

**Seismic Waves Beta Test - Evaluation Report**  
**March 2, 2016 – Version 2.0**

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## Executive Summary

The Seismic Waves (<http://ds.iris.edu/seismon/swaves/>) website is a browser-based tool to visualize the propagation of seismic waves from historic earthquakes through Earth's interior and around its surface. Simple controls speed-up, slow-down, or reverse the wave propagation. By carefully examining these seismic wave fronts and their propagation, the Seismic Waves tool illustrates how earthquakes can provide evidence to infer Earth's interior structure.

To test the efficacy of the beta website's design and functionality, an evaluation was conducted with experienced classroom instructors at both the middle/high school, and post-secondary levels. In addition the testing also solicited expert feedback (teacher and college faculty) on future enhancements for the site. Both qualitative and quantitative data was collected through an online post-use survey, and an in-person usability test of the website.

### Findings

- 1) 93% of survey 31 respondents (14 high school teachers, 12 undergraduate instructors and 5 middle school teachers) found the site "Very Easy" or "Extremely Easy" to use.
- 2) While easy to use, usability testing revealed that some participants encountered challenges locating or executing some of the site's core functionality.
- 3) A majority of participants described the site as an engaging (68%) tool they anticipated using as part of their instruction (67%).
- 4) Post-secondary educators found the site more engaging and reported that they were more likely to use the site instructionally than their middle/high school counterparts.
- 5) Based on the current design and functionality, just over half of respondents, regardless of educator type, are likely to be "Promoters" or enthusiasts who will keep using the site and refer others to it.

### Recommendations

- 1) Refine the core functionality by implementing the principal enhancements, listed on page 15, that were identified through the usability testing and expert feedback.
- 2) Improve the appeal and perceived usefulness of the site to the middle/high school audience by implementing small adjustments and additions to the site. Some possibilities are listed on page 16.
- 3) Plan for possible new functionality and audiences by exploring the identified feature suggestions, listed on page 16, provided by beta testers.

## Background

The Seismic Waves website is a browser-based tool to visualize the propagation of seismic waves from historic earthquakes through Earth's interior and around its surface. Simple controls speed-up, slow-down, or reverse the wave propagation. By carefully examining these seismic wave fronts and their propagation, the Seismic Waves tool illustrates how earthquakes can provide evidence that allows us to infer Earth's interior structure.

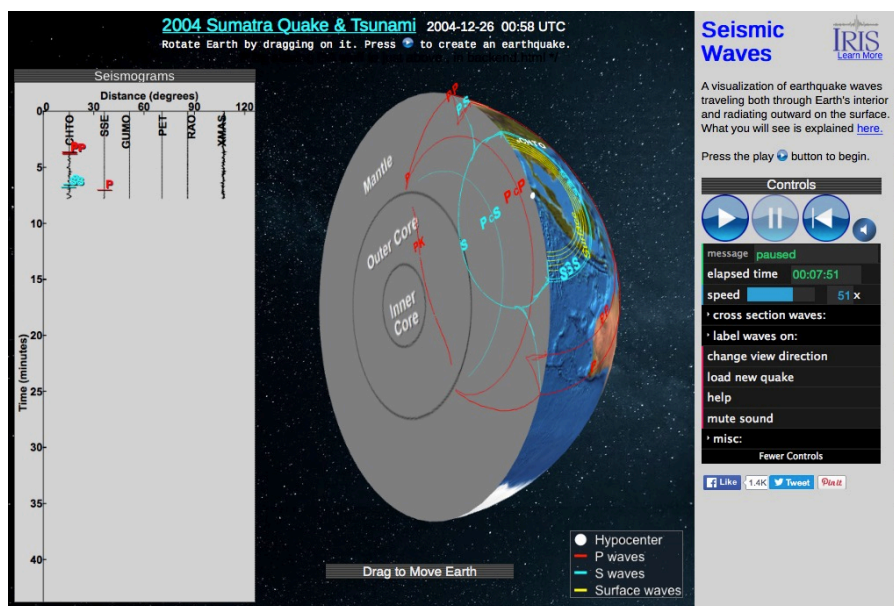


Figure 1: The seismic waves website accessible at <http://ds.iris.edu/seismon/swaves/>.

Shear waves (S waves), for example, travel through the Earth at approximately one-half the speed of compression waves (P waves). Stations close to the earthquake record strong P, S, and Surface waves in quick succession just after the earthquake occurred. Stations farther away record the arrival of these waves after a few minutes, and the times between the arrivals are greater.

