Gigapixel Image Environments for Science Communication and Learning: Macroinvertebrates Digital Teaching Collection Summative Evaluation

Submitted by:

Rockman et al
Research & Evaluation

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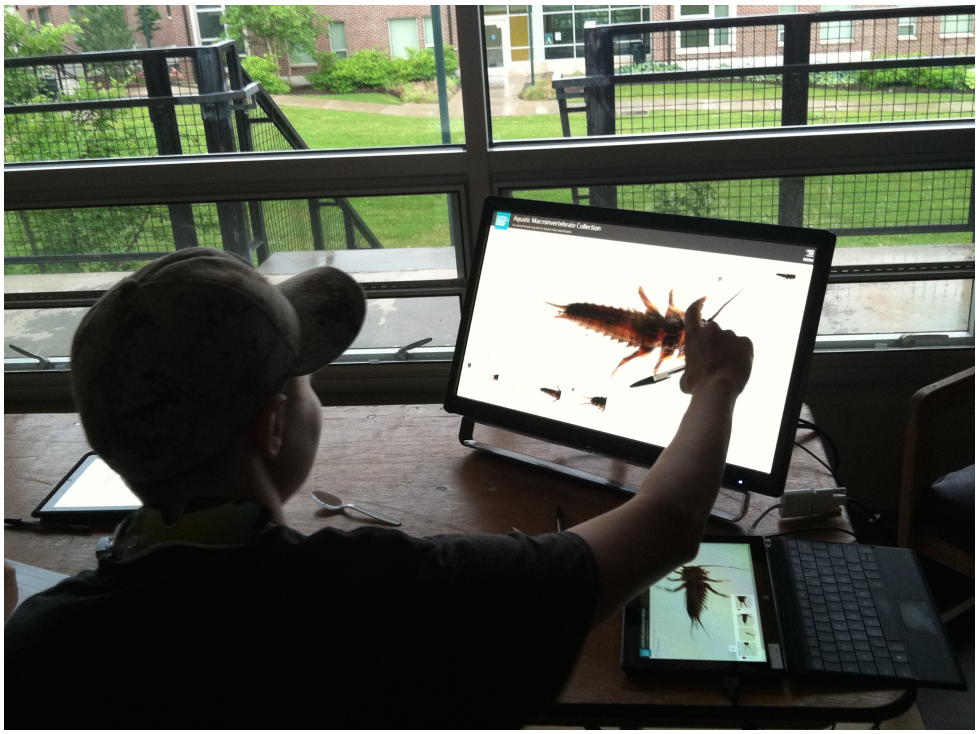
Macroinvertebrate Digital Teaching Collection

Summative Evaluation



Submitted to:
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in Out-of-School Environments

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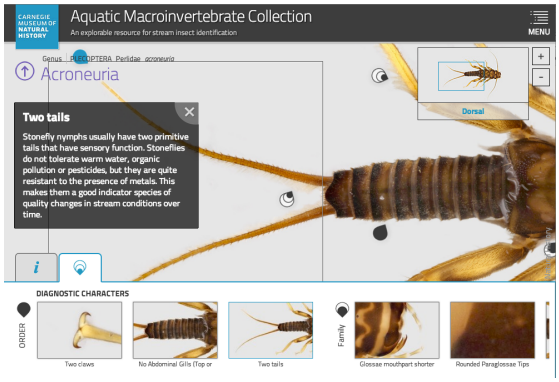
Executive Summary

"Now I know what characteristics I'm looking for. Before it was like, 'Oh that bug sort of looks what she's describing,' but now I can be like, 'It has this number of legs, this number of tails.'"
- Youth Volunteer

"It makes a great comparative platform…having a good digital image that you can zoom in that's fully annotated with all these different characteristics, I think that really helps a novice to take away the main point about this insect…because they do this a time or two, they start to remember things…Stoneflies have two tails. Mayflies have three tails. Mayflies have gills on their abdomen. Stoneflies have gills on their thorax. So without really knowing it, they're training themselves on some of the really basic identification techniques."
- Participating Scientist

Rockman et al (REA), in partnership with Marti Louw and the **University of Pittsburgh Center for Learning in Out-of-School Environments** (UPCLOSE) conducted a summative evaluation in Summer 2014 of an aquatic macroinvertebrate digital teaching collection (macroinvertebrates.org) containing voucher specimens from the Carnegie Museum of Natural History (CMNH) in Pittsburgh, PA. The digital teaching collection groups three orders of aquatic insects (stoneflies, caddisflies, and mayflies), and users can click on a specific insect and get information on its genus, habitat, behaviors, size, abundance, pollution tolerance, and where and when it was collected. Videos and audio from expert scientists and relevant links to other websites are also provided. Each insect is tagged with interest spots that, when clicked, open up an overlay that indicates a specific diagnostic characteristic that can be used to identify that insect's genus. The images are zoomable and can be viewed in a high level of detail (see Figure A).

Figure A: The landing page for macroinvertebrates.org; Interest spot for a stonefly



The digital teaching collection was the second in a set of demonstration projects to study the extent to which gigapixel image technology can support scientific communication and learning within different approaches to interactions between scientists and public audiences. The collection was designed to address the need for more robust materials to support citizen scientists in more accurately and confidently conducting insect identification work, with the goal of cataloging insects that can indicate the health of a stream or river based on their pollution tolerance and presence or absence in a particular area.

To investigate the effectiveness of the digital teaching collection in supporting users' accuracy and confidence in insect identification, REA used a mixed-methods approach to examine the impacts of the digital teaching collection on high school youth at an environmental science summer camp called *Creek Connections*. During the camp experience, youth collected and sorted insects from two portions of a local stream using traditional identification tools (dichotomous keys and flashcards). Afterwards, they returned to camp headquarters and were asked to fill out a brief demographic survey (see Appendix A). Groups of 2-3 individuals were then asked to work together to identify six insects by order, genus, and family and fill out a worksheet listing their guess, as well as the diagnostic characteristics they used to make that classification (see Appendix A). Each group was given the digital teaching collection for three of the insects, and either a dichotomous key (Tetra Tech's *Family Level Key to Stream Invertebrates* with illustrations and color photographs) or Voshell's illustrated F*lashcards of Common Freshwater Invertebrates* for the other three insects (see Figure B). Evaluators took observation notes and photographs during the identification process, and audio recorded the conversations that took place within each group. After completing their identifications, all youth participated in a focus group to share what they had liked and disliked about each tool, and what they found difficult about insect identification (See Appendix B). Participating educators from the camp, as well as scientists who contributed content to the digital teaching collection, were also interviewed to gather information about the challenges in training people to do insect identification and the affordances of the digital teaching collection See Appendices C & D).

Figure B: Types of resources used during the embedded assessment activity (left: dichotomous key; right: digital teaching collection)

Key Findings

The digital teaching collection addresses the difficulties that volunteers have in identifying insects and meets educators' and scientists' expressed need for effective citizen science training.

- Youth volunteers, scientists and educators all reported slightly different challenges to doing or training someone to do insect identification.
    - Youth participants indicated that the three main challenges to insect identification are that insects are small and it is often difficult to see their features, many types of insects look similar to one another, and that specimens collected in the field often look different from the images provided in field guides (i.e. they may have missing limbs, etc.).
    - Educators also thought that the size of the insects is a challenge. However, they listed volunteers' lack of confidence in the accuracy of their responses as an issue as well.
    - Scientists stated that the main difficulty in conducting insect identifications is finding an appropriate tool with which to compare a specimen. They also felt that the vocabulary used by experts is off-putting to novice volunteers.
- Youth volunteers, scientists, and educators felt that the digital teaching collection addressed the above challenges.
    - Volunteers liked that the digital teaching collection allowed them to zoom in on the images, clearly called out diagnostic characteristics that differentiated one insect from another, and organized the tool by Order and Family, which helped them recognize unique features of a group, regardless of the state of the original specimen.
    - Educators agreed that the digital teaching collection provided authentic, detailed images of insects and their relevant features that helped to increase volunteers' confidence in the accuracy of their identifications.
    - Scientists thought that the digital teaching collection was a quality comparative collection and appreciated that it listed both scientific and everyday vocabulary in its descriptions of each insect.

The digital teaching collection is more effective at supporting volunteers' accuracy in and confidence around insect identification than traditional, paper-based resources.

- Volunteers who used digital teaching collection had significantly more correct insect identifications at a deeper level of accuracy, compared to those who used traditional identification tools, such as dichotomous keys and flashcards.

- Volunteers who used the digital teaching collection were significantly more confident in the accuracy of their identifications than those who used the dichotomous key.

The digital teaching collection is preferred by youth volunteers, although educators prefer the dichotomous key for basic identification work.

- Youth volunteers preferred the digital teaching collection to the dichotomous key.

- Volunteers were evenly split between the digital teaching collection and the flashcards in terms of their preferred tool.

