Seeing Scientifically – Iteration 1 Part 2

Formative Evaluation

Jacqueline Wong and Joyce Ma

March 2017

THIS IS **NOT** A DEFINITIVE FINAL 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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EVALUATION PURPOSE

This study is the second in two formative evaluations conducted to assess dynamic scaffolding designed to help visitors investigate live specimens under a research-grade microscope. It also compares two versions of scaffolding, one emphasizing comparisons in developmental stages of zebrafish embryos and one emphasizing identification of visible zebrafish anatomy.

METHOD

The Prototype Exhibit

Visitors were given limited access to a Zeiss Axiovert 200M scientific-grade inverted microscope via a visitor kiosk as shown in Figure 1. The kiosk consists of a touchscreen monitor (Figure 2) with which visitors could 1) move the stage (i.e., the xy position of the scope), 2) focus (i.e., the z position), 3) choose the light (i.e., Differential Interference Contrast (DIC) or fluorescent light), 4) select an objective (i.e., 2.5x or 10x), 5) select one of six specimens of zebrafish embryos, and 6) view information about the specimens. There were also limits placed on the xy coordinates and focus. It is possible for visitors to move to an area without any specimen in view, but they cannot wander far outside a productive search area.

Zebrafish Specimens

The prototype was set up with six specimens of zebrafish embryos at all times. Whenever possible, there were embryos in three distinct developmental stages: 0-day old (same day), 1-day old, and 2-day old. The embryos were displayed in a specimen selection panel across the top of the exhibit, ordered youngest to oldest from left to right. Visitors could touch one of the embryo image to bring that specimen in view on the microscope. The prototype was programmed to have one of the older embryos (1 or 2-day old) in view when visitors began their interactions.

