

Simulation and public communication of ocean response to changing sea ice concentration

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## **Abstract**

With only 50% of the general public agreeing with scientists concerning the extent of climate change and its possible causes, there is a need for scientists to help the public understand what is happening on their planet. The Arctic environment is one of the most rapidly changing due to the increased pressures of climate change. Effects of reducing sea ice concentrations in the Arctic that are still largely unknown. With the incorporation of hands on tank demonstrations with simple technology, complicated processes such as albedo were brought to a simplified level. Thermal responses of water temperatures were measured by two participant groups to demonstrate the effects of varying reductions in sea ice concentrations. Changes in participant responses to questions concerning the effects of differing sea ice concentrations in the Arctic before and after the demonstration were also measured.

## **Introduction**

Since the industrial revolution, the climate in the Arctic has been changing rapidly, having a dramatic effect on global climate. Albedo is one of the processes effecting ocean properties in the Arctic. As the global climate continues to change, so does the ways in which people learn and receive information through media, museums, scientists, and politicians. Climate change is becoming a growing concern throughout the world, as well as the ways in which scientists can teach the general public about how the global climate is changing. As the public debate surrounding climate change impacts become more commonplace, science policy in general and

ocean science policy specifically, now strives to find ways in which the complex link between the earth's climate and world's ocean can be shared. In order to share information effectively about climate change, one will need to discover ways to interpret their own individual conceptualization regarding key processes and to communicate their own findings about those processes.

The National Snow and Ice Data Center (NSIDC), describes albedo as a quantity that gives the ability of a surface to reflect solar energy. Thermal response of Arctic waters is due in part to the light penetration depth as well as the response of albedo. "The optical properties of snow/sea ice vary with age and by the processes they were formed," (Marks et al, 2014). The level of albedo and the penetration depth of light can be affected by a variety of properties including types of sea ice; sea ice in the melting phase, first year ice, and multi-year ice. The importance of albedo in the Arctic relates to the concept that sea ice albedo is higher than any of earth's many surfaces. The average reflectivity of the earth's oceans is approximately 6 percent reflectivity while sea ice ranges from 50 to 70 percent reflectivity (NSIDC, 2016). These factors make studying and understanding processes in the Arctic extremely important, because it raises the important question of what happens when the sea ice concentration and composition change?

Some of the difficulty in presenting climate change research comes from the complexity of explaining the processes associated. Ice-albedo feedback has been associated with the decrease of snow and ice cover and the corresponding increase in surface temperatures (Curry, 1995). Curry was able to show how ice-albedo feedback operated in multiyear is as well as with decreased sea ice extent. That

study explains that in order to understand overall stability of the Arctic one would need to look at the interrelationships between all of the coupled atmosphere-sea ice-ocean feedback processes happening in the region. The Arctic is a region that is sensitive to climate change due to the active ice albedo feedback that has a great impact on temperature stability in the region. Average September Sea ice cover has experienced a steep decline between the years 1979 and 2014. This decline is leading to thinner ice, and a generally warming climate in the Arctic Region, (Serreze, 2015). Serreze did express some uncertainty in predicting these trends because of the variations in atmospheric circulation and the oceanic heat loss in the winter, which acts as a negative feedback or stabilizing effect in the sea ice system.

Informal education is a style of learning where the control is in the hands of the learner (Griffin, 1994). The amount one chooses to learn and partake in these interactions is more flexible than those in a formal education setting, where one is held to in a classroom for a given time. This makes teaching a population about topics such as climate change more complex. Although the Intergovernmental Panel on Climate Change has predicted that the warming of northern high-latitudes would be 40% greater than the global mean by the end of the century (IPCC, 2001) there is still little understanding of exactly what is occurring by the general public. In a study done by Pew Research Center, researchers found that 50% of the general public agreed that humans were worsening climate change, while 87% of scientist agreed that humans were worsening climate change (Santhanam, 2015).

Theories behind education and different learning styles include the ideas of learning from mistakes as well as the process of trial and error (Marsick, 2001).

