



Nano Books: “How Small Is Nano?” & “Is That Robot Real?”

Formative Evaluation

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THIS IS A FORMATIVE EVALUATION REPORT

Formative evaluation studies like this one often:

- **are conducted quickly**, which may mean
 - small sample sizes
 - expedited analyses
 - brief reports
- **look at an earlier version** of the exhibit/program, which may mean
 - a focus on problems and solutions, rather than successes
 - a change in form or title of the final exhibit/program

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Background

In the fall of 2008, visitors to the Science Museum of Minnesota provided feedback on the books, *How Small Is Nano?* (subsequently referred to as *Small*) and *Is That Robot Real?* (subsequently referred to as *Robot*). The visitors, 63 adults in all, were asked to read one of the books to the child or children accompanying them. The adults were then asked a series of questions about their experience. The “n” value given for each question is reflective of the number of responses for that particular question. Additional visitor demographic information is available at the end of the report.

Results and Discussion

Exhibit’s Objective

While both books are part of a larger program, the purpose of this study is to determine if each book could impart knowledge of nanoscience independent of the program’s context. The goal of *How Small is Nano?* is to teach readers that nano is very, very small. There are multiple learning objectives of the book *Is that Robot Real?* It is hoped that readers will take away four ideas: 1) Nano is very, very small; 2) Nanobots are not real and do not currently exist; 3) There are many challenges related to creating a nano-sized robot; and 4) In the future, nanobots might exist and might be able to do useful things.

To assess whether the books were successful in meeting these objectives, visitors were asked what they thought each book was about. Themes are reported below and include several representative answers. A complete list of responses may be found in Appendix D.

Over half of the *Small* readers (50%) seemed to learn that nano is about measurement and relative size (see Table 1). Just under one third of visitors (31%) reported that the book was about nanometers, and a number of visitors (22%) indicated that the book was about microscopic or nanoscale objects. These responses show that the book *How Small is Nano?* does very well at conveying relative size and the nanoscale to readers.

Table 1: Main Messages of “Small” (n=32)

	Percent of Visitors
Measurement and relative size	50%
Nanometers	31%
Nanoscale	22%
Other	6%

*Note: Visitors shared more than one response.

Three of the four learning objectives of the book *Is that Robot Real?* were touched upon in what visitors took away as the main messages of the book. Just over a tenth of the visitors (16%) identified size as being a topic of the book, and another tenth (10%) suggested that the book was about understanding what robots exist and don’t exist (see Table 2). No visitors identified aspects of the third objective as being conveyed through

the book, but nearly two-fifths (39%) described the book as discussing the future of robotics and technology. Over three-fifths (84%) of the visitors said the book was about the use of robots, technology, or robots in general. These responses show that, though they were following the book, the specifics about nanotechnology and the nanoscale were not aspects that stayed with the visitor after they closed the book.

Table 2: Main Messages of “Robots” (n=31)

	Percent of Visitors
Robots and technology	84%
Future possibilities	39%
Size	16%
Other	10%

*Note: Visitors shared more than one response.

Samples of Visitor Main Messages

“Small” Book (n=32*)

*Some visitors provided more than one response.

50% (16) Measurement and relative size

- The scale of things.
- How big and small things are -- how small things can get.
- Size. Just the difference. How small a nanometer really is.

31% (10) Nanometers

- Nanometers. (4)
- How and why things were nanometers.

22% (7) Nanoscale

- It was about how teeny weeny a nano is.
- It was about giving us a visual perspective of things unseen.
- About the unseen world. How incredibly small things around us are. Teach form of a measurement.

6% (2) Other

- The science of things.
- Spatial relationships.

“Robot” Book (n=31*)

*Some visitors gave more than one response.

84% (26) Robots and technology

- Robots and technology. How robots are used today.
- About robots and what they can be used for.
- Robots. (8)
- Robot technology - where we are now.

39% (12) Future possibilities

- How technology is being developed for the future.
- Robotic technology – what they are now and what they might become.
- What robots someday might exist.

16% (5) Size

- Size.
- Robots evolving from larger to smaller.
- The size of robots.

10% (3) Other

- Science and blood.
- That's what inventors work on -- scientists. Engineers take things that scientists discover and find a use for them and that's how things get better.
- How robotics is part of society.