    - Those who preferred the flashcards acknowledged that they had actually been more accurate in their identifications using the digital teaching collection than they had been using the flashcards.

- While educators liked the digital teaching collection's detailed imagery and attention-grabbing technology, they thought that the dichotomous key was more practical for data collection in the field and was useful if volunteers were only going to Order.

The digital teaching collection is accessible to be used in a variety of educational contexts.

- Scientists liked that the tool was available to the public online, rather being locked in a museum or laboratory and unable to be utilized.

- Educators thought that the digital teaching collection would be best used as an extension activity with volunteers who had time and interest in a more in-depth examination of diagnostic features.

- Educators felt that the digital teaching collection would be a great resource for classroom teachers, either during professional development workshops or with their students - particularly those who were unable to visit an actual creek or stream.

The digital teaching collection is valued by scientists as a way for citizen scientists to make an evidence-based case for the health of their local streams, and as a tool for supporting their own identification practices.

- Scientists indicated that unlike typical field guides, which are difficult for novices to use, the digital teaching collection is intuitive and supports citizen science volunteers' observations by highlighting the relevant features of each insect.

- Scientists indicated that their observations of the digital teaching collection in-action had given them a new perspective on novices' ability to do identification work - They now saw value in and trusted the quality of volunteers' insect identifications.

- Scientists shared that making expert videos describing their practices helped them to realize the important elements of their own identification processes.

Conclusions

The digital teaching collection was successful in meeting the main goal of the project - to effectively support volunteers' accuracy in and confidence around their insect identifications. Outcomes from the embedded assessment activity suggest that the digital teaching collection could be an effective tool for other citizen science programs to use to conduct volunteer training on identifying aquatic insects.

Scientists and educators often already know what to look for, but the digital teaching collection can help novice volunteers begin to recognize diagnostic characteristics that are important to identification work. In this way, the digital teaching collection provides an organizer for trainers to use to facilitate more expert kinds of noticing, so that novices start to see insects through the eyes of an entomologist.

Introduction

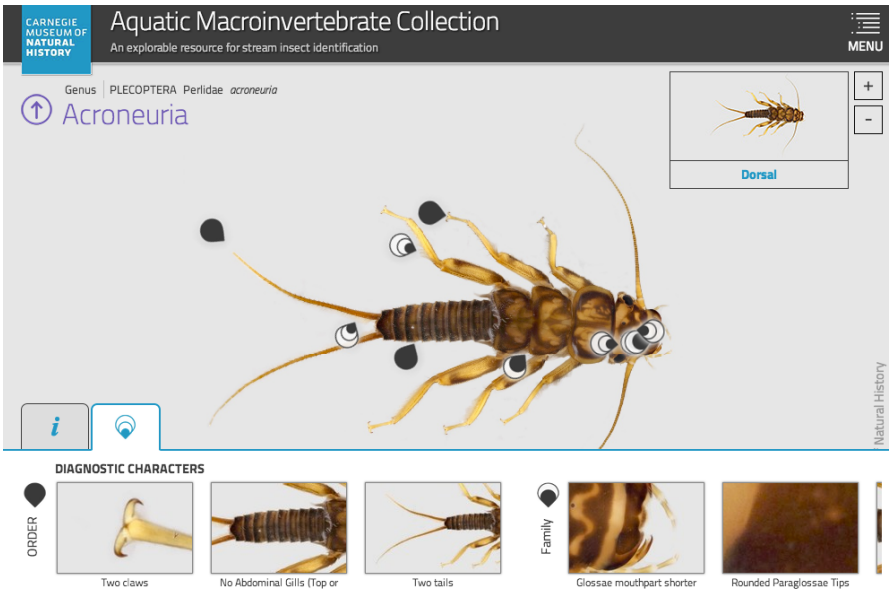
Project Description

Rockman et al (REA), in partnership with Marti Louw and the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE) conducted a summative evaluation in Summer 2014 of an aquatic macroinvertebrate digital teaching collection (macroinvertebrates.org) containing voucher specimens from the Carnegie Museum of Natural History (CMNH) in Pittsburgh, PA.

The digital teaching collection was the second in a set of National Science Foundation-funded demonstration projects to study the extent to which gigapixel image technology can support scientific communication and learning between scientists and public audiences. The collection was designed to address the need for more robust materials to support citizen scientists in more accurately and confidently conducting insect identification work, with the goal of cataloging insects that can indicate the health of a stream or river based on their pollution tolerance and presence or absence in a particular area.

The digital teaching collection groups three orders of aquatic insects (stoneflies, caddisflies, and mayflies), and users can click on a specific insect and get information on its genus, habitat, behaviors, size, abundance, pollution tolerance, and where and when it was collected. Videos and audio from expert scientists and relevant links to other websites are also provided. Each insect is tagged with interest spots that, when clicked, open up an overlay that indicates a specific diagnostic characteristic that can be used to identify that insect's genus (see Figure C). The images are zoomable and can be viewed in a high level of detail.

Figure C: Screenshot from the macroinvertebrates.org website



Evaluation Focus & Methodology

The main purpose of the evaluation was to see to what extent the aquatic macrointervebrate digital teaching collection facilitates science communication and learning, and to demonstrate the kinds of interactive visual supports that can impact citizen science volunteers' accuracy in and confidence around identifying insects. A secondary goal of the study was to see how volunteers used and talked about the technology while engaged in observational practices, and to find out what youth volunteers, informal educators, and scientists thought about the digital teaching collection compared to more traditional paper-based resources.

Questions guiding REA's evaluation were as follows:

1.) Are volunteers able to use the aquatic macroinvertebrate digital teaching collection to accurately identify insects?

a.) Can they do so at the Order and Family level?

b.) Are volunteers significantly more accurate when using the digital teaching collection, compared to more traditional paper-based resources?

c.) Does volunteers' gender, grade level, prior interest in or knowledge about insects affect their accuracy?

2.) Are volunteers confident in their ability to accurately identify insects using the digital teaching collection?

a.) Are they confident at the Order and Family level?

b.) Are volunteers significantly more confident when using the digital teaching collection, compared to more traditional paper-based resources?

c.) Does volunteers' gender, grade level, prior interest in or knowledge about insects affect their confidence?

3.) How many diagnostic characteristics do volunteers notice when using the digital teaching collection, compared to more traditional paper-based resources?

a.) Does volunteers' gender, grade level, prior interest in or knowledge about insects affect the quantity of characteristics mentioned?

4.) How do volunteers use the aquatic macroinvertebrate digital teaching collection?

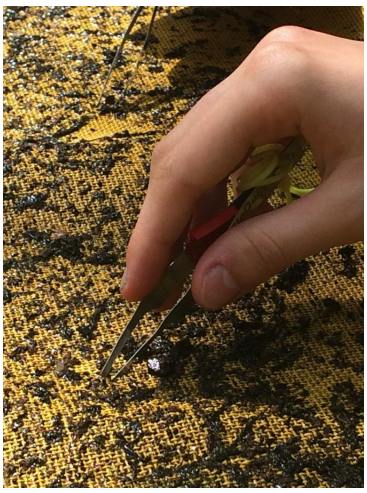
a.) Are there differences in the conversations that occur around the digital teaching collection compared to those that take place while using a traditional dichotomous key or flashcards?

5.) What do volunteers, informal science educators, and scientists think about the digital teaching collection?

6.) What do volunteers, informal science educators and scientists think is challenging about observing and identifying insects?

To find out whether the aquatic macroinvertebrates digital teaching collection was effective in impacting volunteers' accuracy with and confidence in their aquatic insect identifications compared to more traditionally used resources, Rockman et al conducted an embedded assessment activity with two groups of high school-aged youth participating in a summer camp experience called *Creek Connections*. In the *Creek Connections* program, youth collect insects from local streams and seek to identify and count those insects as one indicator of water quality (see Figure D). The campers use a dichotomous key and have access to flashcards on-site, but are only asked to identify to Order for the purposes of the program.

Figure D: Identification Activities Within the Creek Connections Program



The embedded assessment activity occurred in the evening back at the dormitory after the campers had already used the traditional identification tools that morning and taken part in other camp-related activities, such as chemical water quality testing and a field trip to a local dam. The embedded assessment consisted of six stations of petri dishes with voucher specimens taken from the Carnegie Museum of Natural History's collection. Each station also had a magnifying glass and flashlight for the participants to use. During data collection with Group 1, three stations had a dichotomous key (Tetra Tech's *Family Level Key to Stream Invertebrates* with illustrations and color photographs) and three stations had an iPad with the digital teaching collection (macroinvertebrates.org). During data collection with Group 2, three stations had Voshell's illustrated F*lashcards of Common Freshwater Invertebrates* and three stations had an iPad with the digital teaching collection (see Figure E). The insects at the digital teaching collection stations were rotated between Group 1 & 2 data collections as one method of ensuring that it was the tool itself, rather than the insects chosen, that affected the results. Participants were asked to work in groups of one to two other students and went to

each of the six stations, using the resource available at that station to try to identify the insect at the Family, Order, and Genus level. They were also asked to indicate their level of confidence in their identification and to provide a list of characteristics they used to categorize each insect on the data entry form provided (See Appendix A). Evaluators took observation notes and photographs during the identification process, and audio recorded the conversations that took place within each group. At the end of the experience, students listed what they liked and disliked about each resource that they used and participated in a focus group in order to gather further information about their experiences using each resource during the identification process (See Appendix B).