Although there is no set style of learning, several that have been found to be important aspects of informal education are, experimental learning, self-directed learning, and reflection and action. In a study conducted by Brian L. Gerber et al (2001), it was stated that the formal classroom was not the only setting science reasoning and literacy could be developed. Instead the majority of students had science learning experiences outside of the formal classroom. From the beginning of a students' education to the end of their time in high school, students will have spent approximately 11,000 hours in the classroom and 65,000 hours outside of the classroom (Medrich, 1982).

This investigation exploited the time people spent outside of their workplace and school settings, while addressing the concerning disconnect between scientists and the general public. Understanding of why sea ice loss in the Arctic can result in positive feedback that has potential to cause global climate change. Using education modes is essential in finding effective ways to spread scientific information through the general public. This study will summarize participant responses to different modes of education, while also giving insight of the effects changing sea ice concentration has on the Arctic environment.

## **Methods**

A simulator of sea ice regulation of thermal heating was developed as a tool for educating participant groups about the potential results of sea ice loss in the Arctic. I developed a tank model of Arctic water and sea ice concentration for use in a hands on activity setting. These were used along with a video demonstration, and

a testing tool to document the changed response and opinions of two participant groups, as well as the ability for the tank model to show thermal response.

Design parameters for the simulator of sea ice regulation of thermal heating were that: a) it had to be portable, b) it had to be visible from the front as well as the top, c) must have a digital read out of the thermal response, d) be simple enough for those of a younger age range to participate, while providing enough educational stimulation for adults of all ages, e) have multi-user access, and f) show heat exchange between a primary heat source and different water depths within a given amount of time.

The first build involved a 20-gallon aquarium tank with the dimensions of 30.3" x 12.5" x 12.8", a heat lamp stand that allowed the 250 watt heat source to be 19.5 inches away from the surface water, and had three digital temperature sensors for acquiring temperatures at the surface of the water, the bottom, and one for collecting a temperature depth profile before and after tests. The four tests were of the thermal response of 10%, 50%, and 75% sea ice coverage that was represented using foam balls and one test using a solid sheet of foam that was equal to the 50%.

Three trials were done with the simulator, 2 by participant groups, and one done by myself. After completing trial 1 of the simulation with a group of participants, changes were made where the height of the heat lamp was lowered to 12.6 inches above the water's surface, and the beginning temperature for each percentage test was lowered using ice, in order to provide a constant beginning temperature. In total, 3 trials were done using the simulation, to measure its effectiveness in accurately representing thermal response in a system with varying

sea ice concentration. Trials 1 and 2 measured thermal response over the course of 10 minutes for each sea ice concentration, while trial 3 used 5 minute increments.

Two teaching types were used in order to educate participants on the impacts of sea ice change in the Arctic. The first mode was a hands-on experiment where a group of 6 and a group of 5 were brought into the University of Washington Ocean Tech Center to participate in a 4-part activity set. Participants were recruited from the University of Washington School of Oceanography, as well as small college groups throughout the Seattle area.

Pre and post tests were created in order to evaluate the effectiveness of the hands on demonstration to show a change in response to 5 questions before and after. The pre test had 6 questions, one of which was more opinion based, whereas the other 5 could be answered with data from the demonstration. Parameters for the tests were that they would be almost entirely answerable from the information given during the demonstration, they would be short enough to take little time, but would be able to address all aspects of the simulation that may be needed to understand the Arctic process related to surface albedo change and thermal response of sea water.

