mathematical problem solving as open-ended, with multiple strategies and multiple outcomes or representations of answers.

Following our study of *Moneyville 1* and the written feedback we provided to OMSI staff, the *Moneyville* project leaders were interested in getting more information about the kind of mathematics learning that was or was not happening for visitors. It was decided that, as part of the *Moneyville 2* study, members of the evaluation team would focus on a subset of key exhibits to examine more closely how visitors were engaging with mathematics concepts and skills. The Inverness Research team collaborated with OMSI staff to select the exhibits. The final list included: Lemonade Stand, Get Real, Quick Change, Balancing Your Budget, and Kids Bank. At each of these exhibits, researchers spent considerable time experimenting with the exhibits themselves, making naturalistic observations, and conducting mediated interviews, in which visitors actually talked researchers through their interactions with the exhibit. In this section, we consider each of the exhibits individually and discuss the following:

- the extent to which each exhibit provides an opportunity for mathematics learning according to its associated math strands
- the evidence that visitors are taking advantage of these opportunities
- researcher reflections

Lemonade Stand

Math Learning Opportunities

Understanding Numbers: Visitors can calculate the cost per glass of making lemonade based on the given cost per pitcher and the fact that there are 10 cups in each pitcher. Visitors see the number of cups sold and can estimate how much profit they have made. They can check these estimates against graphs provided by the computer interface.

Interpreting Data: Visitors make choices about how much lemonade to make and how much to charge per cup based on information from a variety of sources, including newspaper headlines and weather reports. They can also use sales data from previous days to make current pricing decisions.

Thinking & Reasoning: Visitors incorporate weather and news reports, tips of the day, and information about the cost of making lemonade into their decisions about how much lemonade to make and how much to charge per cup. At the end of each day or

game cycle, they have additional information to weigh into their next decision. Taking in information from a variety of sources, prioritizing it, and making choices accordingly provides many opportunities for thinking and reasoning.

Visitors' Mathematical Experiences

This is an exhibit that draws visitors, especially young children. They like the "game" aspect of the exhibit and are attracted to the life-like casework. If the children have an adult with them, someone who can help them recognize and interpret all of the information they are given, Lemonade Stand can provide a rich opportunity for family learning. We have seen family groups stay as long as 10+ minutes at this single exhibit. However, many younger visitors, including middle-school students, miss important details, such as the cost of making a pitcher of lemonade.

Whether or not visitors see and make use of this fact is critical to the richness of their mathematical experience. For example, we saw one 8th grade girl advise her friend, "Wait…we have to charge more than that or we'll be losing money on every cup." However, in the same school group, two students were baffled when they sold 90 cups of lemonade and lost $4.50–the lemonade cost $2.00 per pitcher and they had only charged 15 cents per cup.

We saw a number of young, unaccompanied visitors use Lemonade like a game where the goal is to "sell out" of lemonade. Once they saw the "Sold Out" sign, acting as if they had won, they would press "start over" rather than "continue." If visitors do this, then they never see the graph of their earnings and losses and can leave Lemonade Stand with serious misconceptions such as this one, spoken by a 3rd grade girl: "Basically, you want to charge a low price, so you sell a lot and make a lot of money."

Researcher Reflection

Lemonade Stand is a visitor favorite within *Moneyville* for a variety of reasons–not the least of which is its real-life context. There is great potential for rich mathematical discussions here, for example, when visitors sell lots of lemonade, realize that they have actually lost money, and try to figure out why. However, it seems that quite often, visitors do not see the price of a pitcher of lemonade until after their first day of sales–sometimes not until after a couple of days in the simulation. When they miss this information, it is difficult to interpret their results. Under these circumstances, we have seen people simply get frustrated and walk away. On the whole we can say that only a small minority of the visitors we observed and interviewed became engaged in a way that would allow them to achieve the kinds of rich mathematical experiences envisioned by the designers. It is difficult for most visitors, especially children, to sit down and fairly immediately make use of all the information in front of them. As a result, they use the newspaper to decide how many pitchers to make, set what seems

like a reasonable price per cup regardless of what it cost to make a pitcher, watch what happens for a couple of rounds, and make adjustments accordingly. If they skip the graphs, or never look at them, some of the most important mathematics in this exhibit is lost.

