

MODELING IN HIGH SCHOOL EARTH AND SPACE SCIENCE

by

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ABSTRACT

Modeling is a key practice embedded in the Next Generation Science Standards (NGSS) and its purpose is to help students develop their ability to reason, explain, and apply their classroom learning to real world phenomena. Students often struggle to take their science content learning and use to explain complex scenarios. In this study, all teaching and learning was done via Zoom for the duration of the research period due the COVID-19 pandemic. In order to develop the skills required for modeling and to help promote engagement during synchronous class sessions, students participated in twelve weeks of virtual modeling-based instruction and synchronous classroom activities as well as two summative assessments that required them to model complex phenomena around Earth and space science. Students were asked to self-evaluate their ability to use and develop models at the beginning and the end of the research period. The data did not show that student confidence improved from the beginning to the end of the treatment, nor did student scores on the summative modeling assessments improve from the beginning to the end. Required remote learning was a new experience for all students and it proved to be a tremendous struggle for both engagement and assignment completion and submission.

INTRODUCTION AND BACKGROUND

Context of the Study

Bremerton High School is an urban, 9-12 school with 1200 students. I have been teaching 9th grade science here for twelve years. The current format of this course is designed to be a survey of Earth, space, and physics with an emphasis on hands-on learning, engineering, and design. The course includes students from all ranges of abilities and backgrounds. Bremerton High School is considered a high poverty school with 62% of our students qualifying for free or reduced lunch in the 2020-21 school year and the median household income for the city of Bremerton was \$52,000 in 2019 (US Census, 2019).

My students come to me from all manner of science backgrounds and their experiences with science have a profound impact on their willingness to engage with me, as the teacher, and the content of the course. The abilities range from elementary level reading and math to students performing above grade level. Out of my 72 9th grade students, 10% were served through our English Language support courses and 21% had either Individual Education Plans (IEP) or Section 504 plans. On average across all racial groups, almost 50% of my students came to me in the fall of 2020 three or more grade levels behind in both math and English Language Arts based on their winter 2020 8th grade i-READY scores (M. Zuber, personal communication, March 9, 2021). This has made creating and delivering curriculum a challenge. Our school-wide 9th grade success rate has come under scrutiny as the State of Washington has increased the required number of credits to graduate, science included. For the 2018-2019 school year, only

53.9% of our 9th graders ended the year having earned all of their credits for the year (OSPI, 2019). At the end of first semester of the 2019-2020 school year, over 40% of 9th grade students were not on track to graduate (J. Streck, personal communication, April 18, 2020). These statistics brought into sharp focus the need for finding methods to engage students and that holding on to traditional instructional methods was not meeting the needs of many students.

Growing up, I had a very traditional science education filled with lectures and confirmation labs. Not until I went to college, did I feel like I experienced inquiry-style science through my science teacher preparation courses. The idea of science as an exploration for students, where questions could be answered with more questions, and where students developed their understanding of science concepts through doing science was the early foundation of my teaching practice. In the twelve years that I have been teaching at Bremerton High School, my vision for my role as a science teacher has undergone many shifts and iterations as I worked to implement more inquiry-based pedagogy.

Washington State adopted the Next Generation Science Standards (NGSS) in 2013, and my practice of teaching science has morphed to incorporate the three-dimensional, interconnected nature of these new teaching and learning guidelines (NGSS Lead States, 2013). The NGSS includes the science and engineering practice of developing and using models. As I began the process of choosing a focus for my action research plan, I kept coming back to this practice as a keystone of my teaching, but that I had not implemented it with any sort of fidelity. When my instruction centered around

the practice of modeling, I felt my students learned more, I had fewer classroom management issues, and my classroom was a more joyful and engaged place. However, without a system to measure student growth, my observations about my classroom remained nothing more than observations.