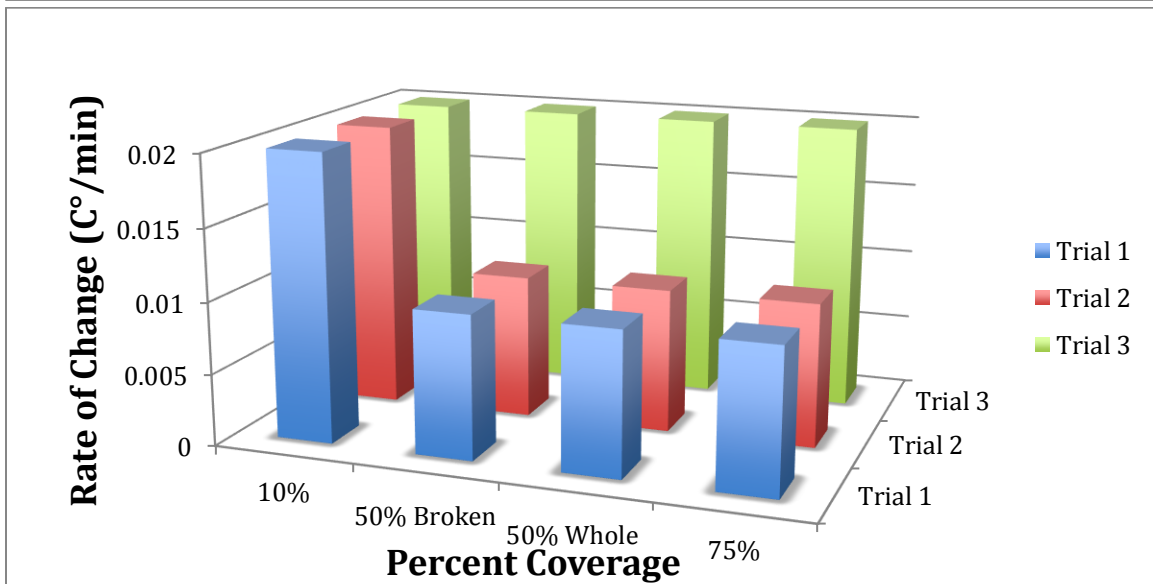
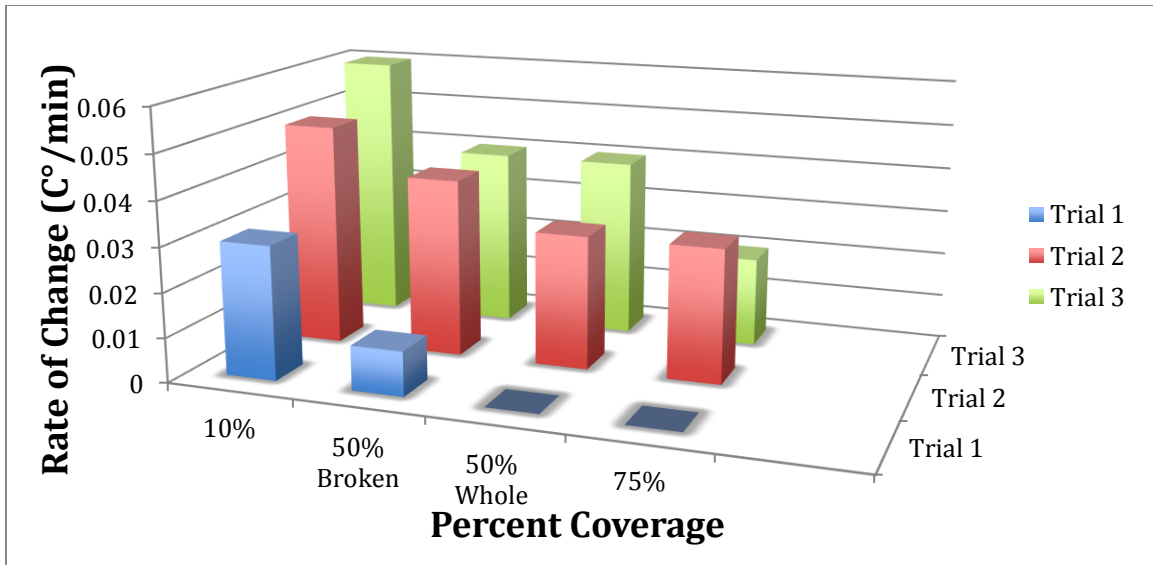
The hands on experiment took approximately 60 minutes to complete. Each group split into 3 sub groups, one for reading temperatures, one for recording data, and one for developing a graph to use to interpret the data at the end. Both groups went through each sea ice percentage discussed above and recorded the temperature response over the course of a time period decided by the group. A pre

test and post test were used in order to evaluate the learning response of each participating group.