The tool also illustrates how seismic waves inform our current understanding of Earth's interior structure. Users will see that between approximately 104 and 140 degrees away from the epicenter, direct P waves do not arrive as they are refracted away from this zone. This suggests the presence of a lower velocity material, Earth's outer core. Users will also observe that no direct S waves arrive beyond 104 degrees.

This product is a replacement for the original stand-alone Windows-based Seismic Waves program written by Alan Jones (Binghamton University). The development of the replacement is the result of a collaboration between Alan Jones & Jeff Baker (Binghamton University), and IRIS EPO staff.

The goal of this evaluation was to determine if experienced classroom instructors (at both the post-secondary and grades middle/high school) found the site engaging, the core functionally (Appendix A) intuitive and easy to use, and something they were likely to use in their instruction and promote to their colleagues. In addition, the evaluation also explored participant responses to possible future development ideas.

## Methodology

To answer the questions outlined above, both qualitative and quantitative data was collected. The first data source was an online survey to get feedback on the site by individuals reviewing it on their own time at their own locations. The second data source was an in-person usability test of the Seismic Waves website to see how users new to the site navigate and use the website.

*Online Survey* - To collect expert instructors' perceptions of the tool, its functionality, and usefulness a brief survey was developed. This survey (Appendix B) consisted of 10 closed-ended items and 3 open-ended items and was completed after participants had an opportunity to explore <http://ds.iris.edu/seismon/swaves/>. Participants for the survey were recruited from several sources as illustrated in the Table below.

Participant Group	Invited	Responded
Faculty and K-12 teachers from the Seismic Waves' Needs Assessment that volunteered to test the beta version	16	9
K-12 Earth Science teachers recruited (via email) from the ESPRIT Listserv	24	14
Foreign seismologist who run school seismograph programs as identified by IRIS EPO staff	4	3
Geophysics instructional experts (K-12, Undergraduate, general public) identified by IRIS EPO staff	13	5
<b>Totals</b>	57	31

Table 1: Sources used to recruit participants for the survey. The sources included both volunteers as well as "experts" identified by IRIS staff. The response rate for the survey was 51%.

*Usability Testing* - Participants for the usability testing were recruited from attendees of the 2015 Fall Meeting of American Geophysics Union who stopped to look at the beta Seismic Waves website displayed on a monitor at the IRIS booth in the convention hall. Seven attendees were asked to participate in the testing. Two attendees declined and five consented to participate.

Participants were brought to a table in the booth where the Seismic Waves was displaying the 2004 Sumatra Quake on a 13" Macbook Pro laptop. Using the functionality outlined in Appendix A, a semi-structured script (Appendix C) was developed to shape the usability testing. Based on the script, participants were asked to complete various tasks, talking aloud about what they saw, what they expected to happen, what actually happened, and how those matched up. An iPhone 5C was used to record audio of both the interviewer and the participant as well as video of the on-screen action.

## Survey Results

While 31 individuals responded to the survey as indicated above, only twenty-eight were complete and are included in the results below. These respondents represented a large range of teaching experience as illustrated in Figure 1. The group had a maximum of 40 years of teaching experience, a minimum of 2 years, and a median of 17 years of teaching experience. The largest population of respondents was high school teachers (n=14), followed by undergraduate instructors (n=12). Five middle school teachers responded to the survey. It should be noted that because the undergraduate faculty were recruited either from an announcement to the IRIS Bulkmail or from connections with the IRIS EPO program staff, nearly all were seismologists.

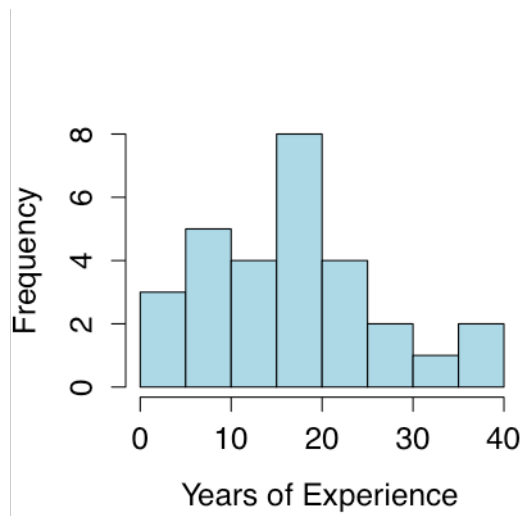


Figure 1: Respondents' self-reported teaching experience.

Most respondents' responses were based on accessing the site from a desktop computer (n=12). Laptops (n=7) were the second most common access device followed by tablets (n=4), and mobile phones (n=1). The total number of respondents for this item is low because the question was added in after the survey was already opened.