(On a non-math note, we want to acknowledge the impressive durability of this exhibit. After six months on the road, with children climbing on it and teenagers grabbing at the lemons to see if they are real, it is holding up beautifully. And the appealing look continues to persuade visitors to sit down and at least potentially encounter some valuable mathematics.)

Get Real

Math Opportunities

Understanding Numbers: Although the computer makes all of the calculations, visitors are continuously adding and deducting values as they proceed through the simulation. They can follow how expenses and savings total to monthly income and make estimations for future choices.

Thinking & Reasoning: Visitors make choices about spending their money according to given constraints and goals associated with their character. When unexpected expenses arise, they must choose to pay for them with either savings or credit.

Finding Patterns: While not a stated strand in the OMSI literature, if visitors take the time to sit through a full year cycle, as the year goes on, they have the opportunity to make choices according to patterns in the simulation.

Visitor Experience

Visitors seem to quickly understand that it is a better idea to pay cash when you can. Much of the math that visitors engage with has to do with seeing their balances–savings and credit charges–making sense of them, and making choices accordingly. Visitors we observed did try to pay down their credit card debt.

Those who create their own characters can learn some valuable lessons about setting non-financial goals and some of the costs associated with various professions–for example, one 6th grade boy who decided to be a lawyer went broke due to the high cost of his expenses: student loans, clothing for the courtroom, etc. However, most visitors choose from the characters that are provided. And many failed to see the goals aspect of the simulation.

Visitors do see and make use of the phone, calendar, and email information. They tend not to make many changes to their housing and car options. And most do not play a full year simulation. Some felt that the forced life choices were not always realistic–for example, a young lawyer probably would not spend $3000 on clothes if he did not have the money, and a teacher could use the computer at school rather than buying a new one.

We encountered some younger visitors who thought that their finance charge was a credit card purchase. But for the most part, even school-age visitors seemed to be internalizing the economic messages of the exhibit. As with Lemonade Stand, visitors like the game aspect of the exhibit and the real-life context. We heard comments like, "OK, made it through another month. Now what's going to happen?"

Researcher Reflection

This exhibit is a favorite among high school age visitors and volunteers, many of whom would sit down and play with it when the exhibition was quiet. From our standpoint, it is arguably the best example of visitors *"making economic choices with the power of math."* Visitors are getting a strong savings message and the importance of distinguishing between luxuries and necessities. For this reason, under ideal conditions, it would be helpful to have Get Real placed near Balancing Your Budget.

While it appears that the overall design intention for Get Real is realized by visitors who sit down and use the interactive for a few minutes, there is some important math, mostly connected to credit cards and finance charges, that is often missed due to the complexity of the simulation and the extent to which the computer completes all calculations. In order for visitors to truly experience the math here they must examine very carefully the statements and accounting information that appears on screen. Otherwise, the money can come and go from month to month without the visitor seeing how his or her choices might be affecting the monthly bottom line. There is potential for visitors to consider how spending reflects values and goals, but this seems to happen rarely.

Quick Change

Math Opportunities

Understanding Numbers: Visitors have an opportunity to combine currency in different ways and to recognize equivalencies as they try to make change. They can use a variety of combinations–within the constraints of the simulation; for example, the visitor cannot use more than 10 pennies to make change. Visitors can also make use of subtraction strategies–including the traditional algorithm, counting up, and using landmark numbers (also referred to as "going to something you know").

Finding Patterns: School-age visitors devise strategies according to what is in the "ones" digit place of the price of the item and the amount of payment. For example, they realize that if the price of an item ends in 5 or 0, they will not need to use pennies in order to make change.