Scaffolding

The primary goal of this exhibit is to evaluate the use of scaffolding to support visitors' inquiry. We targeted two aspects of inquiry: supporting visitors in asking productive questions (i.e. answerable by visual inspection) and interpreting what they see. The main approach of our
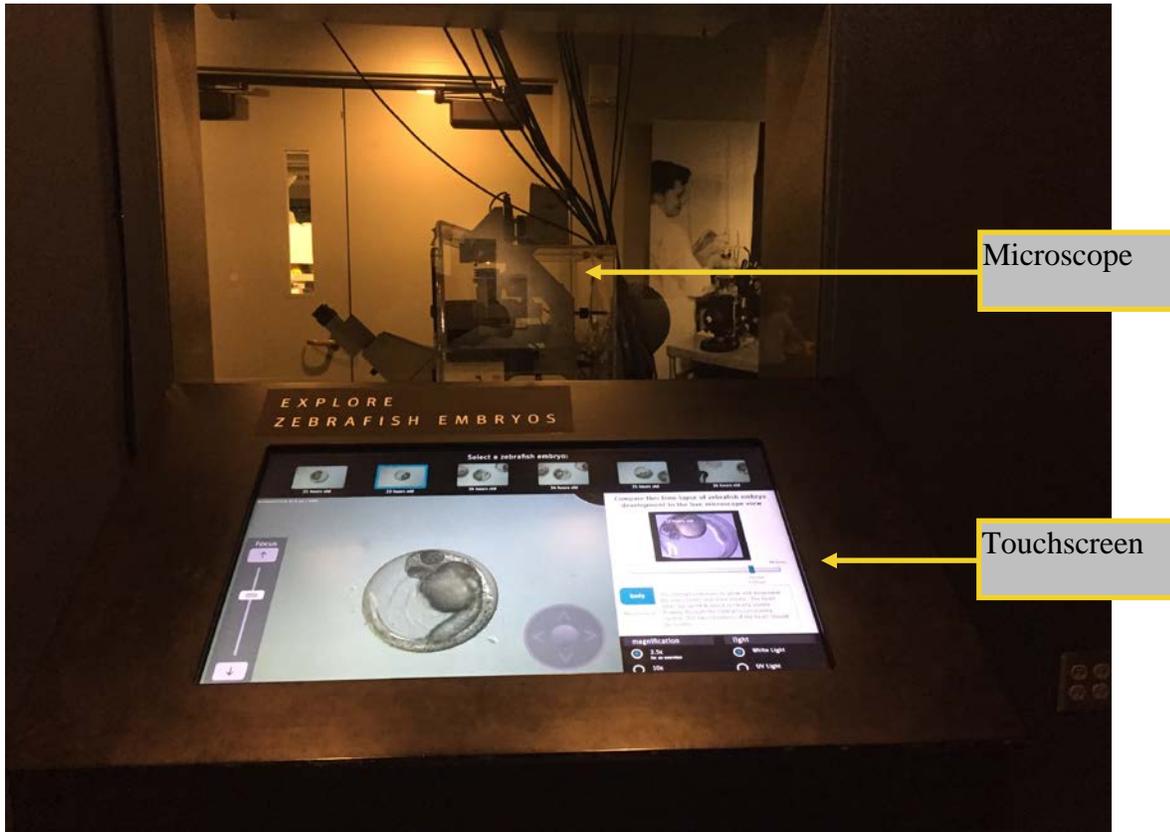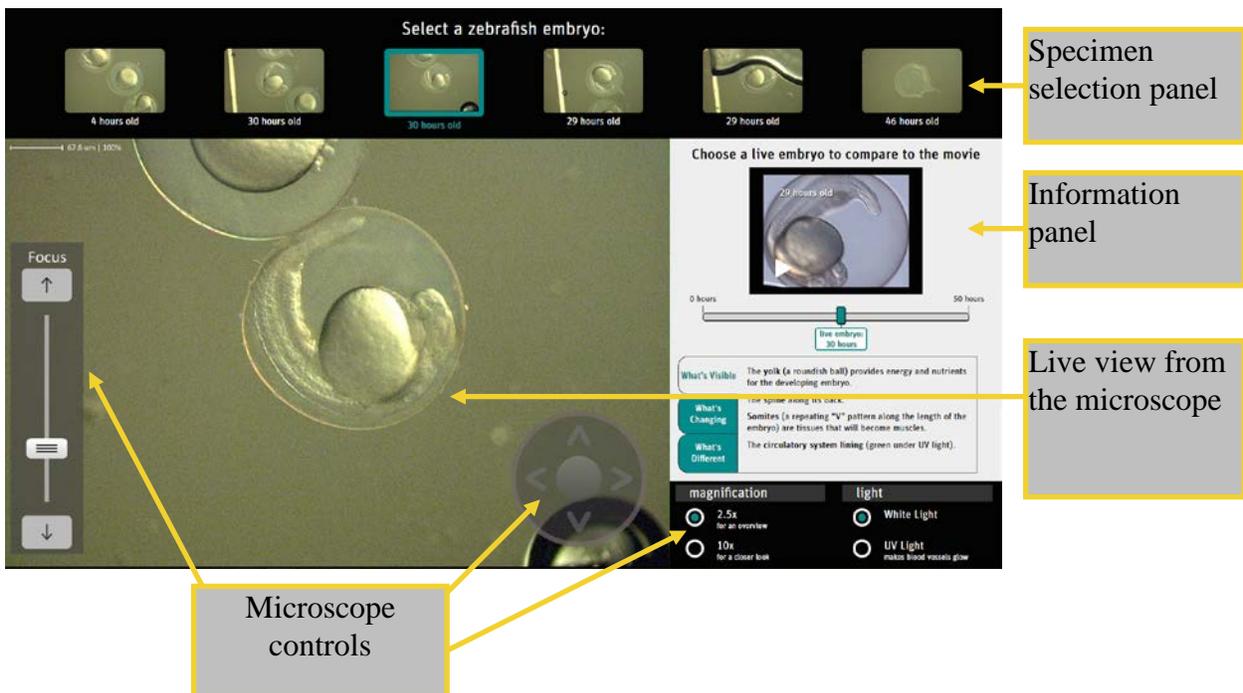
Figure 1. Prototype of exhibit.

Figure 2. Screenshot of the exhibit touchscreen.

scaffolding design is to adapt the exhibit content and controls based on what is visible on the microscope viewer. Table 1 details different aspects of the design. The scaffolding was implemented across three components of the exhibit: microscope control, specimen selection panel, and information panel.

Table 1. Design and implementation of scaffolding.