Visitor Interest and Engagement

A portion of the survey was designed to measure how engaged the visitors were in the books; this included asking visitors to rate their levels of interest in and enjoyment of the books. Both books were interesting to visitors, but *Robot* readers were more often interested in their book than were *Small* readers (97% and 88%, respectively). Table 3 gives the range of interest visitors had in their books. Less than two-fifths (38%) of *Small* readers would read the book again, whereas over half (55%) of those who read the book on robots would read it again.

Table 3: Adult and Child Interest

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
We were so interested we’d read it again.	38%	55%
We were interested, but we wouldn’t read it again.	50%	42%
We weren’t really interested.	12%	0%
We didn’t find it interesting at all.	0%	3%

Visitors were asked to rate how much they enjoyed the book they read. Most of the visitors enjoyed the books, yet *Robot* readers did so more often than *Small* readers (93% compared to 84%). Nearly half (48%) of the *Robot* readers would encourage others to read the book while only one quarter (28%) of those who read about the size of nano would tell others (see Table 4).

Table 4: Adult and Child Enjoyment

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
It was so enjoyable, we’d encourage others to read it.	28%	48%
It was enjoyable.	56%	45%
We didn’t really enjoy it.	16%	7%
We didn’t find it enjoyable at all.	0%	0%

Visitors were asked how their interest in nanotechnology changed after reading the books. None said their interest decreased after reading the books, and just over half of the readers in both groups stated their interest in nanotechnology had increased as a result of reading. A small percentage of both groups reported that they did not know how their opinions about nanotechnology changed because they did not know what nanotechnology was; this was more common among *Small* readers (13%) than *Robot* readers (3%). See Table 5 below for the full range of results.

Table 5: Nanotechnology Interest Change

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
It makes me more interested in nanotechnology.	53%	52%
It makes me less interested in nanotechnology.	0%	0%
I feel the same about nanotechnology.	34%	45%
I don’t know; I’m not sure what nanotechnology is.	13%	3%

Relevance of Book to Visitors’ Lives

Visitors were asked how relevant they found the book to be to their lives. Most visitors from both groups found the book they read to be somewhat relevant to their lives (see Table 6). Only a tenth of *Robot* readers (10%) and a slightly greater number of *Small* readers (16%) thought the books were extremely relevant to their lives.

Table 6: Relevance of book’s content to visitors’ lives

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
It was extremely relevant to our lives.	16%	10%
It was somewhat relevant to our lives.	50%	68%
I didn’t really see much relevance to our lives.	25%	19%
I didn’t find any relevance to our lives at all.	9%	3%

Individuals who found the book to be at least somewhat relevant were asked an open-ended follow up question about what they read in the book that was relevant. Visitors who read the *Small* book often commented about size and scale, anatomy and biology, and nanometers. *Robot* readers often found the evolution and future of robotics, the Roomba,

the description of the structure and uses of robots, and the size of robots to be relevant. Themes arose among responses and are reported below with several representative answers. A complete list of answers can be found in Appendix A.

Relevance

Small (n=21*)

*Several visitors provided more than one response.

33% (7) Size and scale

- It compares to real things. I know technology of nano world, but it's hard to explain, so the way it starts with height of a student and moves to bacteria and atom.
- Because my son is learning about meters in school.
- Need to know metric scale.

29% (6) Anatomy and Biology

- The biology of it. It was interesting how it put different dimensions to our bodies.
- Looking at things within the body.
- The child part.

29% (6) Nanometers

- It surprised both of us how small a nanometer is.
- That one meter is one billion nanometers.
- We've been hearing nano something in the news and it's good to see size of nano.

10% (2) Viruses

- My husband is a chemist so I live with it. I work at a school and deal with exposure to viruses.
- I work in a hospital.

29% (6) Other

- The pictures were the most relevant. Atom and bacteria are not real relatable for children.
- The one [son] loves science.
- Good visuals, quick, simple. Reviewed the information at the end.

Real (n=24*)

*Some visitors gave more than one answer.