The second teaching type was a four-minute video of the hands on experiment done by myself. 5 participants from the previous experiment were asked to participate in this evaluation process. The video provided a brief description of the tank simulation, and included beginning temperatures for each percentage as well as a depth profile of the temperatures in the tank after 5 minutes of heating. Final comparisons were done using a survey, that evaluated effectiveness of each style, which style was preferred, and which would be recommended to someone outside of the participating groups.

## **Results**

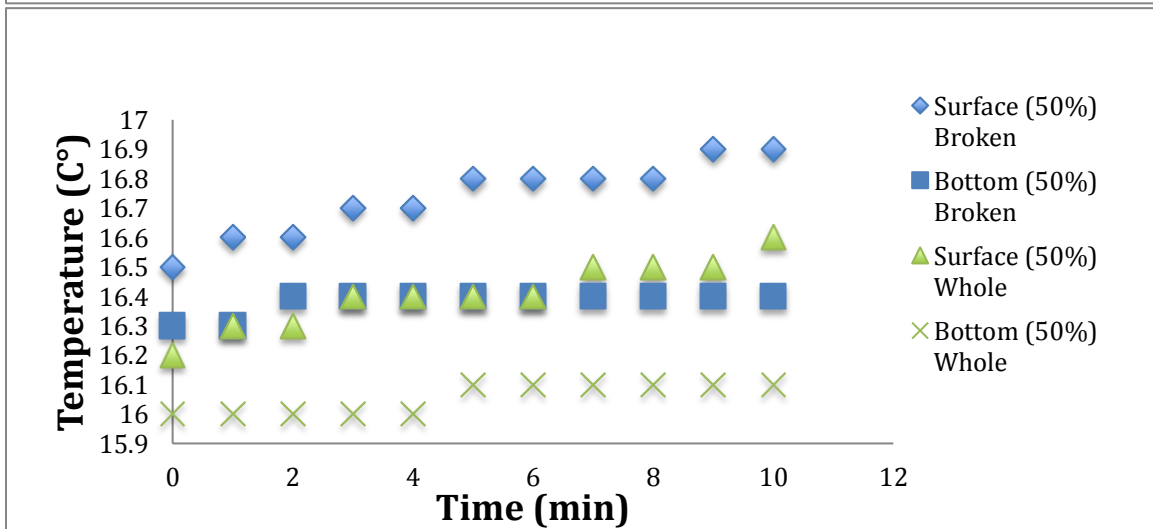
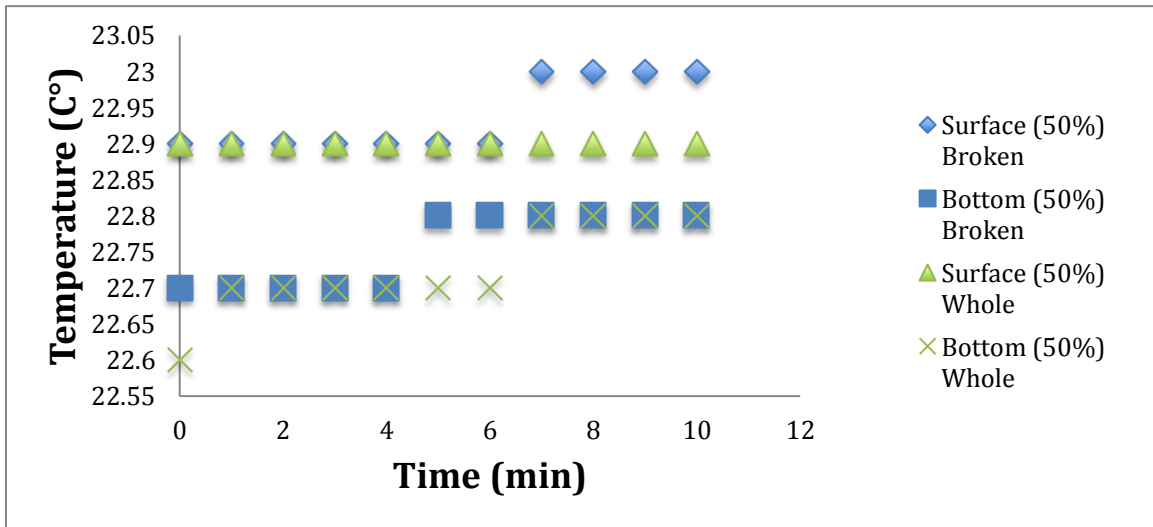
The thermal response of the Arctic simulation showed similar trends for all 3 trials, with the first trial showing the least amount of thermal response overall (Fig. 1a and 1b). Rates of change of surface and bottom temperatures for simulated sea ice concentrations showed the greatest change for 10% sea ice coverage and the least for 75% coverage. The comparison of broken ice to full sheet ice, broken ice showed the greatest rates of change of the surface waters, but both broken and full sheet ice had the same rates of change for the bottom depth (Fig. 2 a, b, and c).