Scaffolding Implementation	Physical Location of Scaffolding
Support visitors in asking productive questions	
Model question asking by providing answerable questions that visitors can investigate with the specimen in view.	Information Panel
Support visitors in interpreting what they see	
Provide background information relevant to the specimen in view.	Information Panel
Guidance on using fluorescent light (UV): • UV control only available when a relevant specimen is in view. • Suggestions on when to use UV embedded within background information (Compare version) • Information on what is visible under UV appear when UV is turned on (Identify version)	Microscope Control, Information Panel
Offer multiple views (different magnifications, light settings, and stages of development) of the specimen.	Microscope Controls, Specimen Selection Panel
Limit the search area to focus visitors on salient features.	Specimen Selection Panel

We developed two versions of the information panel to further support different aspects of inquiry. One of the versions, called *Identify* hereafter, identifies features of the specimen in view and provides further information about these features (see Figure 3 right). Identification is an important part of how a microscopist sees. This design leverages visitors' desire to identify what they see (a finding from our baseline evaluation) to investigate further. In the second version, called *Compare* hereafter, we aimed to support visitors in making comparisons (see Figure 3

left). Comparison is a key part of scientific observation. We explicitly asked visitors to make comparisons in the questions that we posed. We also featured a time-lapse video to aid visitors in comparing their specimen to the developmental trajectory of a zebrafish embryo. Both versions of the information panel adapts their content to what is visible on the microscope viewer as described earlier in this section (Table 1).

Figure 3. Information panel for *Compare* (left) and *Identify* (right) versions of exhibit.
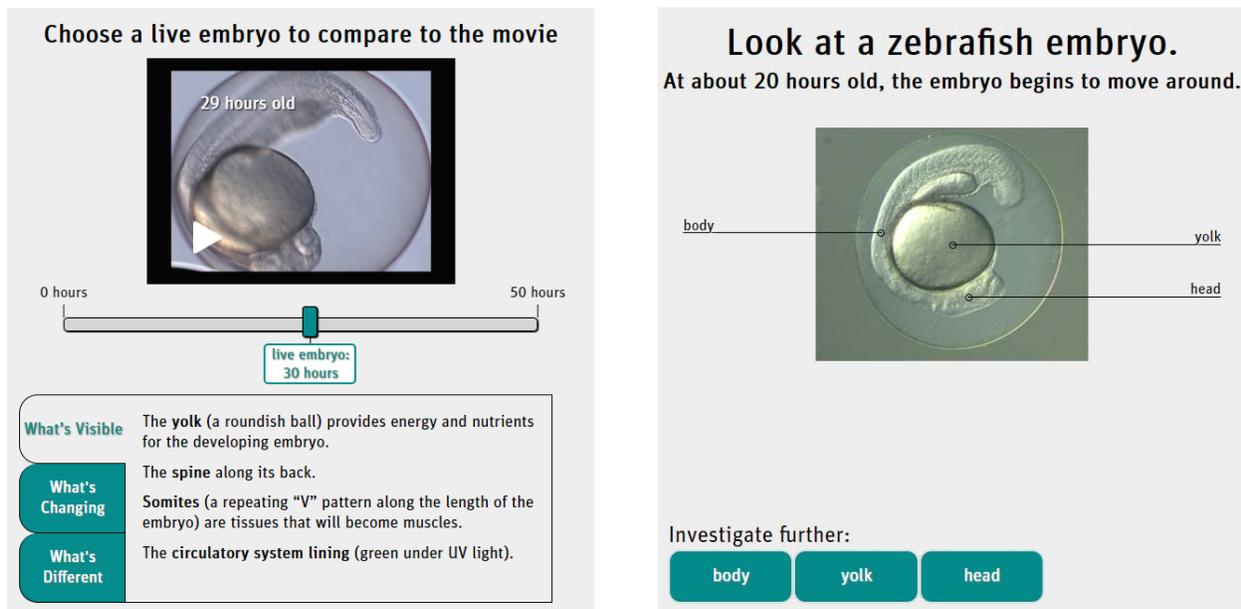
Participants

An assistant evaluator approached every third visitor, who appeared 8 years old or older, as s/he crossed a predefined imaginary line near the exhibit prototype. If the visitor was a minor, the recruiter asked the accompanying adult for permission to talk with the youth. (In most cases, the accompanying adult also participated. In two occasions, the adults gave permission and stayed nearby while the minors participated in the think aloud interviews on their own.) If the visitor was with another person, the evaluator welcomed both visitors to participate. The evaluator asked the selected visitor(s) if s/he would be interested in giving feedback on a new exhibit being developed and would consent to being audio and videotaped at the exhibit. Table 2 and 3 show the demographic information of the visitors who agreed to participate.