Visitor Experience

The exhibit appeals to a much older visitor than many might anticipate. Many teens and adults have trouble making change, and the simulation offers a safe place to

experiment. However, there are simple logistical problems that interfere with the success of this exhibit–the location near Kids Market is problematic, as much younger visitors think Quick Change is a cash register and keep others from using it.

Parents expressed much appreciation for this exhibit–"Kids have so much trouble counting money. This is great practice." While we encountered many school-age students who struggled with the math of this exhibit, when we sat down with them, they were willing to articulate their mathematical thinking. For example, a 5th grader, after some encouragement, used a counting up strategy: "It costs 63 cents and they've got a dollar. So 2 pennies is 65, and 5 is 70, and 5 is 75, and then a quarter is a dollar." Another said: "This is like paying for my lunch at school. I do the math in my head before I pay." Most children, however, tended to use the standard subtraction algorithm–it's difficult to know whether that is because it is what they are learning in school or because the cash register looks like a subtraction problem, probably both.

In terms of family learning, we saw a number of adults in both *Moneyville 1* and *Moneyville 2* encouraging "counting up" or going to "landmark number" strategies.

Researcher Reflections

Visitors like this interactive exhibit and the mathematics is clearly both relevant and valuable. The mathematical ideas underlying the exhibit represent important content at the elementary level that students encounter regularly in grades 2–4. The process of making change is also a basic life skill that everyone needs and OMSI has succeeded in creating a playful interactive for practicing and mastering it. This is an exhibit where we have consistently observed visitors having successful mathematics experiences. It is another example of an exhibit where we have witnessed rich interactions between adults and children who sit down to work together. Still, we feel that this simulation could be significantly improved with minimal adjustments. Below we offer a few of our lingering thoughts and suggestions:

- The money with which the customer pays doesn't appear and stay on the counter. We think this would help particularly younger users refer back to what they are starting with.

- When a visitor makes a mistake giving change, they get a second chance and a digital string appears: 0.00 + 0.00 + 00.0 + 0.00 + 0.00 + 0.00 = 0.00. We have questions about whether this is more useful or confusing to visitors. This string changes as visitors enter a new value for change with the currency buttons below. However, the order of the values in the string is the reverse of the buttons.

- When visitors make a mistake, the original amount of change that they gave should continue to appear so that they can alter it rather than starting over. Especially school-age children lose their train of thought when the visual image of their original answer disappears.

- Given the target audience of this exhibit, we had concerns about the use of misspellings in the background, e.g. "malk" instead of "milk," "gud fud" instead of "good food." In other museum work we have done, people have been critical of this technique.

- The location within Kids Market is limiting the use of this exhibit. Even reorienting it so that the screen faced out rather than in might help.

Balancing Your Budget

Math Opportunities

Measuring & Comparing: Visitors compare the size and weight of blocks, for example, a small house versus a large house or a camping vacation versus a resort vacation. There are multiple ways to organize blocks and to work with the scale. If the visitor places the blocks just right, she can balance her budget. (Note: While this strand is listed in OMSI documentation, it does not appear on the Math At Work copy for *Moneyville 2*.)

Finding Patterns: Visitors notice that yellow blocks represent "needs" (housing, groceries, car/transportation, clothes, education, healthcare) while blue blocks represent "wants" (vacation, picnics, movies, sports equipment, electronic equipment, eating out, and savings). Visitors notice, for the most part, that items costing more money are larger and weigh more.

Thinking & Reasoning: Visitors determine the differences between needs and wants. They consider those items that could be seen as falling into either a need or a want (for example, a computer). Visitors interpret the response of the arrow when the blocks are

placed on the scale–over budget, balanced budget, under budget. They make choices hoping to yield a "balanced budget."

Visitor Experience

This exhibit has been a family favorite since the earliest prototypes were unveiled at OMSI. Families gather at the exhibit together, they take turns putting blocks on the scale, they talk about values and choices–Mom wants to go out to dinner, Dad wants to drive a car rather than take the bus. However, there are again logistical problems that limit the pedagogical effectiveness of the exhibit: the scale does not respond as visitors expect. As one child bluntly put it, "This thing doesn't work." Or as one middle-aged woman exclaimed, adding more luxuries to the scale, "This sure isn't my budget," meaning that it took too many blocks to tip the scale and many more than her household income would accommodate.