Figure E: Types of resources used during the embedded assessment activity (left: dichotomous key; right: digital teaching collection)

Findings

Youth Volunteer Impacts

Who participated in the embedded assessment activity?

Twenty-one 9th through 11th grade volunteers from the *Creek Connections* program participated in the embedded assessment activity (8 from the first camp session and 13 from the second group). Of these, most (86%) were in 10th or 11th grade. The majority of participants (62%) were female.

71% had done some sort of insect identification before, but most were only somewhat confident in their abilities to accurately identify a specimen (see Table 1). In fact, female participants (92%) were significantly more likely than male participants (38%) to have done insect identification before; t(19)=-3.178, p=.005.

Table 1: Participants' Knowledge of and Attitudes Towards Insects Before the ID Activity (N=21)

Statement	No, Not At All (0)	No, Not Really (1)	Yes, Somewhat (2)	Yes, Definitely (3)	Average
I know a lot about insects.	0	13	7	1	1.43
I am confident in my ability to identify insects.	1	3	15	2	1.86
I want to find out more about insects, generally.	0	4	8	9	2.24
I want to find out more about aquatic insects.	0	2	8	11	2.43

*Indicates a significant difference at the p<.05 level
**Participants were not asked to indicate Genus for the Dichotomous Key

Several participants (76%) acknowledged that ID work is difficult. The top three things that volunteers indicated were challenging about ID work were that the insects are small and their features are hard to see, that many types of insects look similar to one another, and that collected specimens often look different than the image provided:

> *"Caddisflies are actually pretty similar to each other: Three tails, six legs – it would be hard to identify which one's which."*

"With the mayflies, with the line one even some of them look alike. There's some features that make them different, like on one of the bugs there was a little spike thing…Not noticing those things, you wouldn't recognize that they were the same or different."

"The sample that you get might not be exactly to the picture. It's missing a leg or a tail or something."

"I think [field guides are] really hard to understand because the drawings aren't very clear and sometimes you'll have something that's a mayfly thing, but it doesn't look like the one that's in the picture because they're different types."

Many participants (86%) liked learning about aquatic insects:

"They seem cool, and I'd like to build a better understanding about some of them too."

"Because they are great bioindicators for water quality and ecosystem health and they are also very unique and interesting."

"I LOVE learning about aquatic insects! It's so much fun to look at all of the diversity."

A few participants weren't into aquatic insects, but had other interests that overlapped:

"Insects don't interest me very specifically, but I do like saltwater/freshwater life. So it's a good common ground."

Only one camper shared her dislike for insects, calling them *"boring"* and *"gross."*

The majority of participants (62%) indicated that they did not know a lot about insects before the assessment activity. Most (81%) were at least somewhat interested in learning more about insect identification, and slightly more (91%) were interested in learning more about aquatic insects, in particular.

How accurate were participants' identifications by resource?

Volunteers' accuracy was measured by whether their identifications at a particular level (Order, Family, or Genus) for each insect were correct or incorrect (0 or 1). Results indicated that participants using the digital teaching collection had more correct insect identifications at a deeper level of accuracy than when they used other resources (see Table 2):

- Youth who used the digital teaching collection OR the flashcards **correctly identified an insect significantly more often** than when they used a dichotomous key.
- Youth who used the digital teaching collection **correctly identified an insect significantly more often** than when they used the flashcards.

- Youth who used the digital teaching collection OR the flashcards were **significantly more accurate in identifying an insect to Order** than when they used a dichotomous key.
- Participants who used the digital teaching collection were **significantly more accurate in identifying an insect to Family** than when they used the flashcards OR the dichotomous key.
- Participants who used the digital teaching collection were **significantly more accurate in identifying an insect to Genus** than when they used the flashcards.

The impacts of various participant demographics on accuracy of identification while using the digital teaching collection were also examined. There were no significant differences by gender or grade level. In addition, there were no significant differences between youth who had done insect identification before and those who had not. There were also no significant differences based on volunteers' interest in insects generally or in aquatic insects specifically, or based on their interest in learning more about insects. Taken together, these results suggest that it was the digital teaching collection, and not prior interest or knowledge that supported volunteers' accurate identifications overall and to Order and Family specifically.

Table 2: Accuracy of Insect Identification By Resource

	Dichotomous Key	Flashcards	Digital Teaching Collection	Significance Level
Order	50%	100%	98%	.000*
Family	17%	38%	86%	.000*
Genus	N/A**	38%	87%	.000*

*Indicates a significant difference at the p<.05 level
**Participants were not asked to indicate Genus for the Dichotomous Key

Surprisingly, participants' who reported being knowledgeable about insects before the embedded assessment activity were significantly less likely to accurately identify an insect to the Genus level while using the digital teaching collection than those who said that they were not very knowledgeable about insects; $F(2,9)= 5.500$, $p=.028$.

How confident were participants in their identifications by resource?

Confidence was measured by participants' self-reported belief in the accuracy of their identifications at a particular level (Order, Family). Participants indicated Low (0), Medium (1), or High (2) levels of confidence for each category. Results indicated that youth using the digital teaching collection were significantly more confident in the accuracy of their identifications than when they used the dichotomous key (see Table 3):

- Volunteers who used the digital teaching collection were **significantly more confident in their identifications to Order** than when they used a dichotomous key.
- Volunteers who used the digital teaching collection OR flashcards were **significantly more confident in their identifications to Family** than when they used the dichotomous key.

The impacts of various participant demographics on their confidence in identification, while using the digital teaching collection were also examined. There were no significant differences, except in participants' confidence in their Order level identifications - Those who had felt more confident in their ability to do insect identification work beforehand were, in fact, significantly more likely to correctly identify insects using the digital teaching collection at the Order level than those who had less confidence to begin with; $F(2,12)= 5.200$, $p=.024$. This did not hold true for identifications at the Family level, suggesting that volunteers' confidence in the accuracy of their identifications was not well-matched for deeper levels of specificity.

Table 3: Confidence In Insect Identification By Resource

	Dichotomous Key	Flashcards	Digital Teaching Collection	Significance Level
Order	1.39	1.76	1.89	.004*
Family	1.09	1.68	1.87	.000*

*Indicates a significant difference at the $p<.05$ level

Did the types of observations made by participants differ by resource?

The quantity of participants' observations was measured by the number of features that they listed to describe each insect. There were no significant differences between volunteers who used the digital teaching collection and those using the other resources, with regards to the amount of diagnostic characteristics mentioned (see Table 4). However, volunteers who used the flashcards listed significantly more features than those who used the dichotomous key.

Table 4: Number of Unique Characteristics Mentioned By Resource

	Dichotomous Key	Flashcards	Digital Teaching Collection	Significance Level
Average Number of Features Mentioned	3.00	4.23	3.53	.007*

*Indicates a significant difference at the $p<.05$ level

The impacts of various participant demographics on the number of diagnostic characteristics mentioned while using the digital teaching collection were also examined, and no significant differences were found.

Regardless it appears that volunteers recognized that the digital teaching collection helped them focus in more on relevant features for insect identification in contrast with a descriptive list of what each insect looks like:

> *"I know for different organisms you can see – on one of the bugs, I don't know which station it was – but if you turn it on its dorsal side, you could see the insides and it has like this black line, and I think that's what helped me the most with the online."*

> *"Now I know what characteristics I'm looking for. Before it was like, 'Oh that bug sort of looks what she's describing,' but now I can be like, 'It has this number of legs, this number of tails.'"*

Therefore, further investigation is needed to determine the ways in which the digital teaching collection might support training around observers' notation of relevant features. Some insights can be gained by exploring conversations that participants had using each of the identification resources. All volunteers started out using a hand lens to magnify their view of the actual specimen and make some initial observations before using the provided tool. In the first example of conversations around a resource, a pair of male youth volunteers are trying to identify a flat headed mayfly using the dichotomous key.