Data Collected

In total, the evaluator recruited 60 visitor groups over the 7 days of evaluation. Visitors were asked to think aloud as they used the exhibit and to answer a few questions about their experience immediately after they were finished using the prototype. The following data were collected for each participating group:
- Video recording of the visitors' hands as they used the exhibit.
- Video recording of what was visible under the microscope.
- Audio recording of the visitors' think aloud as they used the exhibit.

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- Computer logs. A program logged visitors' activities at the exhibit, including:
  - the microscope's xyz position whenever it was moved,
  - the time and nature of any changes in the objective and light setting,
  - clicks on the specimen panel
  - clicks on the information panel.
- Interview data. The assistant evaluator interviewed the study participant(s) immediately after they indicated that they had finished using the prototype. The interview questions can be found in the Appendix.

Table 2. Distribution of group types.

Group type	Total n = 60	Compare n = 29	Identify n = 31
Adult - Adult	29	12	17
Adult - Minor	9	5	4
Lone Adult	20	11	9
Lone Minor	1	1	0
Minor - Minor	1	0	1

Table 3. Participant demographics.

		Total n = 99	Compare n = 46	Identify n = 53
Sex	F	53	26	27
	M	46	20	26
Age	8-10	6	3	3
	11-12	2	1	1
	13-17	4	2	2
	18-20s	34	15	19
	30s	20	13	7
	40s	17	6	11
	50s	9	1	8
	60+	7	5	2

RESULTS AND DISCUSSION

What did visitors do at the exhibit?

Dwell time

We measured dwell time at the exhibit from video recordings, starting at the end of the interviewer's instructions and ending when visitors indicated that they were ready for interview questions. Visitors spent an average of 7.10 minutes ($SD = 3.2$) at the exhibit. Visitors using the two versions of the exhibit did not differ significantly in their dwell time (Compare: $M = 6.71$ minutes, Identify: $M = 7.46$ minutes, $t = -0.90$, $p = 0.37$).

Specimen selection and Microscope control

Almost all visitors used the specimen selection panel to navigate to an embryo (57/60). On average, visitors navigated to 4.95 different embryos out of the 6 available. Most visitors also used the 10x magnification (54/60) and the fluorescent light (53/60). Visitors used the 10x magnification on average 3.47 times while they used the fluorescent light 4.90 times.

Information Panel

The two prototype versions had different layouts. On the Compare prototype, scaffolding content were displayed in three layers, with clickable tabs labelled *What's Visible, What's Changing, and What's Different* (see Figure 3 left). The top tab, What's Visible, is the content displayed by default when visitors began at the exhibit. 20 of 29 groups (68.97%) made at least one click to access another tab. Among those 20 groups, they clicked the tabs an average of 6.29 times.

On the Identify prototype, the information panel displayed the age of the embryo in view and a picture of a similarly aged embryo with some visible features labelled. There were buttons along the bottom of the panel that visitors could click to investigate further content (see Figure 3 right). 29 of 30 groups (96.67%) clicked on at least one content buttons. Among those 29, they clicked on an average of 4.28 different content buttons.

What did visitors say they tried to do?

After using the exhibit, visitors were interviewed and asked what they tried to do. The most common responses were seeing development of embryos (29/60), identifying features of embryos (20/60), and navigating and trying out exhibit controls (19/60). Visitors also talked about using the UV light (7/60) and information panel (4/60). (Some visitors mentioned more than one activity and their responses were coded accordingly.) Table 4 provides examples of visitors' responses.

Table 4. Examples of visitor responses to what they tried to do.