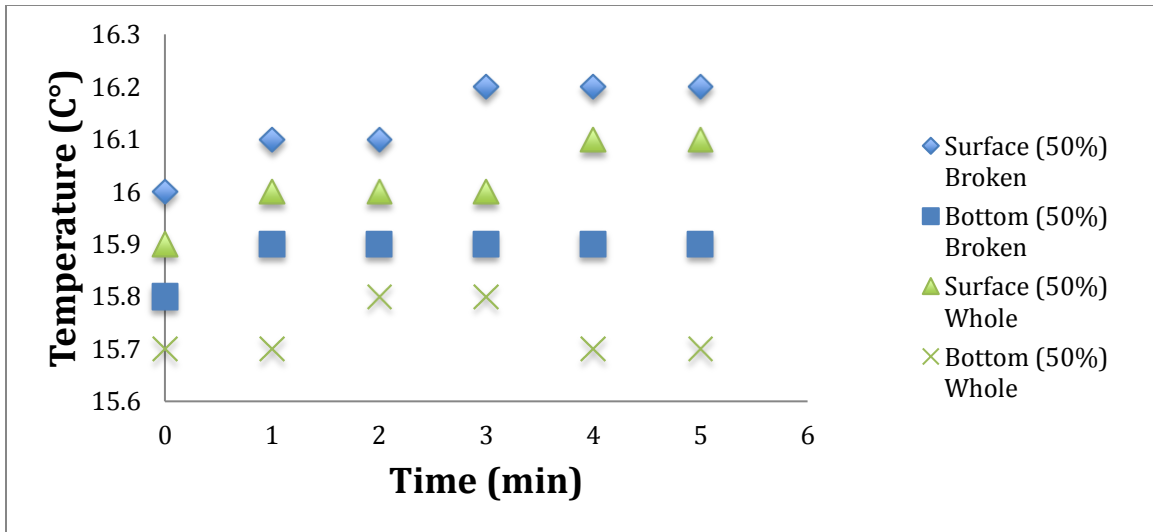


**Figure 1 a and b:** Rates of temperature change for the surface water (a) and for the water at the bottom (b) of the aquarium tank for three trials. Trials 1 and 2 were done in the time interval of ten minutes while trial 3 was done in only five minutes.

Rates of change for 10% sea ice coverage varied between 0.03 and 0.06 C° per minute at the surface, and the bottom rate of change remained the same for all three trials at 0.02 C° per minute. 50% broken sea ice coverage varied for both surface and bottom waters, between 0.01 and 0.04 C° per minute at the surface, and 0.01 and 0.02 C° per minute at the bottom. 50% full sheet ice coverage varied