29% (7) Evolution and Future Direction of Robotics

- [My] interest of what is and what can be.
- They, the kids, are already thinking of ideas of things to invent. Things to electrocute, do homework, protect people.
- Futuristic.

29% (7) Specific Examples Used or Seen in Current Life

- My mother has the Roomba.
- Some of the applicable things like the vacuum and how you can use robots in your daily life.
- 'Cause I've heard of the Roomba.

29% (7) Description of Structure and Uses of Robots

- He’s really interested in robots and what they can do.
- The description of different robots. (2)
- The structure of a robot.

29% (7) Size

- We didn’t realize they made stuff that small.
- The part when it started talking about robots the size of blood cells and viruses.
- My son seemed to connect with things getting smaller.

13% (3) Other

- The stuff at the beginning that is actually real.
- Going down to bacteria and molecules and red blood cells, no understanding for children.
- The part about blood cells.

Determining Appropriate Audience

Visitors were asked to help determine the appropriate age levels for children reading the books. Visitors were first asked to rate the appropriateness of the vocabulary used in the books. Two thirds (66%) of *Small* readers and three fourths (74%) of *Robot* readers felt the vocabulary was appropriate. About one quarter of readers from both groups found the vocabulary in the books to be too difficult (see Table 7).

Table 7: Level of vocabulary used in book

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
The vocabulary was too difficult.	25%	23%
The vocabulary was just right.	66%	74%
The vocabulary was too easy.	9%	3%

Visitors who thought that the vocabulary was too difficult were asked to identify what they found to be difficult to understand. A common theme among responses from both groups was that some of the vocabulary was too difficult for children who don’t understand measurements or references to such a small scale. Themes are reported below with several representative responses. A complete list of answers can be found in Appendix B.

Difficult Words

Small (n=10)

50% (5) Measurement terms

- Micrometers, nanometers.
- Meter, one tenth. Kid’s don’t grasp the large numbers.

20% (2) Specific words

- Depends on age. [Child] doesn’t know atoms and molecules. Hair okay, fingernail okay.
- Cell membranes, Molecules.

30% (3) Other

- Too easy for a nine year old – could go more in depth.
- The book should speak in feet and inches because kids in America don’t understand millimeters.
- Even after reading, I don’t really know what a nano is. Putting it all together.

Real (n=7)

*Some visitors gave more than one answer.

57% (4) Too difficult for children

- The way they talked was more adult. Especially at the smaller level, [it] should be more general.
- Too difficult for my daughter. I don’t remember a specific word.

29% (2) Specific words

- Nanotechnology, Mechanical.
- Then, when it went into power and other things she lost interest.

38% (3) Other

- Nothing that I can remember.
- I liked the big question and answer.
- Six different colors on the robots would be more interesting.

Visitors were asked to share how young and how old children could be to read the books with an adult or on their own. For *How Small is Nano?*, visitors thought that the youngest age for the book was somewhere between the ages of 2 and 11, and the oldest an individual should be to read it was between 7 and adulthood. The majority of visitors thought the book was appropriate for children as young as 4-7 years of age (81%) and as old as 10-12 (50%), with a fifth of visitors (22%) stating that it was appropriate for adults. The medians for each end of the age range were 6 and 12.

For *Is that Robot Real?*, visitors placed the youngest age of children at 5 or 6 (65%) and the oldest age at 12 to 13 (45%). More visitors thought that the book on robots could be appropriate for teenagers (16%), and only one-twentieth (6%) of these visitors identified the book as being appropriate for adult readers. The median for the youngest age of readers was 5 and for the oldest, the median age was 12.

Additional Information

Visitors were asked if they would like more information about anything included in the books. Approximately three-quarters (76%) said that they would not need any more information beyond what was provided. Another quarter (24%) indicated that they would like more information specific to the topics discussed in the book or more examples of the topics.

A little over half of the *Small* readers wanted more specific information about terms and ideas raised in the book, while another third wanted help describing the nanoscale to their children.

Robots readers were more focused on getting more examples of small robots or having more information about the robots referred to in the book. Another two-fifths wanted more information about how scientists created the robots or about nanotechnology in general.

What information would you want?