Visitors tried to see the development of embryos (29/60).
Group 6: Once I kind of figured out what was going on, just starting from the beginning, 3 hours, to 31 hours and seeing the difference, seeing what developed at what time.
Group 14: I was just trying to see what was going to develop.
Group 24: I was trying to go across here [navigation panel] and see what changed between each of them [embryos]. Like what I could pick out being the differences.
Group 30: kind of trying to see the development of the zebrafish and seeing from birth upwards, that was pretty cool.
Group 55: [f1] I'm trying to see how it changed from the 5 hours old to the 44 hours old. [f2] just the development of the zebrafish embryo.
Visitors tried to identify features of embryos (20/60).
Group 8: [c] we tried to find stuff or look at stuff. [a] guided by what was here [info panel]; we were trying to find the heart. Trying to find the blood under the UV light.
Group 31: so just looking at the circulatory system or the head or the body and trying to go in alignment with what was being led to me via the screen, trying to see if I could compare and contrast on my own and what the differences were.
Group 48: what is what in the picture. Where's the heart? Where's the head? Where's the blood?
Group 64: try to find as much parts as we can but unfortunately it wasn't as much.
Group 67: I wanted to see the heartbeat and stuff.
Visitors tried to use the different exhibit controls (19/60).
Group 1: [m] we tried to first figure out the controls, that was step one… [f] You were really into zooming in for some reason. [m] I am. I like getting straight in and zooming back out slowly. I like starting in and then pulling back rather than...
Group 45: [m] the main thing was trying to use the camera focus and move it. [Anything else?] Playing around with the UV light.
Group 47: just try to maneuver it and see if I can figure things out.
Group 49: at first I was moving the camera around cause that was fun. And then I saw when you went on to each of the eggs it showed you what hours it was at. That was cool. It took me a second to figure that out.
Group 54: [f] we started um... [m] I think I just wanted to figure this out by looking at what are the different controls. I had no idea what to expect but once we started playing with it I could figure out what the exhibit is asking us to do,

Table 5 compares the frequencies of these activities across the two exhibit versions. Over 41.38% of those in the Compare group mentioned exhibit controls as what they tried to do. This activity was also common in the Identify group (22.58%) although it was less so. Navigating and trying out exhibit controls are necessary part of the exhibit experience. However, too much attention to the exhibit controls exclusive of exploring the specimen and content could be problematic. Identifying features of embryos was more common among those who used the Identify version of the exhibit. Since the Identify version was designed to facilitate identification, this pattern isn't surprising. Perhaps the emphasis on identification drew visitors' attention to the specimen. Without an equally accessible entry point to the specimen, visitors in the Compare group might have focused more of their attention on the navigation and controls.

Table 5. Visitors' responses to "What did you try to do at the exhibit?"

	Compare n = 29	Identify n = 31	Total n = 60
Seeing development of embryos	15	14	29
Identifying features of embryos	5	15	20
Navigating and trying out exhibit controls	12	7	19
Using the UV light	3	4	7
Using the Information Panel	3	1	4

Design implication 1:
A large majority of visitors used the specimen selection panel and microscope control. This is overall a positive finding, particularly since these controls are a part of our scaffolding design. But the interactive appeal of these controls might come at a cost of less attention to the specimens and scaffolding content for some visitors. This is particularly true for those using the Compare version. About a third of the Compare group did not access the content tabs and never saw key scaffolding content located there. An even larger fraction of this group reported using exhibit controls in their descriptions of what they did at the exhibit. The next iteration of the exhibit might consider limiting access to exhibit controls. For example, access to exhibit controls (i.e. light setting, magnification, and/or specimen selection) could be made available only after a certain amount of time spent at the exhibit or could be triggered by specified visitor activity.

Were visitors interested in looking at the specimen under the microscope?

A majority of visitors found the exhibit either interesting or somewhat interesting (see Table 6). There is no significant difference in interest between the two versions of the exhibit ($\chi^2 = 4.14$, $df = 4$, $p = 0.39$). When visitors were asked what they found particularly interesting at the exhibit, the most common response was seeing a live, moving specimen (31/60). Other common responses were seeing the developmental stages of the embryos (20/60), seeing the heart and/or blood flow (20/60), and seeing with the UV light (8/60).

Table 6. Interview responses to "How interesting did you find this exhibit?"

	Compare	Identify	Total
Not interesting	1 (3.45%)	1 (3.23%)	2 (3.33%)
Somewhat not interesting	0 (0%)	1 (3.23%)	1 (1.67%)
Neutral	3 (10.34%)	7 (22.58%)	10 (16.67%)
Somewhat interesting	11 (37.93%)	6 (19.35%)	17 (28.33%)
Interesting	14 (48.28%)	16 (51.61%)	30 (50%)

Design implication 2:
If it is necessary to streamline the content currently in the information panel (see design implication 4 below), developmental stages of the embryos and heart/blood are two topics that many visitors found interesting.

How did the visitors engage in inquiry?