Table 5: Example Volunteer Conversation Using Dichotomous Key

Conversation	Further Description of Activity
P1: Okay, so definitely- three tails.	*The pair is using the hand lens to identify some features of the specimen, having already done the task a few times at other stations using either the dichotomous key or the digital teaching collection.*
P2: You can definitely tell that it has gills. No, maybe that's- No, that's- So this is B5. We're playing BINGO. Three tails.	*P2 is unsure whether he is seeing gills on the specimen (B5).*
P1: Uh, four legs. Two pairs.	
P2: I think we're looking at its stomach. Can we flip this over?	*The pair receives a small spoon to move their specimen around its petri dish.*

Conversation	Further Description of Activity
P1: …Okay, so big eyes again. Brownish to dark brown color.	
P2: …Its legs look like fins or something to swim.	
P1: Can I see? Thanks. Oh, yeah. It looks like frog legs almost. Can I see? Definitely not stonefly.	*After viewing the specimen in the dish, P1 declares that it is not a stonefly.*
P2: Look for like a three tail. This is the different book.	*P2 tells P1 to look in the dichotomous key to determine what kind of insect it is.*
P1: Three tails. It's a mayfly.	*P1 is able to successfully identify the insect's Order.*
P2: Well, here. Try and find it in here.	
P2 [flipping through the pages]: …Hold on, let's- Maybe it's a Damesfly.	*However, he becomes unsure of his ID as he continues to look through the dichotomous key.*
P1: It's the what?	
P2: A Damesfly. I don't know.	
P1: I think it's the mayfly, because remember there were only like mayfly, stonefly, and the one larvae that we were working-	*P1 posits that each station likely has one representative from the three Orders of aquatic insects, so he uses a process of elimination strategy to make his case for their specimen's Order.*
P2: Yeah, maybe. Well, didn't the mayfly only have two tails and this has three?	*P2 cannot remember what the diagnostic characteristics of a mayfly are.*
P1: No, in this book it says - So the last one was stonefly. See? Alright.	*P1 realizes that they miscategorized their last specimen as a mayfly using the dichotomous key. He hypothesizes that it was probably a stonefly because it only had two tails.*
P2: No, look. It says the same.	*P2 is confused by the imagery in the dichotomous key that deals with the number of tails.*
P1: Huh. We have a question.	
P2: They both say mayfly and they both look -	
P1: Except one has one more tail.	*The pair questions whether an insect with two tails and an insect with three tails can both be mayflies.*

The two boys using the dichotomous key eventually identify specimen B5 as a mayfly, which is the correct Order, but they are not able to determine the correct Family due to the ambiguity they encountered in matching the imagery and information from the key to what they were seeing with the specimen. This pattern was quite frequent among volunteers using

the dichotomous key, perhaps because the branches of the key led them down a particular path that was hard for them to backtrack from once they had committed to a feature (i.e. number of tails).

Volunteers who used the flashcards often had a similar experience, with many being able to identify an insect correctly to Order, but had trouble providing a more detailed classification. In the next example, two male youth volunteers are correctly able to identify specimen B1 to Order and Family as a case maker caddisfly, but they are unable to figure out to which Genus it belongs.

Table 6: Example Volunteer Conversation Using Flashcards

Conversation	Further Description of Activity
P1: So I'm gonna say white body, black head. White, almost see through body.	*The pair begin by looking at the specimen through the hand lens and discussing its features.*
P2: Yeah, because this is-	
P1: See through body.	
P2: Let's talk about its shell.	*P2 recognizes the importance of the shell as a unique characteristic for this insect.*
P1: Separate from brown shell.	
P2: Brown shell.	
P1: Do you think that's enough to count- I can't really tell how many.	*P1 wonders if they have gathered enough information to make an identification.*
P2: It looks like he has about two antennaes. Let's-	*P2 wants to continue his observations.*
P1: I'll set them right here. Oh, wait! That's brown shell, but the head.	*P1 flips through the flashcards, trying to find an insect that matches their specimen.*
P2: Yeah.	
P1: This is the only one that sort of looks the same as ours...Wait, wait. I mean that's the only one that has a brown shell. Look, we should like- no, because look at the shell. Look at- and look at this shell.	*P1 encounters an issue when the shell of the insect on the flashcard looks like the shell that their specimen has, but the head is different.*
P2: Let me see what his head looks like. Maybe his head just looks like because it's like from the top and from here we can see it from the side, because he does look like he has legs.	*P2 hypothesizes that perhaps the head looks different because of the perspective that the artist took on the flashcard.*

Conversation	Further Description of Activity
P1: Want to move it over? Here, use the brush.	*P1 and P2 decide to move the specimen around to get a better look from multiple angles.*
P2: Definitely has legs.	
P1: There. It looks like he has two, maybe three legs on each side.	*P1 & P2 identify the number of legs that they think their specimen has.*
P2: Um, it looks like three legs, because it looks like he has one right under him.	
P1: Wait, wait. Let's look at the shape of his head.	*P1 remembers that the head is what they wanted to look at to determine whether the specimen matched the picture on the flashcard.*
P2: Yeah! It looks like that! Because he has them directly under.	*The view that they get of the specimen convinces P2 that they have found a match.*
P1: I want to flip him back over again.	
P2: Okay. I think it's that one. I'm very sure that it's that one.	
P1: and it's the only one that has this kind of shell- the brown shell.	*P1 agrees that the shell on their specimen and the shell pictured on the flashcard are the closest match.*
P2: …Okay, it's the giant case-maker caddisfly. Huge name! … Okay, his Order is a weird thing that I can't pronounce and Family.	

Here, the two youth are able to use relevant diagnostic features on the flashcards to try to determine the identity of their unknown specimen. The boys run into trouble when the image on the flashcard does not quite match up with the specimen they are viewing, a challenge that several volunteers identified as a common issue when doing identification work.

Finally, the third example shows two female volunteers successfully using the digital teaching collection to correctly determine that specimen A5 is a flat headed mayfly. The girls begin their observation by looking at the specimen from multiple angles.

Table 7: Example Volunteer Conversation Using the Digital Teaching Collection

Conversation	Further Description of Activity
P1: Can you pass me the spoon? I want to move it around.	*P1 wants to examine the specimen first.*
P2: Yeah. Okay, so-	
P1: So it has three tails.	
P2: Three tails- oh, I know what he is, maybe. Yeah.	*P1 notices a feature, and P2 uses the digital teaching collection to figure out its Order.*
P1: Well, we have to do it.	
P2: it's definitely a mayfly.	
P1: Three tails, two legs.	
P2: Two legs?	*P1 finds a second feature of the specimen, which surprises P2 because it is not a characteristic of mayflies.*
P1: Yeah.	
P2: Okay, then. Maybe not.	*P2 begins to doubt her classification.*
P1: I think he has white spots on like the front of his face. Like right on the front of his face. You see those little white spots?	*P1 sees another feature on the specimen and points it out to P2.*
P2: Yeah, there's about five of them.	
P1: I'm just gonna say-	
P2: White spots on face.	*Both girls write down their observations.*
P1: White spots.	
P2: Oh, I know who he is. It's that one! Only one with the white spots.	*P2 becomes excited when she is able to find an insect in the digital teaching collection that has the unique characteristic of white spots.*
P1: No, he has three legs.	*P1 doubts the classification because of her earlier observation that their specimen has two legs.*
P2: He might be missing legs. But he's the only one that matches. Well, that matches the closest.	*P2 is able to overcome a common hurdle in insect identification, recognizing that their specimen might not look identical to the voucher specimen online.*

Conversation	Further Description of Activity
P1: I know, and then it could be any of those guys… But like look at the front legs. The design is a little different, like the shape of them. I mean I don't know who else it could be, but-.	*P1 uses evidence from the digital teaching collection to question whether the legs on the voucher specimen are the same shape as the legs on their specimen.*
P2: Yeah, let's look closer.	
P1: Can you look closer at the legs?	*The girls agree to zoom in on the legs using the digital teaching collection.*
P2: Yeah, do they have-	
P1: It looks like this guy has two legs, but the one that matches has three legs.	*P1 is still not convinced that the voucher specimen and their specimen are the same type.*
P2: Yeah.	
P1: I don't know.	
P2: I mean, no because his front leg matches that one.	*P2 is able to get to a level of detail on the screen where she can make the claim that the legs of the voucher specimen are the same as their specimen.*
P1: Let me see! Let me see!	*P1 is excited by this new development and wants to observe for herself.*
P2: See, because the way it's-	
P1: Maybe one of them's just bent under it or something. Broke off, I don't know. I mean it's the only one that matches it.	*P1 now agrees with P2, that their specimen might not be exactly identical to the voucher specimen, but that it has all of the salient features to make an ID.*
P2: Yeah.	
P1: Okay, it has to be that one. That's the only one with white spots.	*P1 concludes that their specimen and the voucher specimen are the same type of insect. Soon after, they indicate that their specimen is a flat headed mayfly.*

The girls are able to correctly identify their specimen by using the digital teaching collection to build a body of evidence using diagnostic features of aquatic insects. By using features like tails and legs to narrow down their search, the girls are also able to see unique characteristics (i.e. white spots) that give them the confidence to claim that their specimen is, in fact, a flat headed mayfly. In this way, the digital teaching collection scaffolds volunteer observations by allowing them to zoom in using a fine level of detail in order to look for similarities and differences between insects.

Youth Volunteers' Perspectives

What features did volunteers use to help them identify a particular insect?