Implementing the use and development of models as a practice was intended to level the playing field in my classroom, providing access to my curriculum to all students. The mantra of the NGSS is, “science for all.” I did not feel my classroom was meeting that mission and I struggled to find an area to focus my attention to improve both my curriculum and my instruction, as I have no district-determined curriculum. Every year, my 9th grade science team plans a basic scope, sequence, and timeline for assessments. Our team shares resources, but we are able to be creative with implementation and delivery of our curriculum. In the 2019-2020 school year, my school district went 1:1 with Chromebooks for all secondary students. Although I had full time access to a laptop cart in my classroom for the prior five years, managing individual student devices brought frustrations as did the district’s expectation of immediate classroom use of the technology. I was overwhelmed and felt like I was just using technology for technology's sake. The work I had done in the past using anchoring phenomena and cohesive storylines within NGSS and my curriculum was forgotten to focus on the new technology initiative. I was unhappy with my teaching practice because my students didn’t have a purpose for our daily work, and I struggled to manage several very challenging class periods. The units of study in that semester felt meaningless and I needed a way to return to my purpose as a teacher.

With those struggles in mind, I came back to the work with modeling that I had been doing through a series of professional development sessions with science colleagues from my region. I came back to my need to see, hear, and interact with my students in the way that NGSS had intended. I wanted my students to find relevance in their work and not wonder why they would ever need to know what I was teaching. The development and use of models helped bring students into the process of doing and experiencing science. The availability of resources around utilizing modeling in classrooms has increased dramatically since the development and publication of the NGSS. Finding examples and methods of successful implementation takes time and developing my own action plan took even more time and energy.

The COVID-19 pandemic turned my teaching life upside down. At the end of July 2020, it was announced that we would be starting the school year in an all remote format. A re-evaluation of the status of in-person learning was done at the nine-week mark in the semester and we stayed all remote until April 1, 2021. This meant that the entirety of my research treatment period would be done online with students. I had no experience with trying to do modeling-based teaching with virtual classes. I was deeply concerned about the engagement of students in their learning while all remote. This only increased my desire to make my class accessible, high interest, and a source of science success for my students in this new world of online education. This was a year of trial and error, profound frustration, and every day provided me with learning experiences. Throughout the semester, the struggle to get and keep students engaged forced me to the edge of my

creative boundaries and the practice of modeling is where I felt I could have a positive impact on an otherwise very tough year for students.

Focus Statement

I knew I could put together a method to measure my students' abilities to create and use their own models as well as apply those models to real-world science problems. I also wanted them to be self-reflective around their learning and engagement as it related to the elements in the NGSS, specifically pertaining to modeling as a practice. I felt I was a more engaged teacher during the units when modeling was the focus, but I wanted data and documentation to support my observations and feelings.

My focus question was, How does model based instruction impact student performance on phenomena-based assessments?

My sub-question included the following:

1. What effect does model-based instruction have on student engagement during remote learning?

CONCEPTUAL FRAMEWORK

Modeling as a Classroom Practice

The Next Generation Science Standards were released in 2013 and the foundational research, *A Framework for K-12 Science Education*, laid out a vision for the future of science education. The *Framework* and standards included the eight science and engineering practices that would enable all students, in kindergarten through high school, to become more scientifically literate and better equipped for the increasingly competitive Science, Technology, Engineering, and Math driven world. For too long, the focus in science education has been on learning narrow content information without a bigger picture of applying learning to solving problems or making predictions about how and why the world works the way it does. The science and engineering practices require students to develop the skills of a scientist or engineer while also applying content knowledge. The eight practices include asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The breadth and depth of skills encompassed within the practices is intended to discourage the idea that there is one way to do science and that the scientific method is a lock-step checklist for how science is done in the real world. Instead, NGSS more accurately reflects that science inquiry is a dynamic and innovative process and invites students to participate in that process (National Research Council, 2012).

Modeling as a key classroom practice came about with the 2013 release of the NGSS. Teachers have been using modeling as a strategy for many years, but more often it is in the format of modeling-of instead of modeling-for. This often looks like students recreating textbook images or simply reconstructing commonly accepted science ideas or concepts (Gouvea & Passmore, 2017). In a classroom, reconstructive modeling is often seen as edible models of cells or pasta and marshmallow models of atoms. In reality, models need to represent events or processes, not things. By reframing the way that modeling is presented to students, sense-making around science phenomena becomes a space for creative thinking, linking mechanisms, asking questions, and making predictions. Modeling becomes a place to tell the story of scientific phenomena (Windschitl, Thompson, & Braaten, 2018).