To understand how visitors engaged in inquiry at the exhibit, we examined visitors' conversations during the think alouds. In particular, we looked for four types of talk as indicators of inquiry: 1) interpretations, 2) questions, 3) inferences, and 4) comparisons. See Table 7 for definitions and examples of these four types of talks. There was no significant difference between the frequency of inquiry talk between the two exhibit versions. We combined data from the two versions in subsequent findings on inquiry talk.

Interpretations were the most common type of inquiry talk. All but one group of visitors made interpretations during their time at the exhibit (see Table 8). It was also the most frequent type of inquiry talk. Visitors made on average 18.73 interpretations during their time at the exhibit. Questions were also common across groups but were less frequent. 57 of the 60 groups asked at least one question. Comparisons and inferences were relatively uncommon. 32 of 60 groups made at least one comparison. 25 of 60 groups made at least one inference. In summary, most visitors engaged in inquiry at the exhibit by describing what they see and asking questions.

Table 7. Definitions and examples of inquiry talk.

Types of talk	Definitions	Examples
Interpretation	Visitors' descriptions of what they saw at the exhibit, including their identifications of the embryos' salient features	Group 7: Its eye is right here. Group 16: Yeah, that's the heart. Look at it pumping away. Group 34: They're constantly moving. That's cool.
Question	Visitors' questions about the content of the exhibit, including talk about what they intended to investigate, predictions about what will happen.	Group 15: What age is that one though? Group 39: What's the yolk? Group 62: Let's see blood.
Inference	Visitors' attempts to explain what they saw from prior knowledge or other resources not directly in front of them at the exhibit.	Group 19: I think the yolk disappears, or starts to decrease in size as it grows, as it eats it. Group 33: It's going through cell division, I learned that in science. Group 45: Oh, I think he's asleep.
Comparison	Visitors' comments on the difference / similarity between two (or more) embryos, or comparisons of parts within one embryo.	Group 13: This one's kind of bigger than that one. Group 24: The difference in what? 14 hours. It's a lot different from this one [points to another embryo]. Group 47: This one looks like a heartbeat or something's moving. This one is not.

Table 8. Mean frequencies of inquiry talk

	Total	Compare	Identify	
Interpretations	18.73	17.34	20.03	(t = -0.87, df = 57.60, p = 0.39)
Questions	9.15	7.86	10.35	(t = -1.55, df = 57.68, p = 0.13)
Inferences	1.00	0.93	1.06	(t = -0.30, df = 56.85, p = 0.76)
Comparisons	1.18	1.34	1.03	(t = 0.76, df = 53.54, p = 0.45)

What types of questions did visitors ask?

Since question asking was a common form of inquiry talk, we examined some characteristics of visitors' questions more closely. First, visitors attempted to answer 69.76% of their questions. We did not assess whether visitors answered their question correctly, only that they attempted an answer or followed through their intentions to investigate.

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Second, we categorized visitors' questions by the type of inquiry (see Table 9). The most common type of question was proposals to investigate (38.94%). For example, visitors expressed their intention to look at an embryo from a particular stage or to use a different light setting. The next most common type was identification question (32.61%). These included largely instances when visitors asked about a feature or stage of an embryo in view. Visitors also asked inference (22.72%) and comparison (5.73%) questions. Inference questions are ones that require background knowledge (e.g. zebrafish physiology, microscope functions, etc.) to answer. Comparison questions were mostly questions about similarities or differences between two or more embryos.

Table 9. Examples of visitors' questions.

Types of question	Examples
Proposals to investigate	Group 14: Let's see what 32 looks like Group 37: So I want to see how this looks at four hours old. Group 54: Let's see if we can see anything under ultraviolent with this guy.
Identification	Group 19: What is that? Group 47: Is this the heart beat? Group 55: Is this the eye?
Inference	Group 20: How long does it take for it to hatch? Group 32: So they're like in a petri dish or something, huh? Group 44: What does it look like with the naked eye?
Comparison	Group 11: What's the difference between that and then this? Group 13: Why is this one shaped differently? Group 20: So that's the oldest?