To gain a sense of participants' reactions to the site, respondents were asked to rate how engaging they found the website. The majority of respondents reported that the Seismic Waves website was "Very engaging" (n=15) or "Moderately engaging" (n=7). Only four described the site as "Extremely engaging" while two described it as "Slightly engaging". As illustrated in Table 2, when aggregated by educator type, middle/high school educators were slightly less likely to describe the site as "Extremely" or "Very engaging" and more likely to describe the site as "Moderately engaging". There was no discernable differentiation to this question based on years of experience or the device used to access the site.

	<b>Extremely engaging</b>	<b>Very engaging</b>	<b>Moderately engaging</b>	<b>Slightly engaging</b>	<b>Not at all engaging</b>
<b>Middle/High</b>	12% (2)	47% (8)	35% (6)	6% (1)	0
<b>Post-Secondary</b>	18% (2)	64% (7)	9% (1)	9% (1)	0
<b>Total</b>	14% (4)	54% (15)	25% (7)	7% (2)	0

Table 2: Perceived engagement of the Seismic Waves site by educator type.

In addition to finding the site engaging, nearly all users reported that they found the site either “Extremely easy” (25%) or “Very easy” (68%) to use. There was no discernable differentiation to this question based on teaching venue, years of experience, or the device used to access the site. Roughly a third of respondents reported never looking at the help menu (n=9). Of those that did look at the help menu, 13 found it to be “Quite useful” or “Extremely useful”.

While respondents primarily found the site engaging and easy to use, they were asked what improvements they would make to the design of the website. Respondents provided both suggestions for the design of the site and feature requests. To make the interpretation of the design suggestions easier, all feature requests have been moved down into the item dealing with feature requests (page 10). Suggestions for improvements to the design of the site cover a range of topics but had little consistency. In fact, the only repeated suggestion dealt with the selection of waves to show on the cross-section view.

#### *Seismograms*

- *“Make seismograms horizontal for easier viewing.”*
- *“The graphics seem dated”*

#### *Waves on cross section*

- *“I would like a choice of seeing only the P and S waves before a second trial in which the PP SS PK and all of the mind-boggling array of waves are depicted”*
- *“During an earthquake, it would be nice to be able to toggle off/on the various types of seismic waves. This might help students to focus in on the behavior of only one or two waves at a time.”*
- *“When choosing waves under the “Custom” section I’d like to select more than one wave. Custom can be more customized.”*
- *“The multiple P and S waves are a bit confusing for students who will not read.”*

#### *Playing of Waves*

- *“If I choose a wave under custom, all the waves still appear on the Earth’s surface. If I pick only the P wave, I’d like only the P wave on the surface as well as the interior.”*
- *“I would have the simulation stop at the end of the time instead of automatically repeating the earthquake. I wanted to see the entire seismogram at the end of the time frame. Possible, but when the time is ramped up x100 it was difficult to stop it at the very end. Yeah, I could slow it down, but it would be nice to let it go and not have to worry about stopping it right at the end.”*

#### *Shadow zone*

- *“It would also be great to see the shadow zone on the inside of the Earth.”*

#### *Views*

- *“Unless I am missing something, I was unable to view the entire surface as well as the interior. I do not like the hybrid view. The old version had two images side by side. I would prefer that view to the new view. I do like the detail and the illustration of the p/s waves.”*

*Buttons*

- *“High school students will overlook the current button. I would like to see Load New Quake more noticeable too”*
- *“Put the help button at the top of the website so we can find it easier”*
- *“The buttons for the seismic shadow zones do not work very well for iPads, but work on my laptop”*

*Other*

- *“There may be a bug in the software: when the quake is paused, the seismic waves pause for a moment, and then start moving again, without clicking the play button again.” [IRISNote: This could not be replicated]*

To gain a sense of how valuable the Seismic Waves website was to the participants as educational experts, respondents were asked to report how likely they were to include the Seismic Waves site as part of their instruction. A majority of respondents reported being “Very likely” (n=7) or “Extremely likely” (n=11) to use it. An additional nine respondents reported that they were “Moderately” (n=7) or “Slightly likely” (n=2) to use the site. As illustrated in Table 3, when aggregated by educator type, middle/high school educators were slightly less likely to predict their use of the site as “Extremely likely” and more likely to describe it as “Very” or “Moderately likely”. There was no discernable differentiation to this question based on years of experience or the device used to access the site.