The question of whether modeling improves student's understanding, application of science content, and attitudes towards science has been investigated at many levels. One study found both middle and high school science students who were taught using a model-based inquiry format had a greater ability to develop predictive models and to evaluate the effectiveness of a scientific model than their peers who were simply presented with material and a textbook model. The study focused on a unit about magnetism and magnetic properties. The students in the modeling group created, revised, and discussed their constructed models. As a result, they were able to make predictions about magnetic properties, especially those properties that were not visible (Cheng et al., 2017). Making predictions is a critical component of models for processes. To be effective, students must be able to show how the system behaves, even when the

mechanisms involved cannot be seen because they are too large or too small in scale (Schwartz, Passmore, & Reiser, 2017). Students must be able to identify limitations of a model and make assessments of where improvements could be made to more accurately represent the system or process being illustrated. This critical thinking skill demonstrates a student's understanding that science processes are dynamic and that new and better models are created in light of new evidence (Krajcik & Merritt, 2012).

A 2014 study looking at how modeling facilitates conceptual change in eighth grade science found that students engaged in the process of modeling were “empowered to seek answers to broader questions, and they became problem solvers and critical thinkers” (Carrejo & Reinhartz, 2014, p.17). The study showed that the dynamic nature of modeling is a way to engage students in building new scientific knowledge. As students grappled with complex ideas around motion, they were manipulating physical objects, collecting data, analyzing graphs, and were ultimately able to tell the story of the motion for a variety of objects. The idea that students should be constructing and telling stories through their science learning becomes an essential component of how they negotiate meaning about their world (Carrejo & Reinhartz, 2014).

As a way to examine the potential influence of modeling on student attitudes and success in science, a study compared traditional lecture and demonstration instruction to Model-Based Inquiry teaching methods in high school physics classrooms. Both groups were working on a unit on the topic of buoyancy. Twenty-six students were taught in the traditional method and 28 students received Model-Based Inquiry instruction. The research centered on whether there was a significant difference in students’

understanding and application of science content knowledge, science process/reasoning, the nature of science, and students' overall attitude towards science based on the type of instruction they received. The authors found no significant difference between the treatment group and non-treatment group at any of the three assessment points in the unit (pre-, post-, or delayed). In fact, the traditional group scored higher in most of the measures at the pre- and post-unit assessments, however the differences were never significant and was further reduced at the delayed-assessment point. Both groups were able to make gains in scientific content knowledge, but the authors were unable to attribute the gains to a specific type of instruction. Additionally, there was no statistically significant change in student attitudes, nor in the learning of the nature of science. (Campbell et al., 2010).

Implementation of Modeling

Implementing modeling in classrooms is a difficult task. The way a teacher frames modeling with their students is critical to the success of the practice as a means for sense making. Talk practices in two teachers' classrooms as they taught a model-based inquiry unit using the Ambitious Science Teaching framework from Windschitl et al. (2008) were examined in a 2018 study by Gray and Rogan-Klyve. Methods of communication can have wide-ranging impacts on building student agency and participation in classroom discourse. An evaluation of metamodeling knowledge of these two teachers was based on four categories that included the nature of science, the nature or process of modelling, the evaluation of models, and the purpose of models. The authors coded 159 instances of modeling talk during the unit of study with 121 of these

instances being considered metamodeling talk with the rest being identified as modeling directions. Metamodeling talk is explicit in nature, with specific attention to the understanding and process of modeling. In contrast, talk about the logistics of constructing a model is considered implicit. Data showed the days that corresponded with the greatest amount of metamodeling talk were during sessions that involved share-out or co-construction of models and promoted group idea sharing and group consensus modeling. This explicit talk only constituted about 10% of the coded talk instances. Therefore, the models being utilized were more likely pedagogical tools and models of a particular phenomenon, rather than a tool for reasoning, predicting, or explaining why (Gray & Rogan-Klyve, 2018).

This research brings to light the fact that there needs to be a priority in assisting teachers to move from implicit to explicit metamodeling talk so that students can move from models-of to models-for when interacting with phenomena. The authors suggest that to create meaningful sense-making opportunities for students, teachers should focus on talk-specific scaffolding tools. This critical component of modeling will enable them to make this shift to more explicit metamodeling talk (Gray & Rogan-Klyve, 2018).