Participants used a variety of characteristics to assist them in making their insect identifications. These included looking for insects with gills, antennae, claws, and shells. Volunteers also paid attention to the number of legs, the tail length, and the shape of the insect's body.

What did youth think about the digital teaching collection compared to the other resources?

Participants were asked what they liked and disliked about using the digital teaching collection (see Table 8). The top three things that students self-reported liking about the digital teaching collection were the detailed images (52%), ease and efficiency of use (29%), and the way in which the insects were organized within the online interface (29%):

> *"The high resolution images were helpful to see the details on the insects."*

> *"The digital one is really nice because of the touch screen and how easy it is to use. The pictures are also extremely good, so it is easy to compare the real specimen and the picture."*

> *"It goes from family to order, and you can see all the family things and all the characteristics. You can go back from order to family and you can see the features that make it a certain order or certain family or certain genus."*

In addition, campers found the focus on the salient features of each insect to be particularly helpful in doing their identification work:

> *"There were like the three different sections, so you could narrow it down by the tails, gills or whatever, and you could narrow down what it was a lot faster."*

> *"You clicked on a certain body part and the information's there on that body part, and you're like, 'Oh yeah. That matches that bug.'"*

Volunteers also appreciated that the layout of the website afforded them opportunities to compare one type of insect to another:

> *"On the website, it was all laid out for you. So you could kind of compare and say, 'Oh, well! That one can't be it and this is the one that's left.' It was just easier to see all of them together to see the characteristics."*

"I feel like on the website, you were able to see different bugs next to each other, you could see the Family, Order, whatever. You could see a bunch of them next to each other, so you could spot them out easily. Tell differences between each other."

Table 8: Aspects Participants Liked About the Digital Teaching Collection*

Aspect	Percentage of Respondents Who Mentioned (N=21)
Detailed Images	52%
Ease of Use/Efficiency	29%
Categorization of Insects	29%
Information Provided	19%
Hands-On	14%
Ability to Zoom	14%
Fun	10%
Interest Spots with Annotations	5%
None Listed	5%

* Participants could list more than one aspect

Most (52%) could not think of anything that they disliked (see Table 9). Of those that listed something, a few (29%) found the organization of the interface confusing and hard to navigate:

"You just had so many options that you didn't really know how to use it. After awhile, you kind of got used to how it worked, but still there are probably things on there that most of us didn't use."

Several participants indicated that they had not noticed that some of the insects could be viewed from different angles on the website, but that they liked this feature and wished that all of the insects had been able to be viewed in this manner.

Table 9: Aspects Participants Disliked About the Digital Teaching Collection

Aspect	Percentage of Respondents Who Mentioned (N=21)
None Listed	52%
Hard to Navigate/Confusing	29%
Not Enough Insects	10%
Too Many Options	10%
Cannot Rotate All Insects	10%
Requires Internet Connection	5%

* Participants could list more than one aspect

Volunteers also shared the characteristics that they liked and disliked about the flashcards and the dichotomous key. Participants liked that the flashcards were easy to use, had detailed pictures, and had helped them learn (15% of the volunteers mentioned each of these aspects, N=13). One camper noted that the flashcards had each insect's measurements to-scale:

> *"One thing that I did like about the flashcards was it would tell you how big or how small they were going to be. Right down in the bottom corner, it showed a line that showed how long it was gonna be for reference."*

However, over half of the youth (54%) found that the flashcards took longer to use:

> *"I was just thinking that the flashcards were a lot more time consuming because you had to flip through a lot of things, even if you knew it wasn't a snail, you still had to look through all the snails. The online program made that a lot faster."*

A few participants also shared that it was difficult to tell the insects apart on the cards:

> *"When we used the flashcards we were going through stuff to look at all different bugs, but telling the difference between them was kind of hard…a lot more similar features."*

> *"I know when we were flipping through the flashcards, it was actually harder to tell which shell was which because there were some that had different textures looking, different colors. That was pretty hard to identify."*

In terms of the dichotomous key, several participants (25%, N=8) liked the amount of information provided. However, they also found the key to be time consuming and full of confusing terminology (25% of the volunteers mentioned each of these aspects):

"[With the digital teaching collection], it was a lot easier to go mostly by the pictures where we could zoom in and look at everything that the book was talking about, but we didn't have to read the whole paragraphs and try to figure out what some of the words meant."

When asked to compare the resources, 100% of those who used the dichotomous key and the digital teaching collection (N=8) selected the digital teaching collection as the superior identification tool:

"There were like the three different sections, so you could narrow it down by the tails, gills or whatever and you could narrow down what it was a lot faster."

Several participants contrasted the *"ugly"* pictures in the dichotomous key with the *"awesome"* and *"clear"* pictures from the digital teaching collection *("[I] like zooming in a lot so you get a lot of detail.")*. Others liked the *"hands-on,"* interactive nature of the digital teaching collection, and felt that it was easier to use than the dichotomous key (*"It's a lot more efficient. It's a lot easier to narrow it down."*). One camper also liked that some of the images in the digital teaching collection allowed the user to view the insect from different perspectives (i.e. dorsal and ventral views).

Volunteers who used the flashcards and the digital teaching collection were more mixed in their preferences. They were about evenly split between those who liked the flashcards (N=7) and those who preferred the digital teaching collection (N=6). Those who selected the digital teaching collection over the flashcards felt that the online tool was *"quicker"* and *"more organized,"* had relevant information on insect features, and contained more accurate imagery:

"I thought the pictures were more accurate because at one point we looked for one through the flashcards and we were unsure about what it was, but as soon as we got to the teaching thing, the online thing, we were like, 'Oh! That's what it was.' The picture made more sense."

"On the flashcards, you could kind of just read a small page about it, but [the digital teaching collection] had the video, and a bunch of information and pictures, and you could zoom in. Everything just seemed a lot easier. You could see the different characteristics and which defined what Family, Order."

"With the online one, it's less time consuming. With the flashcards, you've got to flip, flip, flip, and [with the digital teaching collection] it's just right there."

"I also think the pictures are more accurate, but it's a lot easier to identify it if you are comparing two side by side, rather than having to go back and forth between them."

Those who preferred the flashcards were drawn to the challenge of trying to figure out which insect it was, whereas they felt that they had been able to tell more quickly which insect they were looking at on the website:

> *"To remember it better, if you are actually looking for the facts not just looking at the picture, you'll be able to match the facts to the picture.:*

> *"I thought the flashcards looked for more like the characteristics of the bug, like the tails, the gills, that kind of thing and with the online program, we just knew right away if it looked like it or not, so it was kind of faster, but less in-depth, less observation."*

> *"In terms of actually classifying which bug it was, I kind of liked having to flip through the cards and tick off the characteristics that match up with the actual specimen. I kind of liked having to work for it vs. just looking at a screen and immediately recognizing what it was."*

> *"On one of the bugs, you actually flipped it over and the fibrous hairs it had going down its column and on the flashcards it actually had a picture that showed you what it looked like on the bottom of the bug and it actually helped us pinpoint what it was because there were actually two that we weren't sure about, and then we looked at the bottom and we saw it, so we could see the features."*

Volunteers who liked the flashcards also appreciated the amount of information provided, that the size of the insect was specified on the cards, and felt that it had been easier to find the Order and Family names on the card, whereas they had to search for the location of this information online.

Regardless of their preferences, many volunteers acknowledged that they had been more accurate in their identifications while using the digital teaching collection, compared to the flashcards:

> *"I had to work a lot over there to figure out what it was, but in the end I was still wrong. The online – I got the right answer."*

Did youth volunteers have any suggestions for improving the digital teaching collection?

Volunteers did have some recommendations for improving the digital teaching collection in the future. The main recommendation was to include more insects on the website. In addition, several campers thought that being able to zoom in on the features of two insects side-by-side would be helpful for identification purposes:

"I know in other field guides, they have two pictures at once that you can pull up on the same screen and compare them. That would be nice to be able to just look at two different families."

Some campers had difficulty finding the names of the Order and Family on an individual insects' page. One person suggested color-coding Order information in one color and Family information in another as a visual cue. Another camper liked the chart-like organizer on the dichotomous key (*"It was helpful to see the lineage of lines like a tree."*). Others thought it would be interesting to show the insects in their native habitats and to provide information about what and how each bug eats:

"If you show them in their natural state, I think the videos should be longer so you can get a better feel for what they are like."

"Maybe add like a picture of a stream and put where the insects live in that stream and you click on the insect and it takes you to where that insect was."

"I know the caddis flies have little stick houses that they build. It would be nice to have a picture of one of those."

Participants also noted that while the tool was easy to use on an iPad, volunteers would either need to bring insects back from the field to categorize them or make sure that they had a waterproof case. Some were concerned with the lack of internet connectivity in the field, and suggested using wireless hotspots or creating a mobile app version of the collection.