	<b>Extremely likely</b>	<b>Very likely</b>	<b>Moderately likely</b>	<b>Slightly likely</b>	<b>Not at all likely</b>
<b>Middle/High</b>	31% (5)	31% (5)	31% (5)	7% (1)	0
<b>Post-Secondary</b>	55% (6)	18% (2)	18% (2)	9% (1)	0
<b>Total</b>	41% (11)	26% (7)	26% (7)	7% (2)	0

Table 3: Predicted use of the Seismic Waves site for instruction by educator type.

To gain a sense of how the instructors might use the Seismic Waves site, participants were asked to identify up to three primary learning objectives that they could envision using the Seismic Waves website to teach. As illustrated in Table 4 below, the most common concepts included the paths and relative speeds waves travel as the move through Earth.



Count	Concepts	Examples
13	Wave Paths	<ul style="list-style-type: none"> <li>- <i>“Visualize how seismic waves travel and refract/reflect through (and on) the Earth”</i></li> <li>- <i>“Recognize that seismic waves travel in more complex ways than textbooks often discuss”</i></li> <li>- <i>“Diagram basic body wave paths through the earth’s interior”</i></li> </ul>
9	Relative Wave Speeds	<ul style="list-style-type: none"> <li>- <i>“Relate the speed of the waves to their arrival times.”</i></li> <li>- <i>“Determine the relative speed of P, S and surface waves”</i></li> <li>- <i>“Understand the difference in travel speed between p and s waves”</i></li> </ul>
9	Earth’s Structure and composition	<ul style="list-style-type: none"> <li>- <i>“Understand how p and s wave transmission or absorption help explain interior properties of the earth (liquid outer core)”</i></li> <li>- <i>“Observe the diffraction and refraction of the waves as they move through the various layers”</i></li> <li>- <i>“how the waves pass through the different mediums”</i></li> </ul>
5	Shadow Zone	<ul style="list-style-type: none"> <li>- <i>“explain why shadow zones exist”</i></li> <li>- <i>“model how shadow zones are made by the Earth's core”</i></li> </ul>
4	Wave Types	<ul style="list-style-type: none"> <li>- <i>“Better understand the difference between types of waves”</i></li> <li>- <i>“Distinguish between P and S waves”</i></li> </ul>
4	Science skills and processes	<ul style="list-style-type: none"> <li>- <i>“Explain how the data helps to show that the outer core is liquid”</i></li> <li>- <i>“Experiment with wave propagation”</i></li> </ul>
1	Connection between waves and seismograms	<ul style="list-style-type: none"> <li>- <i>“Understand how seismograms are generated”</i></li> </ul>

Table 4: Seismological concepts conveyed by the Seismic Waves site as defined by participants’ example learning objectives.

To gauge participants’ enthusiasm for the site, they were asked how likely they were to recommend the Seismic Waves website to a friend or colleague. Over half (n=15) the responses indicated that they were likely to be “Promoters” according to the Net Promoter Score (NPS) index (Reichheld, 2003). According to this index, promoters are loyal enthusiasts who will keep using and refer others. Another seven participants’ responses were classified as passive promoters, or satisfied but unenthusiastic users who are vulnerable to competitive offerings by others. Finally, six were classified as detractors of the site. “Detractors” are unhappy customers who can impede growth through negative word-of-mouth. In this case, middle/high school teachers were four of the six detractors.

To explore possible new features, participants were asked about two ideas for the Seismic Waves site. First, respondents were asked if it would be valuable to their instruction if the Seismic Waves site were to automatically update the "Load new quake" list to include recent, newsworthy events. The majority of users felt that this would be “Valuable” (n=11) or “Very valuable” (n=11). Respondents were also asked if it would be valuable to their instruction if the Seismic Waves site allowed users to select custom past events for inclusion in the "Load new quake" list. Results were mixed. Half of users felt that this would be “Valuable” (n=5) or “Very valuable” (n=9). Nearly a third felt that this would be

of “Limited value” (n=7) or “No value” (n=2). The remaining five were neutral about the feature.

Finally, respondents were asked in an open-ended item, what if any, additional functions would they suggest for the Seismic Waves website. A spectrum of ideas was offered along with some praise for the site.