While the failings of the mechanism create the potential for significant misconceptions among younger visitors, people are generally tolerant and accommodating with respect to the less-than-accurate balance. They manage to get the message that the exhibit is about figuring out what is important in life, and how that affects the way people spend their money.

Researcher Reflection

Given the exhibit's popularity and relative simplicity, it is unfortunate that the balancing mechanism has never been better perfected. Simply put, it does not balance unless visitors fiddle with the blocks and scale. Instead the arrow registers "under budget" until nearly all the blocks are placed on the scale, at which point it tips to "over budget." If the scale does not function properly, then the quality of the mathematics that can happen is significantly diminished. It is difficult to "measure & compare" if one of your measurement tools is faulty or to "find patterns" when you question the validity of your data.

Kids Bank

OMSI staff suggested that we select either the Kids Bank or the Kids Market for our more detailed study of mathematics learning. Originally, we intended to take a closer look at Kids Bank exclusively because we felt this exhibit was more unique to *Moneyville*. However, as in *Moneyville 1*, children put these two exhibits together even when they are located at opposite ends of the room, as was the case at MODS. So, while we focus on Kids Bank, we refer to both here.

Math Opportunities

Understanding Numbers: Visitors can count and sort coins. They can determine the value of various combinations of coins. At the bank, they can add and subtract numbers representing deposits and withdrawals. At the store, they can role play purchasing fruits and vegetables and making change.

Measuring & Comparing: Using the racks for coin storage, visitors can make comparisons across currency, for example, $2.00 is 8 quarters, or 20 dimes, or 40 nickels, and readily recognize equivalencies.

Thinking & Reasoning: The role playing encouraged by both Kids Bank and Kids Market, as well as the interaction between the two, creates the possibility of many different problem solving scenarios.

Visitor Experience

Both Kids Bank and Kids Market attract very young visitors. Especially in *Moneyville 2*, this is where the youngest visitors and their parents tended to spend much of their time. Partly because of the age of the visitors and partly because of the reliance on role playing for content, the math that we observed here is fairly minimal.

Most children do not have enough experience with bank teller windows to independently role play here, and unless they work with an adult, there is not an opportunity to learn about how this aspect of banking actually works. In addition, they have no money to deposit unless they borrow it from the Kids Market. So they use the teller window for making withdrawals only and the concepts of depositing and withdrawing are generally lost.

For the most part, even adult visitors are not making a connection between the calculators, the manual rotary "counters" (representing deposit/withdrawal slips), and the money. One group of girls decided the bank was really another store–they thought that the counters were supposed to be used as scales. The phone is used in role-playing but not as intended–children call in orders for money rather than calling "Counterfeit Police."

Researcher Reflection

The math here that happens on a regular basis is primarily about comparing coins and finding equivalencies. Any sort of adding and subtracting needs to be scaffolded and mediated by an adult. Based on our experience with both versions of the exhibition, something is lost when Kids Bank and Kids Market are at opposite ends of the room. Children made the trek across the hall but got distracted as they did so. Perhaps more than any other, this exhibit feels like a missed opportunity for math learning. We are left wondering how it could be modified to ensure a higher quality visitor mathematics experience–if there might be some way to incorporate a compound interest lesson or design more purposeful interaction between the Kids Market and the Kids Bank. One possibility might be to give children *currency* that they could spend or deposit.

APPENDIX B–Exhibit Descriptions[9]

Exhibition Overview

There are five major exhibition areas in *Moneyville*: The Money Factory; The Bank; To Market, To Market; Dollars and Sense; and Global Trade.

THE MONEY FACTORY

Making Money
The visitor can look at money from around the world and then design his/her own money using crayons to rub on borders, designs, and values.