Attending to Equity

A common theme throughout the NGSS and a goal for their implementation is to improve equity in science education. Science for all students at all grade levels forms the foundation of the NGSS. Implementing such practice is difficult and requires both time for planning and time for implementation to be effective (Schwartz et al., 2017). In reference to a phenomena-based unit of study anchored on a man who was able to fly in a

lawn chair attached to numerous balloons, Windschitl et al. (2017) asked, “[h]ow little would we know about this individual’s thinking if *all he did* was complete the traditional force diagrams?”(p. 145). The model for this phenomenon went far beyond the traditional force diagrams allowing the teacher to see the mechanisms involved, to evaluate the student’s explanation of how forces acted on each component, and it allowed the student to connect previous learning to the anchoring phenomenon. This example showcases how modeling allows for equitable science teaching and learning. At each stage of the modeling process the teacher was providing scaffolds. These scaffolds include an intentionally created modeling template with components such as “gotta haves” checklists, designated spaces to write and draw, a set of directions for expected model items, and an anchoring question that can be answered by the model. Teachers must ask specifically for what they want in a model and teach these skills explicitly to students. Providing these scaffolds allows all students accessibility to the learning expectations. Modeling with scaffolds encourages creativity, as no two students’ models will be identical, even if they convey the same scientific content (Windschitl et al., 2017).

A common pitfall in teaching is the act of funneling, or making students try to guess what right answer their teachers are looking for. Instead, student voice should be heard throughout the modeling process, from the initial discussion of ideas all the way to the end final model where students demonstrate their most cohesive explanations (Schwartz et al., 2017). Throughout a model-based unit, students are offered opportunities to reflect, improve, and build their knowledge. This provides engagement in the content, collaboration as a classroom community, and application of learning in new

or novel scenarios. These opportunities are critical for engaging student populations who often feel marginalized or left out of instruction. Instead, students can view themselves as being the owners of their own success, enabling them to engage more deeply and confidently in their science learning (Windschitl et al., 2017).

METHODOLOGY

The purpose of this study was to determine the effect of modeling on student engagement and explanation of scientific phenomena while in a remote teaching setting. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A). Seventy-three students in three sections of Physical Science and Engineering 9 participated in this study.

Treatment

Students began the year with a challenging transition to remote learning as schools were closed for in person instruction due to COVID-19. Traditional instruction was not possible in our remote setting; learning to teach via Zoom was challenging for me and equally challenging for students. I did not begin the year with any model-based instruction because I needed some time to figure out how to approach it in this new teaching and learning format. The treatment began six weeks into the semester and culminated at the end of the first semester. During the treatment period, students completed two major modeling-based assessments that were evaluated based on an NGSS-aligned rubric and completed reflections. Students participated in bi-weekly modeling-based activities during synchronous time and their engagement in these activities was tracked over the course of the treatment period. A teacher reflection journal helped me to monitor progress and setbacks experienced during the treatment.

Data Collection

The treatment period began with the Developing and Using Models Survey to gauge student confidence and level of experience with the practice of modeling and using models to explain scientific phenomena (Appendix B). The survey consisted of twelve questions each with four response options, Strongly Agree, Agree, Disagree, and Strongly Disagree. This same survey was then administered at the end of the semester in order to determine student confidence and attitude changes as a result of participation in model-based instruction. Pre and post treatment results from the student surveys were tabulated and represented in stacked bar charts in order to see how the responses to each question shifted.

The Build a Better Model: Solar System was the first modeling-based assessment (Appendix C). This assessment was completed early in the treatment cycle when only one synchronous modeling activity had taken place. This assessment was designed to give me insight into students' ability to represent a complex scientific phenomenon and explain their thinking. Our first unit of study for the year is space science and the modeling assessment was designed to have students evaluate four models of the solar system to determine the flaws in those models and then construct a more complete model. The assessment was designed to integrate students' new learning and thinking about the structure-function relationship between objects in our solar system. Students then recorded a tour of their solar system on the video application FlipGrid. The assessment had multiple steps and the project guidelines were provided in a HyperDoc format that would lead students from one step to the next, similar to a project checklist so that all

components of the project could be met. I also provided videos explaining each step of the process for students as much of the work would need to be accomplished asynchronously as I only had two 45-minute periods a week with students online.