#### *Seismograms*

- *“It would be useful if a teacher could isolate specific seismic stations for a particular earthquake and only view the seismogram for that particular station. This would allow for a more scaffolded approach and would make it easier for students to develop a deeper understanding of what is happening.”*
- *“It would be great if there were measuring tools that students could move around the screen to determine distances, P-S travel time differences, etc.”*
- *“NYS high school students need to learn how P and S wave differences can be used to determine distance to epicenter. It might be beneficial to include a P-S wave travel time chart that one can manipulate to use data from each quake to determine distances, origin times, magnitudes, etc. “*

#### *Cross section view*

- *“Have different learning levels for the waves. For example: middle school kids probably do not need to know about the multiple types of P and S waves”*
- *“Display the shadow zone inside of the Earth.”*
- *“Insert videos of the actual damage from the earthquake as the p and s wave hits”*
- *“Please allow for multiple selections of waves within custom waves.”*
- *“Just the 2 views at once.”*
- *“For individual student use...short tutorial on using the site, buttons, etc.”*

#### *Other*

- *“Have some lesson plans loaded.”*
- *“Add more simulations”*
- *“Have a link so we can download seismograms so students can triangulate where the earthquake happened”*
- *“Allow students to generate their own earthquake. Have links available to see impact of quakes.”*
- *“Would love to see a version of this page packaged for aed museum displays, this would involve having a version with external links disabled (no Facebook, Twitter Wikipedia etc) and an option to open the page with quake running (for non-touch screen sites cycling between pages on time. Also maybe an option to have the globe spinning slowly) maybe via url parameters?”*

#### *Praise*

- *“I haven't been able to use the older Jones program. So happy to see this is available.”*
- *“The addition of seismograms makes this page a “must use” resource, congratulations to the team! I would love to see the html5 code used to generate the seismograms now used for a web based seismogram analysis toolkit that would allow simple interactive*

*analysis (zoom, freq filter and travel time only) of web service based data picking, eg a simplified wilber3 interface that pops up an interactive waveform viewer, all accessible in schools through basic web browsers with no flash or Java enabled."*

- *"I like that "shadow zone only" is an option; great idea. (x2)"*
- *"I think it's great. I did not look at the help file, and was able to work out what I wanted to see pretty easily. "*

## Usability Test Results

Participants in the usability testing included two graduate students in the geosciences, two geoscience faculty, and one 6<sup>th</sup> grade teacher. All reported at least some experience teaching students about seismic waves and Earth's interior, but the graduate students were obviously less experienced. Additional supporting evidence for each task can be provided in the of video/audio clips.

### Initial observations and place to start:

When looking at the first screen all subjects reported that they were inclined to click the play button to “see what would happen”. One of the five subjects did observe that the initial screen “had too many things on it”.

Upon pressing play participants are attracted to the globe and the movement of the waves on it. With a brief examination all were able to see the two body waves and the surface waves. For all participants the seismograms were a secondary item. Sometimes they noticed the movement and looked at them. Others noticed the seismograms while trying to figure out what the sounds were.

### Pausing the waves:

When asked to pause and then restart the quake five of five participants easily and quickly clicked the pause and play control buttons.

### Viewing backside of the globe:

When asked to find the other stations not visible from the startup view, 3 of 5 respondents intuitively used the click and drag functionality to rotate the globe. The remaining two participants looked first to the control panel and clicked “Change View Direction.” Only after seeing that “Changing View Direction” didn't get them what they wanted, they used the click-n-drag to rotate the globe.

### Meaning of sounds:

The sounds were not initially obvious to any of the participants. They reported hearing the beeps and then scanning the screen visually to see what correlated with the sounds. There seemed to be a mix between those that correlated the sounds to the phase arrivals on the seismograms, and those that were watching a station and noticed the wave front arrive at it. In the end, all were able to deduce the sounds' meaning with one noting, “it was interesting to figure out” what the sounds were. Interestingly, only one of the five specifically mentioned that different waves had different tones.

### Mute sound:

When asked to mute the sounds all five participants clicked the small “Mute” button next to the reload button. None used the “Mute Sound” item in the menu of controls.

### Restarting simulation:

When asked to restart the simulation from the beginning 3 of 5 participants navigated the pointer directly to the correct button and clicked it. The remaining two had difficulty finding the correct button. One tried to use “Load New Quake”, while the other tried to click “Play” several times in a row. One eventually did discover the “Restart” button while the other required help from the interviewer. There were two observations regarding the functionality of the “Restart button”.

- 1) When asked if the behavior of the site matched what they expected, all were unanimously surprised and thought “it would let me hit play” before restarting.
- 2) One subject was looking at the full non-cutaway Earth when s/he hit restart. For this user, it was quite difficult to tell that something had occurred. It took about 10 seconds before s/he noticed that time was running.