Face Value
Aspects of money design are explored as the visitor uses a computer to design and print money with his/her face on it.

Anti-Counterfeiting Lab
Using a video microscope and ultraviolet light to find some of the security features found on U.S. currency, visitors can learn how to spot counterfeit bills.

How Money is Made/Video Kiosks
Two short videos allow the visitor to examine how currency is printed at the Bureau of Engraving and Printing and how coins are made at the U.S. Mint.

Barterville
The visitor navigates through a virtual marketplace to try to trade for what he/she wants in the world without using money and discovers how barter works and how money has made trade easier.

The History of Money Timeline
The visitor explores the connections between money, technology, math, and society on this interactive timeline that tells the global story of the evolution of money.

Money Mysteries Artifact Cases
The visitor examines some of the many forms that money has taken throughout time and around the world in this interactive artifact display.

[9] These exhibit descriptions are composite descriptions based on OMSI literature and our own observations.

Moneyworks Park
In this light-controlled area the visitor experiments with different ways of using his/her own shadow to interact with computer-generated images of money projected on a wall. This piece of interactive "public art" provides the opportunity to reflect on public goods and services and the role of tax dollars in paying for them.

THE BANK

Million Dollars
The visitor gets to see what a million dollars looks like inside a transparent "safe." A series of questions helps the visitor make sense of big numbers by making comparisons.

Money on the Move
The visitor follows the life of a dollar bill (represented by a ball) as it moves through an economic system in the form of a kinetic sculpture. It begins at the Bureau of Engraving and Printing, then goes to the Fed, to a local bank, and finally to the visitor, who then makes decisions about spending or saving to see where the money goes.

Make a Million
The visitor learns about exponential growth in a computer simulation on compound interest. The visitor predicts who will be a millionaire by the time they are 65: Earl–who saves a little but starts saving early, or Louise–who saves a lot but starts saving late in life. Then the visitor gets to try to make a million dollars by choosing a savings rate, an interest rate, and using an interactive graph to see how their investment grows over time with compound interest.

Kids Bank
Younger visitors role-play bank tellers and customers using oversized play coins. At an activity table, children can learn about coins and their values by putting together puzzles and using clues to guess the coins hidden inside "safes."

TO MARKET, TO MARKET

Lemonade Stand
The visitor sets up a virtual lemonade stand and can learn about profit, loss, supply, demand, price, and what it takes to run a business. The challenge is to stay in business while making daily decisions based on certain information, such as the cost of making a pitcher of lemonade, the weather forecast, graphs of profit and loss, and local news.

Kids Market
Children become buyers and sellers in a farmers market using shopping baskets, play money, and produce. They become engaged in setting prices, weighing produce, and making change.

Quick Change
The visitor makes change for customers at a virtual store using this interactive "cash register." There are three levels of play from "trainee" to "sales manager."

Stock Market
The visitor begins with $10,000 and learns how buyers and sellers interact in a virtual stock market. The player examines company profiles, analyzes financial graphs, and watches for breaking news that may affect stock prices.

DOLLARS AND SENSE

Balancing Your Budget
Using weighted "expense" blocks and fixed "income" weight on a balance scale the visitor considers economic choices and trade-offs as they try to balance their monthly household budget.

Get Real
The visitor makes economic decisions based on real-life scenarios in a computer simulation.

Inflation Station
The visitor can see how the costs of the same five items have changed over time and discover how inflation reduces the value of money.

The Real Cost of Credit
By putting a hand over an air tube and watching as a ball rises to different dollar amounts, the visitor is shown how much it really costs to use a credit card to make a purchase of $1,000 and make only the minimum monthly payment on the credit card bill.

The Better Buy
The visitor becomes a virtual shopper and uses a computer screen to view pairs of identical items, one with a percent discount price and the other without, to pick the item that is the "better buy" using a "price code scanner."

GLOBAL TRADE

Money from Around the World
The visitor examines bills and coins from around the world and can compare their values in terms of U.S. dollars.