Small (n=9)

56% (5) More specific information

- More definitions and their functions. Atoms and sugar molecule for example.
- Explain more for younger children. Explain what a nano is.
- Learn more about red blood cells.
- Important to show nanotechnology in water filtration and importance of water.
- It would be fun to see other ways to make connections between nano's and the body.

33% (3) Guidance on how to relate nano for children

- For the book, some concrete information concerning the size of a nano would be helpful for kids to understand. For example, if a freckle is the size of a football field then a nano is the size of a hand.
- Have reference of a nano on one sheet.
- If an adult is reading to kids, a guide or instructions for breaking it down for kids would be nice, such as how to explain a cell or virus.

11% (1) Other

- How did nano as measurement come about? Nano background information would be interesting. How will it be used in the future?

Robot (n=7*)

*Some visitors gave more than one response.

71% (5) More examples and information on the robots discussed

- Pictures of what they do.
- More about robots they're working on would be cool.
- What kinds of things the robots do; more examples.
- The finger sized robots.
- Soccer [playing robots] – how they made it do that stuff.

43% (3) Technology behind creating tiny robots (3)

- How they make robots that tiny.
- What are they doing to control that molecular technology stable, so not sticking to other molecules.
- About nanotechnology in general, making things smaller and smaller.

14% (1) Other

- Parallel developments in other fields.

Reading at Home

Visitors were asked about their reading practices and if they would read the books with their children at home. Two-thirds of the visitors (67%, including two visitors answering “other” because their children are homeschooled) read to their children at least once per day (see Table 9). Visitors who answered “other” were asked to elaborate their response. Themes are reported below. Of those who answered “other”, most (79%) reported that their children read on their own or that they were not the primary caregivers to the children they were with (i.e. grandparent or nanny). A complete list of responses can be found in Appendix C.

Table 9: At home reading with children

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
Multiple times a day	9%	16%
Daily	59%	42%
A few times a week	6%	23%
Less than once a week	0%	0%
Other	25%	19%

Visitors were then asked if they would read the books at home with their children. A majority of visitors (71%) in both groups indicated that they would read the book at home (see Table 10). Interestingly, nearly one fifth (16%) of the visitors who read the book on robots did not specifically answer “yes” or “no,” but with a different response. Those who answered “Other” said that they were unsure, that it would depend on the interest of the child, or that their children read on his/her own.

Table 10: Would you read this book with your child at home?

	Percent of Visitors “Small” (n=32)	Percent of Visitors “Robot” (n=31)
Yes	71%	71%
No	29%	13%
Other	0%	16%

Visitor Demographics

Due to the nature of the reading activity, only groups of adults and children were recruited. Visitor information was self-reported. There were no differences between the groups recruited for each book. Of the adult-child groups that participated, over four-fifths (84%) were parents with their children; a tenth (10%) of these adults were parents with other children in tow, as well (see Table 6). Three-quarters of the visitors interviewed were female (75%).

Table 6: Readers’ relationship to children (n=62)

Percent of Visitors	
Parent	84%
Relative	10%
Caregiver	6%

Ages of visitors and children were recorded. Three-quarters of adult visitors (76%) were between the ages of 30 and 49 (see Table 9). Of the children who accompanied the visitors, approximately one third (34%) were age 5 years or younger, while one third (33%) were between the ages of 9 and 12. Only a small percentage of children (6%) were identified as teens (see Table 8).

Table 7: Readers’ Age (n=63)

Percent of Visitors	
18-21	3%
22-29	13%
30-39	41%
40-49	35%
50-59	6%
60-69	2%

Table 8: Age of Children in Groups (n=131)

Percent of Visitors	
0-5	34%
6-8	27%
9-12	33%
13-17	6%

Visitors were asked to rate their interest of science on a scale from one to ten, one being no interest and ten being extremely interested. Nearly four-fifths of the visitors (79%) rated their interest in science between 7 and 10. A few adults rated themselves as low as 1 and 3, while the rest gave themselves interest levels between 4 and 6.

Appendix

Appendix A – Main Messages

“How Small is Nano?”

Visitor Quotes (n=32)

*Some visitors gave more than one response.