### Obtaining more info about the quake:

All participants immediately identified the title of the quake as a link and clicked on it for more information. The feedback on where the link took you (e.g. to Wikipedia) was mixed. One liked this with no hesitation. One thought it was okay but worried that some think of Wikipedia as unofficial. This participant, along with two others would have preferred something like the USGS event page or an IRIS event page to get more “official” technical info. The final participant, who teaches 6<sup>th</sup> graders, noted that the Wikipedia page was probably to high of reading level for her students.

### Speed:

When asked to increase the speed of the waves, one of the five participants grabbed the bar and slid it to the right on the first try. The remaining four participants clicked first on the box containing the numbers rather than on the slider bar. Upon seeing that this didn't do anything they next focused on the slider bar. Two of these participants grabbed the bar and slid to the right. The other two, clicked next to the right of the slider bar in the blank space, which caused the bar to jump ahead. Then after this they grabbed the bar and slid to the right.

When asked to slow the waves down, all participants grabbed the bar and slid to the left. Most went all the way to the left. When noticing that this made the waves run backwards all found this cool but commented that it would be nice if it had a line or color change to indicate where the zero point was. As one participant described it, I “assumed the far left would be the zero point.”

All participants were able to explain that the speed was being shown as 2X times real time. While noting a specific item in the interview guide, it is worth noting that one participant did have difficulty explaining what it meant when the speed became a negative times real time while thinking aloud.

An interesting occurrence involving a negative speed was also observed. A participant set the speed to -50x, which ran the waves back to the source as expected. At this point s/he clicked play to make the waves go forward again and was confused when nothing happened on the screen (even noting that the dialogue window said playing.” It took

him/her a while to figure out s/he they needed to slide the speed back to at least 1x real time.

#### Displaying phases on cross section

When asked to simplify the phases displayed on the cross section to only show the direct p and s phases to set up a discussion of the shadow zone only two of five participants were able to navigate quickly to complete the task. Of the remaining three, one already had “Cross Section Waves” opened and after scanning around discovered “Shadow zone only” and selected it. The other two started by first expanding “Label Waves On.” Then after not finding what they wanted, opened the “Cross Section Waves.”

When playing with selecting what phases to display on the cross section two participants were surprised that when P waves were selected the surface waves still were shown.

*The entire group did not complete the following tasks so this feedback should be taken with some skepticism.*

#### Learning more about what is shown:

One participant was asked where to go to learn more. S/he had great difficulty finding the “What you see is explained HERE” link and noted that this was not obvious at all. While exploring the rollover the participant was very confused that the audio seemed out of sync with anything they were clicking. It took a while for him/her to realize that there was an animation below the rollover playing and that the sound was not tied to the rollover. The participant also expressed frustration that if you moved your mouse off the buttons of the rollover, the page reverted back to its original state. In the end the participant concluded that the components felt like something that was repurposed from another product and just stuck on.

#### Viewing another quake:

Two of the participants were asked if they could view an earthquake other than the one they were currently viewing. One subject was able to quickly navigate to “Load New Quake” while the second had initial difficulty locating it. However, once “Load New Quake” was found, both were easily able to bring up a new event.

## Findings and Recommendations

- 1) 93% of survey respondents found the site “Very Easy” or “Extremely Easy” to use.
- 2) While easy to use, usability testing revealed that participants encountered challenges locating or executing some of the site’s core functionality.
- 3) A majority of participants described the site as an engaging (68%) tool that they anticipated using as part of their instruction (67%).
- 4) Post-secondary educators found the site more engaging and reported that they were more likely to use the site instructionally than their middle/high school counterparts.
- 5) Based on the current design and functionality, just over half of respondents, regardless of educator type, are likely to be “Promoters” or enthusiasts who will keep using and refer others to the site.

To further enhance the design and functionality of the Seismic Waves website, three main recommendations can be derived from the results and findings described above.

First, refine the core functionality. Implement the following primary enhancements, based on usability test results, to ensure the core functionality of the site is easily discovered and operates as most users anticipate.