From Around the World
The visitor uses clues about resources and the countries they come from to guess what's inside four shipping crates. Then they can look through a viewfinder to "x-ray" each crate to uncover the contents.

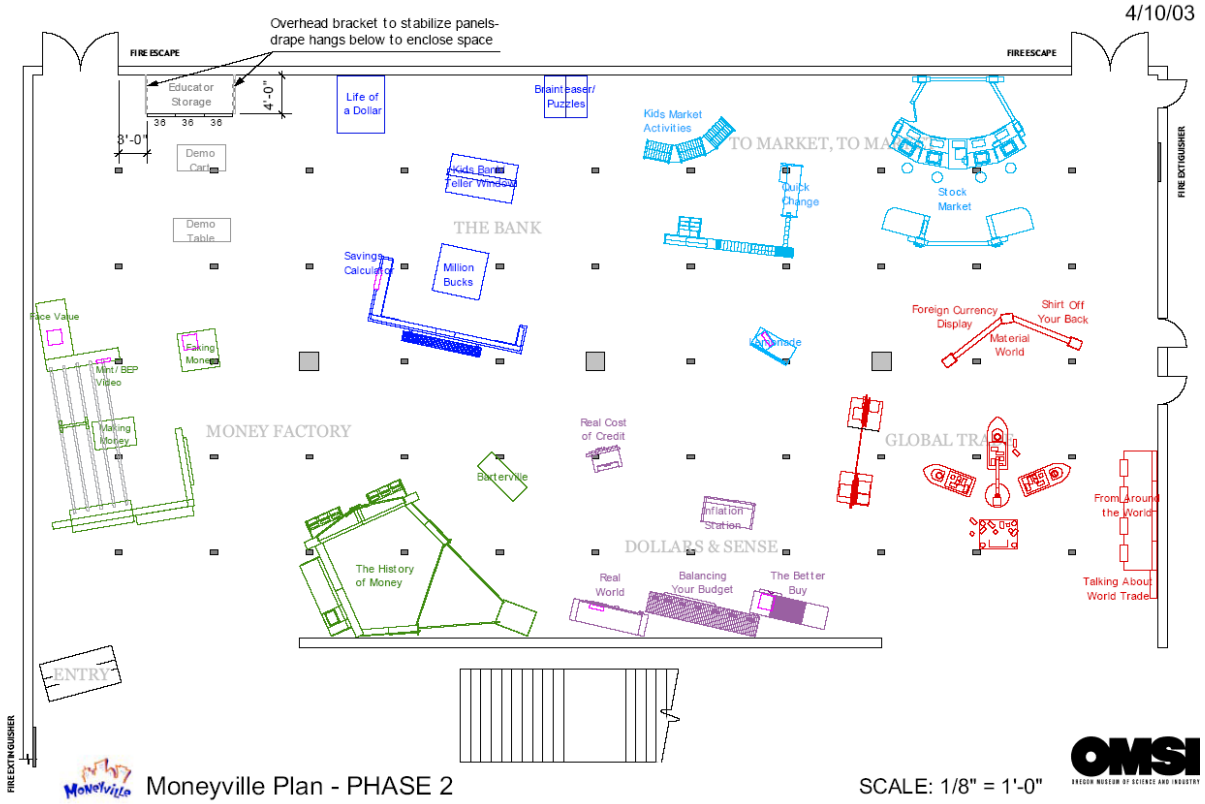
Material World
This exhibit displays photos of families and their possessions from around the world.

The Shirt Off Your Back
The visitor checks the "made in…" label on the inside of his/her shirt to find the country and region it was made in and then checks the graph to see how many shirts each region produced for sale in the U.S.

The Shipping Dock
Children can explore international trade as they sort and load export crates on cargo ships heading to three major U.S. trading partners: Canada, Mexico, and Japan.

APPENDIX C–Layout of *Moneyville 1* in Portland, Oregon

Summer 2003



APPENDIX D–Layout of *Moneyville 2* in Ft. Lauderdale, Florida
Fall 2004