Most participants indicated that they had not used the multimedia within the digital teaching collection due to time constraints with the embedded assessment activity, but felt that these materials would be interesting. Volunteers wanted videos that had information about the insects' size, how they move, and how they live. They did caution that such materials needed to *"get to the point fast."* One camper thought that *"it would be easier to listen than just going down the page and looking for text to tell you."* Another volunteer echoed this sentiment:

"If I was doing something for school or in biology class I would definitely rather use the video then sit there and read the paragraph."

Educator Perspectives

What do informal educators already do to assist volunteers in insect identification?

Participating educators had similar approaches to teaching youth volunteers how to identify insects:

"When we go out, we collect insects in the stream and turn over rocks, and we count the species we find, and how many of each species we find, and pollution tolerance."

One educator from Creek Connections stated that she often does not go into details on insect anatomy and just asked questions, whereas another educator from Mission Groundtruth (who had brought his students to the Creek Connections program) indicated that he first brings in samples from the stream for youth to look at, and then asks questions about those insects that he thinks the volunteers might be able to answer before they go out to the stream for the first time:

> *"Do you think they live in ripples in the pool or the stream? Describe what you're seeing. How many legs does it have? Does it have a clear head? Does it look like it's squishy or hard? I think it's helpful before you start throwing data and terms and names at kids, I think it's helpful to kind of let them see what they can tell about it right of the bat and let them let you know what they already know."*

Both educators shared that they use dichotomous keys to help volunteers identify the insects, but felt that these materials were sometimes mislabeled and that many of the pictures looked alike.

What is challenging about teaching volunteers about insect identification?

Educators felt that the size of the insects being collected makes it difficult to point out the relevant characteristics to volunteers:

> *"I think what can be hard, depending on the animal, is whether you can see the features that the key is asking about. Sometimes it asks about how many sets of legs, and one set of legs may be hidden underneath the animal or it's got other projections that look like legs to students that haven't seen the animal before. Or tails and things fall off, and when they're not familiar with what they're looking for they just start counting what they see, and they're not necessarily seeing what they should."*

Another educator shared that youth often lack confidence in their classifications, so they don't say anything because they are afraid of being wrong. He thought that it was important to let youth *"assess information beforehand,"* so that *"they feel well-equipped"* to provide an answer.

The digital teaching collection was viewed by the educators as being able to address both of these issues by providing authentic, detailed images of insects and their relevant features:

> *"Most of the keys we're familiar with are drawings. Even with a photo it's still just going to be with the one individual, but I think with the actual photo it gives the students more confidence in being able to manipulate that photo, to be able to zoom in and really look at the feature they're trying to look it. It gives them more confidence because they know it's a real picture and it's very clear."*

What did educators think about the digital teaching collection?

Educators liked the digital teaching collection overall. They thought that the interface was intuitive and that the technology was engaging for their youth volunteers:

> *"I thought it was really impressive. It's beautiful. It has a lot of information. I think it's easy to navigate."*

> *"I thought it was awesome. I thought the kids immediately gravitated right towards it and they were figuring out how to use it."*

> *"It's not just the old thing you've been using for twenty years, but something that's updated and comes at the student's level where they feel more involved."*

In particular, the educators were excited by the technology's zoom feature, as well as its ability to classify beyond Order, which made it an effective tool for supporting youth volunteers's observations:

> *"You can really get that fine detail and it's so hard to see them and you just have that little preserved specimen in a vial and you can really zoom in. My colleagues and I, we were geeking out because you can really see the gills. You could see the differences that it's almost impossible to see with the naked eye."*

> *"I know exactly what I'm looking at, so I know how many legs it has, so it's easier for me to see six….That's where I think your guy's tool comes in awesome because you can zoom in. You can really count the number."*

> *"I really liked that the digital teaching collection broke it down into much finer detail. There were a bunch of species of mayflies. A lot of times in the dichotomous key that we use, we only ever get to, 'It's a mayfly.' We don't ever get to what kind it is. I think that's an awesome next step. 'You think you're awesome because you can identify that it's a mayfly? You're not done yet. There's plenty more differences amongst mayflies.' I think it's really great for the kids to see that even within a family and an order, there's a lot of differences."*

Educators also liked the level of information provided about each insect and its diagnostic characteristics:

> *"It took something simple and beautiful, but it also allows you to kind of link to other resources – other guides, or videos, or information – so there's a ton of information*

there, but it looks really sleek and simple. It wasn't all overwhelming. You could get a ton of information on a part of the organism that you wanted to."

One educator noted that there had been some initial confusion *"around the functionality of it - Where would they click? How would they go back?"* However, he felt that the participants were able to figure out those navigational issues quickly, and that they *"loved"* the tool.

What did educators think about the digital teaching collection compared to the other resources?

While educators liked the digital teaching collection's detailed imagery and attention-grabbing technology, they felt that the dichotomous key that they already used was more practical for insect identification in the field. For their purposes, they were only asking volunteers to identify insects at the Order level, and did not require youth to know the diagnostic characteristics that differentiated by Family within a particular group. Furthermore, they were often doing their identification work streamside, so they required a durable, waterproof tool. However, the educators did state that if they had more time (they often only had one day with volunteers), they would like to provide opportunities for participants to explore different insects' features via the digital teaching collection.

In terms of the flashcards, one educator noted that the cards *"clearly outlined"* features to look for (*"the antennae, the number of legs, if it has a segmented body"*), whereas the digital teaching collection often focused on a particular feature of an individual insect rather than a drill down list of features:

"It was a depth thing. They could learn a ton about the species looking at the tool, whereas the flashcards it was more of a breadth thing - more different species and being able to pick out, 'It isn't this. It isn't this. It isn't this,' for these reasons - Whereas the tool is really focusing in and learning a lot about the individual species."

Thus, educators thought that the digital teaching collection would be best used with volunteers who had time and interest in a more in-depth examination of diagnostic features.

What ways did educators observe volunteers using the tool?

Educators noticed that volunteers who used either the flashcards or the dichotomous key flipped through the cards or pages a lot, and seemed uncertain in their identifications. Educators thought that the *"interactive comparisons"* in the digital teaching collection seemed *"more helpful for people who are naturally more hands-on or have issues with reading directions."*

One educator observed that a volunteer not only noticed a diagnostic feature during the embedded assessment activity, but also remembered that feature during data collection the next day in the stream:

> *"A student of mine was fixated by the term, 'anal hooks,' which is apparently how caddisflies affix to things, so we would see an organism in the stream after that and she was like, 'Oh, does it have the hooks?' So I think really picked up on being able to click on individual parts of it, and really retain that information and think about it when they were outside of the computer lab."*

These anecdotal observations support educators' opinions of the digital teaching collection as a tool that can increase volunteers' confidence and accuracy in their insect identifications.

How would educators use the digital teaching collection with youth volunteers?

Educators thought of a few applications for the digital teaching collection, with regards to training youth volunteers. While all educators indicated that they wouldn't lead off with the tool (*"Having that much information and being able to go that deep with it right off the bat might be a little scary."*), they all thought that the digital teaching collection would be a nice extension activity. For instance, one educator indicated that he would use the digital teaching collection after an *"initial exploration"* of a stream to help youth volunteers be better able to identify insects at the Family level:

> *"I think that in an ideal world, I would take some of my kids out, explore a stream, find some things, go back, really be able to make sense of what we saw and go back out to really parse out what kind of mayfly was that…They would be looking at the activity in a totally different way. 'Ah, this is a flatheaded mayfly versus another type because of a feature,' which I think could be really powerful."*

All participating educators felt that the digital teaching collection would be a great resource for classroom teachers, either during professional development workshops or with their students. Here, educators thought that teachers who weren't able to visit an actual creek with their students would benefit from going beyond *"just drawings"* and get more information about a particular insect (*"where they live, how they breathe, how they move, all those things."*). They noted that in a classroom, students would be able to do identification down to the Family level. Another educator thought that teachers whose students were able to visit a creek could also extend their students' explorations by taking some of the insects back to the classroom and using *"the online tool to investigate them further and identify them further. Have the students really get into the life cycles of particular animals they found, or habitat requirements, or adaptations."* However, this same educator cautioned that it might be difficult to *"facilitate a whole class because some kids will need constant attention and help going through and some kids are just gonna go off on their own and you don't want to stifle that kind of exploration of the software."* Regardless, he thought that with the right guided activity, a whole class investigation would be successful.

Did educators have any suggestions for improving the digital teaching collection?