- 1) Add symbols to communicate to users that one can click-and-drag to rotate the globe.
- 2) Change the symbol for either the stations or the quake. Currently both use the same map symbol (a small white dot).
- 3) Seek out different icons for the “Reset” button and conduct A/B tests to see if it is more widely recognizable.
- 4) Require users to push play to start the simulation
  - i. After pushing the “Reset” button.
  - ii. After the simulation has reached the end
- 5) Explore options to provide more audience-appropriate information for each quake e.g. forked navigation for middle/high school vs. undergraduate.
- 6) Modify the Speed Slider to make it more obvious that you change the speed by clicking and dragging it.
- 7) Add an indication of where the zero point is on the Speed Slider.
- 8) Simplify the Controls menu
  - i. Remove the “Mute Sound” item from the menu.
  - ii. Simplify menu “Cross Section Waves” to “Waves Shown”
  - iii. Condensing “Wave Labels On” to only offering one option – Labels (all) On/OFF
- 9) Use more obvious markings in “Cross Section Waves” to indicate which of the wave groups is currently selected.
- 10) Allow the selection of multiple phases in Custom waves (e.g. Command click)

- 11) Make surface waves an option in Custom waves menu
- 12) When a custom wave is selected, adjust waves shown on the surface to match what is selected (e.g., if you choose PKIKP then S phases and Surface waves would not be shown on the surface).
- 13) Make the link for "Learn more about what is shown" more obvious to users
- 14) Modify the layout of the "Learn More" page so that it has a left menu with two options. The first (selected at first) "Watch animation". The second option would be "Explore on your own" and would replace the animation with the rollover.
- 15) The animation on the Learn More page should not play automatically when it loads.

Second, improve the appeal and perceived usefulness of the site to the middle/high school audience by implementing small adjustments and additions.

- 1) When the page initially loads, create a invitation to inquiry by placing a question mark on the cut away side of Earth. This would disappear when the play button is pressed.
- 2) Make the simplified "shadow zone group" the default wave set rather than the more complex "standard group"
- 3) Provide a short tutorial video on the use of the sites features.
- 4) Provide links to at least one lesson plan for using the site with students

Finally, Plan for possible new functionality and audiences by exploring the identified feature suggestions, listed on page 16, provided by beta testers.

- 1) Automatically update the "Load new quake" list to include recent, newsworthy events (link to Teachable Moments lessons).
- 2) Provide a labeled overlay of the shadow zones on the cross section.
- 3) Move the help button to the top of the screen to make it more discoverable
- 4) Provide checkboxes to display/hide individual seismograms and corresponding station markers
- 5) Provide a link to download seismograms from the event for an EQ location exercise
- 6) Create a version of Seismic Waves optimized for museum displays e.g. looped, globe slowly rotates, no external links etc.



## Appendix B - Seismic Waves Features / Rationale Matrix

Intended for collaboration between key players in Seismic Waves project to answer the question: Why is it the way it is and also clarify functionality for the help menus.

	<b>Rationale</b> (why it exists, the benefit to users/teachers)		
<b>Feature</b>	Russ	Alan	Michael
Play, pause, restart buttons	To give a familiar way to control the simulation and to be large enough for easy mobile touch use.	Okay.	
Rotatability	To be able to see both surface and cross section, esp. if surface waves have traveled far enough away to be out of view. Also, it's fun.	Agree.	Allows user to change the view to match their focus and interest. For example, they could choose to only see the cross section or they could only choose to see the surface, or they could choose more complete and view both.
Speed control	To make it possible to "skip ahead" or "compress" time, so that many minutes' real time can be seen in seconds.	Also, the feature to allow "time to run backwards" is important. A teacher might be showing a feature and go too far forward.	
Cross Section view	Key to seeing the interior wave propagation, critical feature.	It is important for users to see the composition of the interior of the earth and how this affects the propagation of seismic waves.	
Surface view	Allows terrain and visibility of the slower moving, simpler, concentric patterns of the surface waves.	This view makes it apparent that the P, PP, S, and SS waves on the surface are the same waves as shown on the cross-section because they intersect at the edge of the hemisphere.	
Wave labels (and on/off of them)	To allow user to unclutter the view and focus on the patterns	Agree.	Agree.

	without worrying about the names, some of which are long		
Multiple terrains (maps)	To see how a given quake affects things like population (where are the people) and the time of day a quake happened (e.g. at night), or the locations of nuclear power plants (danger).	This is a great improvement over the original SW.	Is this the purpose of the program? This seems like it could be interesting, but it might be distracting or add unnecessary complexity. To me seems better suited for SM.
Phase selection on cross section	To allow users to focus on preset collections of phases, such as Shadow Zone, only. Even to allow individually-chosen phase selections.	The teacher can show only the P wave. Then add in the waves that are generated at the mantle-outer core boundary such as PcP, PcS, and PK.	We might consider looking at the wording here. If the idea is a setting to illustrate a specific concept, we might consider being explicit in the user "options". For example, "I want to illustrate the shadow zone" or other specific tasks we know or assume users will want to do.
Change view direction	If the population centers or other points of interest (depending on terrain being viewed) lie on the "wrong" side of the cross section slice, you can switch to view the better direction, East or West.		
Sound	It's fun. The "countdown" sound is a hats-off to the original S.W. program, and the rest of the sound is intended to convey/evoke the loud boom and then long, low rumble that one might hear during a quake.	Much better sound than in the original Seismic Waves program.	
Mute of sound	Allow one to not have to hear the sound over and over, especially in a classroom setting. Consider if initial setting should be on or off. Currently is on.	Agree.	This function seems hidden to me as I didn't even know it was there until I went looking for it after seeing it in the list. What about adding a speaker icon? Click and it puts an x over the speaker.
Social buttons	A shortcut for users that	It will be interesting	To expand awareness and