Design implication 3:
There was no significant difference in the two exhibit versions to indicate that either one was more effective in supporting inquiry talk. Most visitors showed some evidence of engaging in inquiry while at the exhibit. Making interpretations was the most common, possibly because it was one aspect of inquiry that we specifically targeted and was the most supported in this iteration of scaffolding (see Table 1). Question asking was another aspect of inquiry that was supported and was also common in visitor talk. Comparisons and inferences were present but infrequent. There will need to be specific content or tools put in place if we intend to encourage more comparisons and inferences.

To what extent did visitors use the information panel to support their inquiry?

In addition to computer logs of how visitors used the information panel (see above), we also examined visitors' inquiry talk for evidence that they used the information panel. For each instance of interpretation made by a visitor, we noted whether visitors referred to the information panel either by reading or pointing out part of the content. We found that 26.25% of all the interpretations were made with the information panel as a resource. This equates to an average of

4.92 interpretations per group. 53 of 60 groups (88.33%) made at least one interpretation with the information panel as a resource.

We performed a similar analysis on the questions that visitors asked while they were using the exhibit. For each question, we noted whether visitors directly read or paraphrased a question that was posed in the information panel. We found that 7.65% of all visitors' questions came from the information panel.

Design implication 4:
While not all visitors made full use of the information panel (see discussion above), most visitors were using it to support their interpretations. This is likely because content useful for making interpretation, such as information to help identify embryo features, was visible on the default screen (i.e. without any clicks) on both versions of the information panel. However, content designed to support question asking and comparisons required at least one visitor click. This was reflected in the relatively low percentage of visitor questions that could be traced to the informational panel. One possible approach for the next iteration is to streamline the information panel, emphasizing key scaffolding content (e.g. examples of answerable questions, suggestions for comparisons, etc.). For example, these scaffolding content could be visible on the first screen or appear automatically at an appropriate point in visitors' interaction.

SUMMARY

- Inquiry talk was common among visitors. Almost all visitor groups made one or more of the following types of inquiry talk: interpretation, question, inference, and comparison.
- There was no significant difference in the amount of inquiry talk between the two versions of scaffoldings. Dwell time and visitor interest were also similar for the two versions. A larger portion of those who used the *Identify* exhibit clicked for content in the information panel, although there was no evidence that they were more likely to reference the information panel in their questions or interpretations.
- The most common type of inquiry talk was interpretation. Visitors frequently described and identified what they saw on the microscope. Question asking was also common. The most common type of questions was proposal to investigate aspects of the exhibit, followed closely by identification questions. Visitors attempted to answer most of their questions. These findings from visitor talk suggest that visitors were actively engaged in activities important to scientific inquiry.
- About half of the visitor groups made comparisons. The infrequency might be due to the relative difficulty and effort needed to make comparisons. While one of two prototype versions was designed to support comparisons, almost half of the visitors assigned that version never reached the content targeted at making comparisons. These findings suggest that visitors might need more explicit support to both propose and carry out comparisons that they can make at this exhibit.
- Less than half of the visitor groups made inferences. Since making inferences often require relevant background knowledge, it was perhaps unsurprising that inferences were relatively infrequent.
- There were some indications that visitors used the information panel to support their inquiry. Most visitors clicked on the supporting content. The content provided was used as a resource

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for making a substantial fraction of visitors' interpretations. Meanwhile, aspects of the content, such as suggested comparisons and questions to investigate, were underutilized. Future iteration of this exhibit should streamline the content, emphasizing components that are most central to scaffold visitors' inquiry.

- A substantial fraction of visitors described what they did at the exhibit as navigating around and trying the different functions of the exhibit. While such behavior was necessary to get acquainted with the exhibit's tools and specimens, the extent of options available could potentially monopolize visitors' attention at the cost of deeper investigations. Careful viewing of a few visitors' recorded interactions echoed visitors' self-reports of going through the various exhibit options. Future iterations might consider limiting the options available by fine-tuning the optimal number of zebrafish specimens and/or further scaffolding the use of microscope settings.

ACKNOWLEDGEMENTS

APPENDIX

Interview questions:

1. How interesting did you find this? Would you say this was ...

Not Interesting	Somewhat Not Interesting	Neutral	Somewhat Interesting	Interesting

2. What made it _____ for you?

3. Can you tell me what you tried to do?

      a.   Was there anything frustrating or confusing about [use their words]? What? [Anything else?]

4. Was there anything particularly interesting that you saw at the exhibit? Anything else?

      a. can you tell me more about that

5. Do you have any special interest or background that might have helped you understand what you saw?