Although the educators liked the digital teaching collection as-is, they each had suggestions for improving the tool in the future. The main recommendation from educators was to include more insects in the collection, particularly insects that are commonly found in Pennsylvania streams:

> *"More critters because right now they're focused on the ones for stream health indicators, and we don't find those in a lot of the streams around Pittsburgh."*

> *"I'd love to see it be expanded, like a larger collection and maybe with some organisms that are more commonly found in our streams because a lot of times when we're going out with kids we're finding scuds and plenaria."*

Educators also wanted the teaching collection to illustrate the habitats and behaviors of particular insects to help learners better visualize these aspects:

> *"I noticed that after a number of years of doing this that I can recognize a lot of these things by the way they move in the water, so I think that some way to show that would be really helpful. They have very distinctive ways they move in the water and it's hard to explain that in words, and certainly you can't show that on a flat piece of paper.:*

> *"At Creek Connections, we're viewing the insects while they're alive, so to see how they move and how they might be acting while they're in the collecting tray and still alive, that would help to identify as well - Like how the stoneflies do their pushups and the mayflies flutter their gills, that kind of thing."*

> *"Trying to get the students to understand that each of these critters have different habitats that they live in. While the creek is a habitat in and of itself, there are separate habitats within the creek. To understand where they fit into those habitats and what their jobs are in the overall picture of how the stream works, I think that's something you could do really easily with that tool and it would be really effective."*

One educator had observed that some of the youth volunteers thought that the digital teaching collection made identification too easy, so he suggested adding some prompts to get participants thinking about the various attributes of each insect:

> *"One of my kids didn't like that it didn't have a step-by-step process. It wasn't as much of a challenge. You looked at the organism and could kind of figure out what it was, so I thought a few more of those guiding type questions up front – Where do you think this*

thing lives? How do you think it moves? What do you think it eats? – that type of question might have got them thinking a little bit more instead of just looking at a silhouette and telling what it was. Instead of looking at a piece, they were looking at the whole thing…I think something that would have asked them to make some observations beforehand would be the answer to that."

Finally, educators wanted a version of the teaching collection that they could use streamside, such as an app:

"If it was a version that didn't require wi-fi connectivity that you could download and take into the field in a waterproof case, that would be ideal for us."

Scientist Perspectives

What is challenging about insect identification?

Both scientists who were interviewed indicated that the main challenge of insect identification is the need to have something with which to compare your specimen:

"There's so many insects and there's so much to learn, that even if you buy the field guide that's not usually enough. You actually have to have some reference materials that you can examine with a microscope."

"These things have to be properly identified and you have to have some sort of way to point to the diagnostic elements that show you why this insect is what it is…you can have your books that have illustrations and identification keys, but ultimately you need to compare whatever thing is in your hand to something else and say, 'No, it's not that. It's not that. Not that either.'"

"The problem with identifying these things is that everything is wrong except a single answer, so you have to eliminate all those other answers and whether you are a beginner or an expert, you still want to take a look a one and say, 'Mine is different from that,' or 'Yes, that looks like mine.'"

One scientist also noted that the vocabulary used by expert entomologists is often difficult to translate into layman's terms:

"The most challenging thing is the disconnect between the entomologist and the novice. As an expert, you tend to speak in terms that the novice doesn't really understand."

Participating scientists thought that the digital teaching collection helped to address these challenges by providing a comparative collection and by listing both the scientific and everyday vocabulary to describe each insect:

"It is something that can be useful to folks who are not experts…Most obviously, it's showing you these important diagnostic characteristics and it's showing them in a way that most anyone can understand it. You know, as much as was possible, we tried to avoid technical terminology."

"It makes a great comparative platform. The twelve insects that we have in there are common insects that you get in healthy streams. So it's often the case that after collecting a sample, you'll get one of these insects and having a good digital image that you can zoom in that's fully annotated with all these different characteristics, I think that really helps a novice to take away the main point about this insect…because they do this a time or two, they start to remember things…stoneflies have two tails. Mayflies have three tails. Mayflies have gills on their abdomen. Stoneflies have gills on their thorax. So without really knowing it, they're training themselves on some of the really basic identification techniques."

What did scientists think about the digital teaching collection?

Participating scientists helped to populate the content of the digital teaching collection and to take the images of the insects using gigapixel technology. They shared that the process for capturing images of the insects had been challenging due to the necessity of keeping each insect hydrated, while not moving the specimen during the photographing process:

"Collecting the specimens themselves is difficult…Using the rig the robot can be very difficult, and the specimen must be preserved in ethanol and that's highly volatile and evaporates very quickly."

The scientists also *"had to get all specimens vouchered to make sure they were the specimen that we said they were,"* which took time. However, the scientists indicated that this process had been worth it in order to get a quality teaching collection online.

The scientists felt that it had been important to start the digital teaching collection with "EPT taxa" (*"These are really sensitive to pollutants and if you find these in your stream, that's a good indicator that your stream is healthy."*) to make sure that the tool was immediately applicable for volunteer training purposes and for the public. They shared that one of the reasons that they had wanted to create the tool in the first place was to provide an accurate insect identification tool that could be used by citizen scientists to make an evidence-based case for the health of their local streams:

"For the public, we chose aquatic insects because the public all over the US is interest in monitoring water quality, and one of the easiest ways to do it - in fact, one of the best

ways to do it - is to have people collect a few insects from the stream, and the reason that works is that even if you did a chemical analysis, that would just be whatever water is there in the moment. You don't have a history. But if you collect insects, you can see the history because those animals had to be in there all year."

"If you consider citizen science agendas, this is one that fits very well. You could train general public to go out to a water course of interest to them, sample some insects, take them home, look at them, and figure out whether this stream is high quality, moderate quality or low quality."

"With the boom in hydraulic fracking, people are concerned with the health of their water systems, so this tool can be valuable for them if they are out there doing citizen science and sampling their stream…because these are such sensitive indicators, if you find lots and lots of sensitive species then you can make a determination about the health of the stream, and if you are finding very few sensitive species - a lot of tolerant species tolerant to pollution - you can make a determination about the health of a stream that way."

The scientists indicated that unlike field guides, which were difficult for novices to use, the digital teaching collection was intuitive and supported citizen science volunteers' observations by highlighting the relevant features of each insect:

"It simply presents the information in a fashion that's familiar and palatable."

"It allows people to see that there's more to an insect. There's more to a bug than eyes and wings. It breaks the insect into manageable sections and they can learn at their own pace with their own eyes, so it gets them thinking about the parts, the anatomy of an insect."

"For instance, stoneflies, they have the gills that attach to the base of the legs at the thorax. Those can be very difficult to see with the naked eye. But when we show them what they are supposed to look like on a computer monitor, then they know what they are looking for and they can go back. They look and say, 'Oh, the spaghetti thing,' cause they're pale and they have little strings attached to the base of the legs."

Scientists were also excited by the accessibility of the tool, and its ability to be used by the public outside of a laboratory or museum setting:

"Normally a collection, you collect it and label it and put it in a drawer somewhere and it goes into storage until someone finds it ten years from now. But because it's online, people can access it whenever they want to and they can use it whenever they want to."

How did scientists use or plan to use the tool to communicate with public and scientific audiences about entymology?

The scientists initially wanted a tool that could be used by other entomologists but realized that professionals already knew how to utilize keys and field guides. Instead, they thought that the tool could be geared towards novices:

"Citizen scientists, and volunteers, and students doing a lesson on freshwater ecology don't really know how to use a key and don't know the terminology and this could be a valuable tool for them."

Thus, the scientists wanted the tool to act like a microscope because their typical volunteer trainings involved, *"me looking through a microscope, positioning a specimen, and having them look through the microscope, adjust the microscope so it fits their eyes, etc."* The scientists do not have access to tablet computers at their facilities, so they currently use the digital teaching collection to project onto *"a screen to show students important characteristics they're looking for when they're looking at these organisms under magnifying glasses."*

Even though the scientists chose not to target the tool design towards other entomologists, one scientist indicated that he had shared the tool at a conference and that his colleagues had recognized its potential:

"I presented this tool to about 120 people who mostly run museums or teach taxonomy and they were stunned by it. I must have had a dozen people come up to me afterwards and ask how they could get in on this because they see the need for this as well in their own daily lives."

What did scientists get out of their participation on the project?

The scientists identified a number of things that they felt they had gotten out of their participation in the design of the digital teaching collection. Both scientists noted that they appreciated the ability to work with learning researchers and computer programmers on the project because they had brought unique perspectives that enhanced the final product (*"I now recognize the importance and the utility of a cross-disciplinary collaboration."*).

The scientists also felt that compiling content, such as videotaped expert interviews, for the digital teaching collection had helped them to recognize the key takeaways from their entomological practices (*"The interview process has been an interesting exercise in distilling down what we need to know."*).

Interestingly, the scientists indicated that through this process they had gained a new perspective on novices' ability to do identification work:

> *"One of the things that they take away from this, which I think is significant, is that a regular person can do this."*

> *"It's much more challenging to do this in the informal paradigm…I was worried that we weren't going to be able to do this such that an untrained public would go for it. But it works."*

This shift in perception of novices' capabilities is especially important, given that many scientists question the value and quality of citizen scientists' identifications (Crall et al, 2013; Reisch & Potter, 2013).

Did scientists have any suggestions for improving the digital teaching collection?