50% (16) Measurement and relative size

- The scale of things.
- How big and small things are -- how small things can get.
- Size. Just the difference. How small a nanometer really is.
- Comparisons of measurement and helping to set up in a person's mind how small nanometers are.
- To me, I would say it's about size. Relative size.
- Measuring how small things are.
- About describing how large or small a nano is and breaking down things we know into nanos.
- The size of things relative to each other.
- Explanation of metric sale. Comparison of sizes.
- It was about measurement and comparing measurement.
- A nano. The relation to size.
- How big is a nano?
- About teaching children scales.
- Measurement.
- Measuring different things.
- It's useful for scale.

31% (10) Nanometers

- Nanometers. (4)
- How and why things were nanometers.
- Trying to explain nanometers.
- The book was trying to visualize just how small a nano is. Trying to define a nanometer.
- Nanometers. The size of nanometers and how many are in certain lengths.
- About the nanometers different things have. It's useful for scale and for how nanometers measure things.
- That nanometers are really small.

22% (7) Nanoscale

- It was about how teeny weeny a nano is.
- It was about giving us a visual perspective of things unseen.
- About the unseen world. How incredibly small things around us are. Teach form of a measurement.
- Trying to introduce what nano is.
- Trying to get children to understand things they can't see.
- About things we don't see that we should know.

- It was about what a nano is.

6% (2) Other

- The science of things.
- Spatial relationships.

"Is that Robot Real?"

Visitor quotes (n=31)

*Some visitors gave more than one response.

84% (26) Robots and technology

- Robots and technology. How robots are used today.
- About robots and what they can be used for.
- Teaching about how robots are used.
- Robotic technology.
- Up to blood cells, it was about the sizes of robots, their functions, and their power sources.
- What robots can do and what robots exist.
- Looking at what current technology can do with robots.
- It's about the current state of robotic technology.
- Present robots.
- Robots. (8)
- Technology. (2)
- Robots evolving from larger to smaller.
- Robot technology - where we are now.
- How technology can be used in various ways.
- Technology and machines.
- Robots that can be very small and helpful.
- What robots exist.
- Robots and where to find them in real life.

39% (12) Future possibilities

- How technology is being developed for the future.
- Robotic technology – what they are now and what they might become.
- What robots someday might exist.
- Speculating about what we can do in the future.
- A glimpse of where future is going.
- Future of robots.
- What they'll be used for in the future.
- The direction technology is going.
- The future robots.
- It was about the future of robotics.
- Robot technology - where we can go in the future.
- What robots could possibly exist.

16% (5) Size

- Size.
- Robots evolving from larger to smaller.
- The size of robots.

- Robots that can be very small and helpful.
- Robots - The size of robots. Helps kids understand the relative size of robots.

10% (3) Other

- Science and blood.
- That's what inventors work on -- scientists. Engineers take things that scientists discover and find a use for them and that's how things get better.
- How robotics is part of society.

Appendix B: Relevance of Book to Visitors' Lives

"How Small is Nano?" (n=21*)

*Some visitors gave more than one response.

33% (7) *Size and scale*

- It compares to real things. I know technology of nano world, but it's hard to explain, so the way it starts with height of a student and moves to bacteria and atom.
- Because my son is learning about meters in school.
- Need to know metric scale.
- We're not studying it but we're always talking about size.
- I just think it helps kids with size.
- I didn't know viruses were smaller than bacteria.
- The part before we got to the micro level.

29% (6) *Anatomy and Biology*

- The biology of it. It was interesting how it put different dimensions to our bodies.
- Looking at things within the body.
- The child part.
- The bacteria stuck out most to him [son].
- Seeing how many nanometers are in a child.
- That the freckle on the kid's face is 10,000 nanometers.

29% (6) *Nanometers*

- It surprised both of us how small a nanometer is.
- That one meter is one billion nanometers.
- We've been hearing nano something in the news and it's good to see size of nano.
- It was interesting to see what a nano is.
- I thought the end was interesting, saying how many nanometers in a meter.
- Nanos are important to think about.

10% (2) *Viruses*

- My husband is a chemist so I live with it. I work at a school and deal with exposure to viruses.
- I work in a hospital.

29% (6) *Other*

- The pictures were the most relevant. Atom and bacteria are not real relatable for children.
- The one [son] loves science.
- Good visuals, quick, simple. Reviewed the information at the end.
- There are things we can't see but should know about.
- Helped us visualize a little better.
- I know people who home school their children and I would recommend it.