	might like to share the site with friends or family	to see if this feature will be used very much.	use of the product
Email us	A quick way to launch your email client and have addressed an email ready for your users' thoughts, comments and questions.		This function seems hidden to me as I didn't even know it was there until I went looking for it after seeing it in the list.
Snapshot	To quickly grab an image of what's on the screen suitable for dragging into an email or a PowerPoint.		I really like this but again, this seems hidden. This could be an important function and we might consider making it more obvious. Allows the instructor to make annotated views in a similar format to emphasize a key point. These, in a ppt, could accompany the instruction in seismic waves.
Ability to load noteworthy events	Provides a hook for engagement by using a noteworthy event that they are likely to remember occurring.		
Ability to load recent events	Provides a hook for engagement by using a recent event that is likely to be fresh in people's memory.		

## Appendix C - Seismic Waves Usability Semi Structured Interview Guide

<http://ds.iris.edu/seismon/swaves/>

**Version 1.0 – 12/15/16**

**Introduction:** Thank you for agreeing to participate in this evaluation. As I mentioned we have a new product, the Seismic Waves website. This product is currently in Beta so we are actively looking for ways we can optimize the interface to make it more user friendly. This means that during our time together the website, not you, is the subject of interest. In this study I will ask you to complete several tasks using the software. As you interact with the software, I will encourage you to “think aloud” as you proceed. This may feel awkward at first, but I have an example we can use for practice.

You may have noticed the camera. With your permission, we're going to videotape the computer screen and record what you have to say. The video will be used only to help us figure out how to improve the site, and it won't be seen by anyone except the people working on the project. It also helps me, because I don't have to take as many notes and can focus better.

If you would, I'd like you to sign something for us. It simply says that we have your permission to tape you, and that the recording will only be seen by the people working on the project.

Great! Let's get on with the study. Our discussion should take about 15 to 20 minutes.

*Do you have any questions before we begin?*

**Talk aloud example:** Take out an empty stapler. Ask them to open it, take the staples out, replace them, shut the stapler and staple some paper – talking all the time about what they see, what they expect to happen, what actually happens and how that matches up.

### **Demographic Questions:**

- 1) Do you teach about Earth's interior structure?
  - a. If yes, in what class? What level are the students?
  - b. If no, opt out of the study.
- 2) How many years have you been teaching?
- 3) Do you have any favorite Web sites that you use for teaching about Earth's interior structure as revealed through seismic waves?

### **Script:**

1) First, I'd like you to look at this page and tell me what you think it is, what strikes you about it, and what you think you would click on first. For now, *don't actually click on anything*; just tell me what you *would* click on.

*And again, as much as possible, it will help us if you can try to think out loud so we know what you're thinking about.*

2) Thanks. Now I'm going to ask you to try doing some specific tasks. I'm going to read each one out loud and give you a printed copy.

3) Please run the simulation.

4) Pause the simulation and describe what you see.

a) Which earthquake is this?

5) Now rotate the Earth so we can see the seismic stations better.

6) The waves haven't made it all the way through Earth but let's restart the simulation from the beginning.

7) Describe what you think the sounds indicate? They might be kind of annoying if the class were all in a lab together. Please turn the sound off.

8) Now let's run the simulation for a different earthquake?

9) Before you run it, let's get more information about this earthquake.

a) What is your impression of the use of Wikipedia?

10) Please make the waves go faster. Now make the waves go slower again.

11) Please turn off the labels on the wave fronts so we can focus more on the waves and less on what the names of each phase is.

12) Please set it up so that we only see the direct P and S phases and then run it so we can illustrate the shadow zone.

13) I think we missed something there. Please run it in reverse and then forward again so we can see how that wave came through the core.

14) Lets learn more about what this simulation shows.

**Post Script:** Okay. That was my last question. Thank you so much for agreeing to help us refine this tool. I am confident that your feedback will contribute to an improved product.