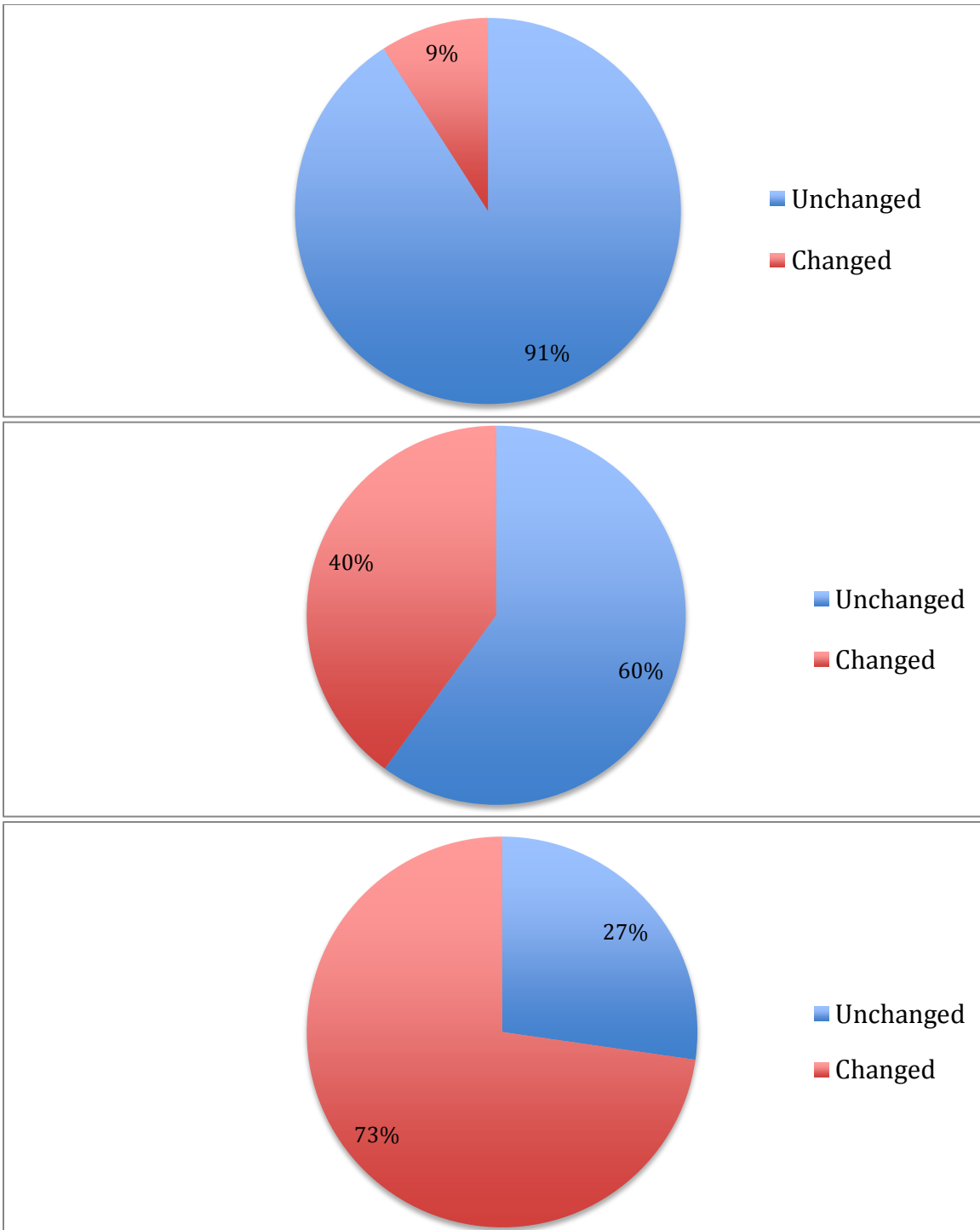
between 0 and 0.04 C° per minute at the surface, and between 0.01 and 0.02 C° per minute at the bottom. 75% sea ice coverage showed the least amount of change for the surface waters, which varied between 0 and 0.03 C° per minute, and matched the variance in rates of change that both 50% coverages shared.





**Figure 2 a, b, and c:** Temperature distributions of bottom and surface waters for trials 1, 2 and 3, when simulated ice is broken up or when it is a whole sheet for three trials.