Like their youth volunteer and educator counterparts, scientists also thought that the digital teaching collection could be expanded to include more images (*"In Pennsylvania alone there are 1200 macroinvertebrates that could be in that teaching tool. Right now we have something like 12 or 15."*). They also thought that the tool could be modified with a dichotomous key-like organizer, so that experts could utilize it as well. Otherwise, the scientists thought that the digital teaching collection had been an excellent proof-of-concept project.

Conclusions

The digital teaching collection was successful in meeting the main goal of the project - to effectively support volunteers' accuracy in and confidence around their insect identifications. In fact, youth volunteers provided more correct identifications at deeper levels of specificity and were more confident in their responses when using the digital teaching collection, compared to traditional, paper-based resources. These outcomes suggest that the digital teaching collection could be an effective tool for other citizen science programs to use to conduct volunteer training on identifying aquatic insects.

In addition, the digital teaching collection was viewed positively by various stakeholders. Youth volunteers, educators, and scientists were drawn to the tool's detailed imagery and most found it to be easy to use. These features are important in a tool designed to be used by audiences with different levels of interest in and knowledge about insects, as well as different comfort levels with technology, since the images have the potential to engage multiple audiences and the tools' intuitive interface can be picked up fairly quickly.

Finally, one of the most important aspects of the digital teaching collection is that it calls out the relevant diagnostic features needed to make a determination about an insect's Order, Family, and Genus. Participating scientists and educators indicated that they already knew what to look for, but the digital teaching collection helped novice volunteers begin to recognize characteristics that are important to identification work. In this way, the digital teaching collection provides an organizer for trainers to use to facilitate more expert kinds of noticing, so that novices start to see insects through the eyes of an entomologist.

References

Crall, A.W., Jordan, R., Holfelder, K., Newman, G.J., Graham, J., & Waller, D.M. (2013). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science*, 22(6), 745-64.

Riesch, H., & Potter, C. (2013). Citizen science as seen by scientists: Methodological, epistemological, and ethnical dimensions. *Public Understanding of Science*, 23(1), 107-120.

Appendix A: Insect Identification Worksheet

Your Age: _____ Grade: _____ Gender: Male | Female

School Name: _____ Home zip code: _____

1. Have you done stream insect identification before (circle one)? YES NO

a. If YES, where? _____

2. Please place a checkmark in the column that best describes you for each of the following statements:

	NO! Not at all	No Not really	Yes Somewhat	YES! Definitely
I know a lot about insects.				
I am confident in my ability to identify insects correctly.				
I want to find out more about insects, generally.				
I want to find out more about aquatic insects.				

3. Tell us if you like learning about aquatic insects. Why, or why not?

Fill in the chart pages below as best you can for each macroinvertebrate your group identifies to family.

Insect ID #1

What kind of insect is it?

(*Include scientific name to family*)

Petri dish # _____(*fill in*)

Observations

What features did you notice about this insect?

Determination

What evidence are you using to support your ID?

Confidence

How confident are you in your identification to Order? High Medium Low

How confident are you in your identification to Family? High Medium Low

Pollution Tolerance

Circle the value which best describes this insect.

- o Low (intolerant/sensitive, indicates good stream health)
- o Medium (somewhat tolerant, indicates fair stream health)
- o High (tolerant, indicates poor stream health)

Check Resource(s) Used:

[ ] Illustrated Guide (dichotomous key) -or- **[ ]** Digital Interactive Collection

Write down some notes about what you <u>like</u> and <u>don't like</u> about using each tool.

Notes on Illustrated Guide:

Notes on Digital Interactive Collection:

What is hard about identifying stream insects?

Appendix B: Youth Focus Group Protocol

I'd like to talk with you all for a few minutes about the illustrated paper key and the online tool that you used to identify bugs today. I'll be audiotaping your responses, but your replies will be completely anonymous. So just answer as honestly as possible, there are no right or wrong answers. Your feedback will help us improve these resources for future use. Any questions before we get started? Great. Let's begin.

1.) So tell me a bit about the process you went through to identify stream insects during the activity that you just did.
    a. What features did you look for to help you identify an insect?
    b. How did you determine which group to place a particular insect in?

2.) How did you use the Illustrated Key to identify the insect?

3.) How did you use the Interactive Digital Collection to identify the insect?

4.) Which resource did you prefer: The Illustrated Guide or the Interactive Digital Collection? Why did you prefer using _X_?

5.) Now, I'd like you to talk a bit more about using the Interactive Digital Collection.
    a. What did you like most about it? What features of the tool helped you the most?
    b. What didn't you like as much? What features of the tool did not help you or felt unnecessary?
    c. Do you have any ideas for ways that the designers could fix that?

6.) Would you recommend Interactive Digital Collection to a friend who wanted to identify stream insects? Why or why not?

7.) So, what's hard about insect identification? What features do you think could be added to the Interactive Digital Collection to address that issue?

8.) Anything else that you want to say about the Interactive Digital Collection?

Appendix C: Educator Interview Protocol

I'd like to ask you about the process that you go through to ID specimens, and then a talk to you a bit about the digital collection.

1.) What are the steps that you typically go through to ID a specimen?

2.) When you have an unknown or difficult to ID specimen, what makes getting an accurate determination easier?

3.) What are some of the challenges in teaching students about macroinvertebrates? [Prompt: What's hard about insect identification for the students, and for you as facilitators?]

a.) In terms of the digital teaching tool, how might that change your practice? Would you incorporate that into what you do?

4.) What did you think of the digital teaching collection? [Prompt: What did you like? What did you dislike?]

5.) Are there other uses that you could see for the tool?

6.) Is there anything else you'd like to see with the tool?

7.) How will the digital collection fit in with what you are already planning on doing?

8.) What do you think are some of the benefits of using the digital collection?

9.) What are some of the challenges of using the digital collection?

10.) Can you give me some examples of students using the digital collection?
    a.) What did they do/how did they use it?
    b.) What did they talk about?
    c.) Do you think they found the tool engaging?

11.) Are there any other things you'd like to say about the digital tool or facilitating macroinvertebrate identification?

Appendix D: Scientist Interview Protocol

Thank you for agreeing talk with me today. I'd like to ask you some questions about the Macroinvertebrate Digital Teaching Collection demonstration project to explore the use of gigapixel technology for science communication and learning. As part of the summative evaluation for the NSF grant, we also want to understand the value of this project for the scientists involved. The call should take about 30-45 minutes. Please be as honest as possible about what you think the benefits and challenges of the project have been. All of your responses will be kept confidential. We may use quotes from this interview, but you will not be identified by name. I'd like to audio record our conversation as a way to take notes. Would that be okay? Do you have any questions before we get started? Great, let's begin.

1.) Tell me a bit about your role at your institution. What kinds of projects and programs are you responsible for?

2.) What interested you about the project?

3.) Now that you have been involved in the project, do you think that the digital teaching collection has worked the way that you expected it to?

- a.) What were/are the goals of the project?
- b.) What do you hope people will learn/take away from it?

4.) Do you think that the digital teaching collection has been successful? In what ways? [Prompt: What's evidence of that success for you?]

- a.) Do you think that the tool has been successful for scientists?
- b.) In what ways do you think that the project has built capacity?
- c.) Have you formed any new partnerships as a result of the project?
- d.) What was it like to work with the university on a shared grant?

5.) Can you talk a little bit about the development process. What is hard about getting your research or getting collections online?

- a.) In terms of annotation, what kinds of things do you think would make it easier, more efficient to communicate some of the content online?
- b.) What are the similarities and differences in putting a collection online?

6.) What is challenging about communicating and engaging public audiences in entomology research or with collections?

- a.) How does gigapixel technology address those challenges?
- b.) In what ways does the technology help you engage public audiences? Support scientific communication?

c.) What aspects of your field are most interesting to public audiences?

7.) What did you value most about this experience?

8.) What, if anything, did you learn from your participation in the project that you didn't know before?

a.) About using technology as a tool in communicating science to public audiences?

b.) About partnering with universities? About working with programmers?

9.) What have been some of the challenges to adoption of the technology? The logistics of the project?

a.) What strategies have you used to address those challenges?

10.) This project explores three approaches to public-science learning interactions. Through your participation in this project, what new information have you found out about public understanding of science programs, Public Engagement with Science programs, or Public Participation in Scientific Research programs?

11.) In what ways do you think that gigapixel technology is deepening or extending the publics' experience?

12.) Were there any surprising interactions that you had with the public around the collection?

13.) What ideas do you have about ways you will apply your experience with this project to your future work?

14.) How likely are you to implement a public engagement activity using the digital teaching collection in the future?

15.) What do you wish you had known about this project or the technology before you started?

16.) I wanted to ask you the steps that you go through to ID a specimen. When you have an unknown or difficult to ID specimen, what makes getting an accurate determination easier?

a.) Can you talk a little bit about scientific observation and what it means to look at something with the eyes of an entomologist?

17.) Is there anything else you'd like to say about the digital teaching collection?