The end of the treatment period culminated with the Why is the Earth so Restless? final modeling project. This assessment dove deep into the processes that drive the geosphere (Appendix D). For this modeling project, students were tasked with selecting a geologic feature of interest or a major geologic event and creating a digital model of how the processes within the Earth cause the feature or the event to occur. The modeling project allowed students to show me that they could apply their knowledge of plate tectonics, convection currents, and how internal processes in the Earth determine surface features. Students once again recorded a tour of their feature, allowing me to see and hear about their learning. For this modeling project, I provided a HyperDoc for students to collect and record their research, and a template for their Jamboard. The initial slide on the Jamboard had a checklist and examples to help students understand the requirements of the assessment. I again recorded and provided explanation videos about each step of the project so that students could access instructions and examples remotely.

The Solar System and Restless Earth modeling assessments were evaluated on a four-point scale using a NGSS-based rubric and student performance was compared from the start of treatment to the end (Appendix E). Normalized gains were calculated for the two assessments and the data was reported in a histogram to show frequency of normalized gain ranges (Hake, 1998). Normalized gains for English Language (EL) learners and students with Individualized Education Plans (IEP)/Section 504 Plans were

isolated and averaged. Average scores for each component of the rubric were calculated and evaluated for the areas that students scored the highest, lowest, and area of most improvement (Table 2).

After each major modeling-based assessment students completed a reflection on their learning through a Google Form, a FlipGrid video reflection, or a written response (Appendix G). The reflections were done in lieu of live interviews due to limited synchronous time with students each week. The reflection responses were analyzed for themes related to effectiveness of the model in assessing content and skills learned and comparison against student performance on the assessment. All students were provided the opportunity to reflect on their learning, but the reflection was not part of the graded portion of the project to maintain voluntary participation in the research and to encourage students to be honest in their self-reflection and feedback.

Throughout the treatment period, students participated in modeling activities during synchronous Zoom sessions. This included short video segments related to a scientific phenomenon that students responded to through noticing/wondering whole class discussions, formative assessment probes submitted through Google Forms, live demonstrations, simulation-based instruction, and the use of digital tools such as Jamboard and Google Slides to do collaborative thinking. The purpose of these stand-alone activities was to provide scaffolds for the vocabulary and practice using modeling outside of the larger assessments. Modeling as an NGSS practice also requires students to integrate many of the cross-cutting concepts including patterns, form and function, cause and effect, and systems. Knowing that the science experience of my students is so varied,

the activities were implemented intentionally to provide exposure and practice for modeling as the summative assessments would require students to do these exact practices to show and tell me about their learning. Providing these scaffolds also helps meet the needs of my diverse learners such as my English Language (EL) learners and students with IEPs and 504 plans. Student engagement in modeling activities was tracked as participation with cameras on/off, audio, or in the Zoom chat (Appendix F). Student engagement counts for each class were collected for each class period and graphed for each week of data collection and analyzed for trends (Figure 2).

I kept a journal for my own reflection during the treatment period. The journal allowed me to keep track of the difficulties and the successes that I experienced while implementing the practice of modeling during this time of remote teaching. The journal was evaluated for themes and for specific highlights as the research period progressed (Appendix H). Together all the instruments were used to answer the focus question (Table 1).

Table 1 Triangulation Matrix.

Data Source	Questions	
	Focus Question: How does model based instruction impact student performance on phenomena-based assessments?	Secondary Question: What effect does model based instruction have on student engagement during remote learning?
Developing and using models: Confidence and experience survey	X	
Modeling-based unit assessments	X	
Tracking sheet for engagement during synchronous class		X
Student reflection after modeling-based assessments	X	X

DATA AND ANALYSIS

The results of the Developing and Using Models survey showed high confidence with creating, using, and analyzing models with no question scoring less than 73% of students in the agree or strongly agree response category (Appendix B). Only seven responses were recorded in the strongly disagree category across all survey questions. Across the entire survey, 456 agree and strongly agree responses were reported versus 96 disagree and strongly disagree responses ($N=73$). When asked if students could identify multiple models to represent scientific phenomena, 68% of students responding agree or strongly agree and 27% students responding disagree or strongly disagree. Themes from the open response question included 39% of students giving “none” or “nope” to the open comment field. Eleven percent of students also responded that they had little or no experience with models, and 7% gave examples of models from previous courses including building rockets, bridges, or making a planet. Results from the second administration of the Developing and Using Models survey were similar to the original survey, all questions scored dominantly in the agree and strongly agree categories. Three questions tied as the lowest scoring questions with 21% responding that they strongly disagree. Overall, 41% of students responded agree or strongly agree to all of the questions and only 7% disagreed or strongly disagreed, indicating a high level of confidence with developing and using models. There was not a shift in responses to indicate students had increased their confidence in modeling from the beginning to the end of the research period. Themes from the free responses again included no or nope-type comments from 39% of students. Nine percent of students specifically replied that