Responses of the pre and post-test taken for the hands-on demonstration showed changes in answers for all questions that were asked. Question 1 asked which sea ice concentration had the greatest cooling effect on the water. The responses to this question had all but one person choosing 75% in the pre test, but all participants answered 75% in the post-test. Question 2 asked which sea ice concentration would lead to the greatest amount of stratification. In the pre-test three participants said 10%, five 50%, and three said 75%. Answers to the post-test ranged with five for the 10%, five for 50%, and 1 participant for 75%. The last multiple choice question asked, which sea ice concentration would lead to the greatest change in deep water temperatures. Answers for this question began with three for 10%, two for 50%, three for 75%, and three for none. Post-test answers had seven participants for 10%, and four for 50%.



**Figure 3 a, b, and c:** The comparison of answers between the pre and post tests for questions one, two, and three respectively, that either changed or remained unchanged after the simulated Arctic activity.

Short answer responses for questions 4 through 6 varied between the pre and post-test. Responses for question 4 pre test were 100% yes, but 18.18% gave incorrect reasoning, and in the post test 90.9% said yes using reasoning from the experiment. Question 5 pre test responses had a larger split where 45.5% of participants said a thermal response would be seen within a year, and 54.5% said it would take several to 100 years. In post test responses many noted that as so as the ice was lost or taken away, they could see an immediate effect in the thermal response of the water. Most agreed with their beginning answers, saying this process would take much longer in the Arctic itself. Question 6 was only asked in the pre test and 100% of participants said the loss of sea ice would have a negative impact on the Arctic environment.

In the video and hands-on demonstration comparison, 2 of the 3 participants responded that the video demonstration was somewhat effective, while one said it was moderately effective. All 3 said the hands-on demonstration was very effective, and said they preferred this style when seeking to learn outside of the classroom. Lastly all 3 said they would recommend the hands-on demonstration to those with little to no background in Ocean or Arctic science.

## **Discussion/Conclusion**

Climate change is becoming a growing concern throughout the world, as well as the ways in which scientists can teach the general public about how the global climate is changing. This series of investigations was able to address this concern in a simplistic way that allowed simulated changes to be observed as well as led to a

changing response to questions for a small sample group. Throughout the course of three trials using a tank simulation both participants and myself were able to further our understanding of how sea ice change could potentially affect Arctic temperatures.

The greatest temperature change observed on average for all 3 trials occurred for the 10% sea ice coverage while the least occurred for 75% coverage for both bottom and surface waters. The simulation also tested the differences in solid ice versus broken pieces, and we found that the broken up pieces showed greater rates of change for both surface and bottom waters. This supports my claim that broken ice would lead to greater rates of change. Changes in answers between the pre and post test showed that overall participants' answers were affected by their involvement in the hands on demonstration.

Results from the experiments investigating rates of change support my hypothesis that reduced sea ice coverage in the Arctic will result in a larger rate of change in temperatures for decreased sea ice coverage. In an experiment done by Bonnie Light et al (2015), they discuss that some forms of broken ice transmitted approximately 4.4 times more total energy to the ocean than ice that didn't have open areas or thinner ice. In relation to the broken versus solid ice, this supports my claim that broken ice would lead to greater rates of change. The investigation of teaching styles showed that overall participants responded better to hands on demonstrations rather than the video demonstration.

Further research would need to be done with a greater sample size of participants in order to better represent responses from the general public to the

two teaching styles. This as well as bringing the tank simulation into museums and testing the difference in response from people in a more informal setting could be part of the next steps in answering the question of which teaching style is most effective. Future work with the simulation itself could potentially involve an interface that would allow participants as well as myself to compare what we found to actual changes in the Arctic, in order to see how well this model represented the albedo feedback system in the Arctic.

In conclusion the simulator did respond in the ways, which were to be expected. Although there was variation in how much change was seen depending on starting temperatures and heat source to water distances, the trends observed remained fairly constant throughout all 3 trials. The pre and post test were able to provide insight into how a sample of the general public responds to being actively taught information about a climate system. The evaluation comparing the hands on demonstration versus the video demonstration supports the idea that hands on demonstration should be something to invest in, in order to reduce the disconnect between climate scientists and the general public.

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