"Is that Robot Real?" (n=24*)

*Some visitors gave more than one answer.

29% (7) Evolution and Future Direction of Robotics

- [My] interest of what is and what can be.
- They, the kids, are already thinking of ideas of things to invent. Things to electrocute, do homework, protect people.
- Futuristic.
- Robots that can repair disease. Maybe not us, right now, but for kids in the future.
- The futuristic part of it.
- To know the technology [is] so far advanced that they could cure disease with robots. [We] know this guy with a rare disease.
- I'm sure things are happening now, scary and riveting and wonderful. If something could go through your skin. [We're] frightened of the bad things.

29% (7) Specific Examples Used or Seen in Current Life

- My mother has the Roomba.
- Some of the applicable things like the vacuum and how you can use robots in your daily life.
- 'Cause I've heard of the Roomba.
- The information, specifically the vacuum robot, things of getting.
- The vacuum robot.
- We know someone who owns a Roomba, interesting to see it in a book.
- Mars Rover.

29% (7) Description of Structure and Uses of Robots

- He's really interested in robots and what they can do.
- The description of different robots. (2)
- The structure of a robot.
- Talking about how you could come up with an idea and robots could help you, that's what scientists and inventors do.
- Different types of robots.
- That you understand that robotics is an integral part of industry and out there a lot.

29% (7) Size

- We didn't realize they made stuff that small.
- The part when it started talking about robots the size of blood cells and viruses.
- My son seemed to connect with things getting smaller.
- Amazing how small they can build things.
- How computers went from big to small.
- The larger robots.
- That we don't have robots that are super small – the understanding of that.

13% (3) Other

- The stuff at the beginning that is actually real.
- Going down to bacteria and molecules and red blood cells, no understanding for children.
- The part about blood cells.

Appendix C – Difficult language identified

“How Small is Nano?” (n=10*)

*Some visitors gave more than one answer.

50% (5) Measurement terms

- Micrometers, nanometers.
- Meter, one tenth. Kid’s don’t grasp the large numbers.
- The number words are difficult but are good for people to get acquainted with.
- The names of sizes such as millimeter are too difficult.
- The numbers aren’t graspable.

20% (2) Specific words

- Depends on age. [Child] doesn’t know atoms and molecules. Hair okay, fingernail okay.
- Cell membranes, Molecules.

30% (3) Other

Too easy for a nine year old – could go more in depth.

The book should speak in feet and inches because kids in America don’t understand millimeters.

Even after reading, I don’t really know what a nano is. Putting it all together.

“Is that Robot Real?” (n=7*)

*Some visitors gave more than one answer.

57% (4) Too difficult for children

- The way they talked was more adult. Especially at the smaller level, [it] should be more general.
- Too difficult for my daughter. I don’t remember a specific word.
- Too difficult for my daughter. I don’t know.
- It was set up so I could use whatever vocabulary I wanted and skip over a lot of stuff.

29% (2) Specific words

- Nanotechnology, Mechanical.
- Then, when it went into power and other things she lost interest.

38% (3) Other

- Nothing that I can remember.
- I liked the big question and answer.
- Six different colors on the robots would be more interesting.

Appendix D: How Often Respondent Reads to Children at Home

“How Small is Nano?” (n=7)

57% (4) *Child reads by him/herself*

- [My] child reads on [his] own.
- [We read] every night when he was younger.
- [My] son reads on his own.
- He’s reading on his own.

14% (1) *Visitor not primary caregiver*

- When I’m with them, I read to them.

29% (2) *Child is homeschooled, read all day*

- Hourly, [they are] home schooled.
- All day. [They are] home schooled and [we] go through curriculum.

“Is that Robot Real?” (n=7)

43% (3) *Child reads by him/herself*

- She reads by herself now.
- [My] child reads to himself.
- [They] read on their own.

57% (4) *Visitor not primary caregiver*

- Once a month, when [my] grandchild is with me.
- [I] generally don’t read with [my] nieces and nephews because we’re doing other things.
- [They’re my] grandchildren.
- I just watch him on Wednesdays.