the instructional method had helped them learn more, and that they enjoyed the solar system modeling, but also that models are difficult.

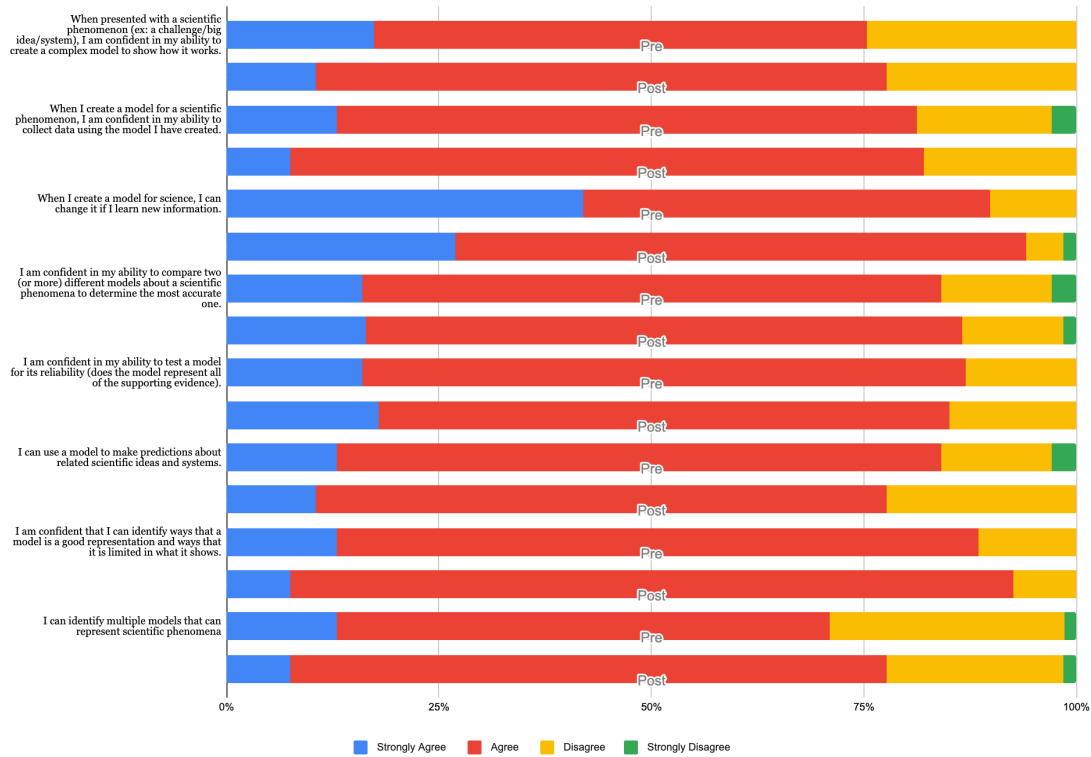


Figure 1. Pre/Post results of the Developing and Using Models Student Survey, ($N=68$).

Student engagement was inconsistent and did not follow a discernable pattern across the semester. Students were least engaged in activities that required them to obtain their own materials such as the Balloon Universe ($n = 12$), redshift rubber band lab ($n = 17$), and Oreo cookie plate boundaries ($n=17$). They were most engaged in the Solar System brainstorm during the first week of tracking ($n=33$). The final week of tracking included a notice/wonder Jamboard around the phenomena of a boat on the roof of a building after a tsunami. Student engagement was the second highest of the semester during this activity ($n=27$). Engagement also varied widely between class periods on the

same activity, demonstrating the difficulty in finding methods to maintain or increase student buy-in during synchronous class (Figure 2).

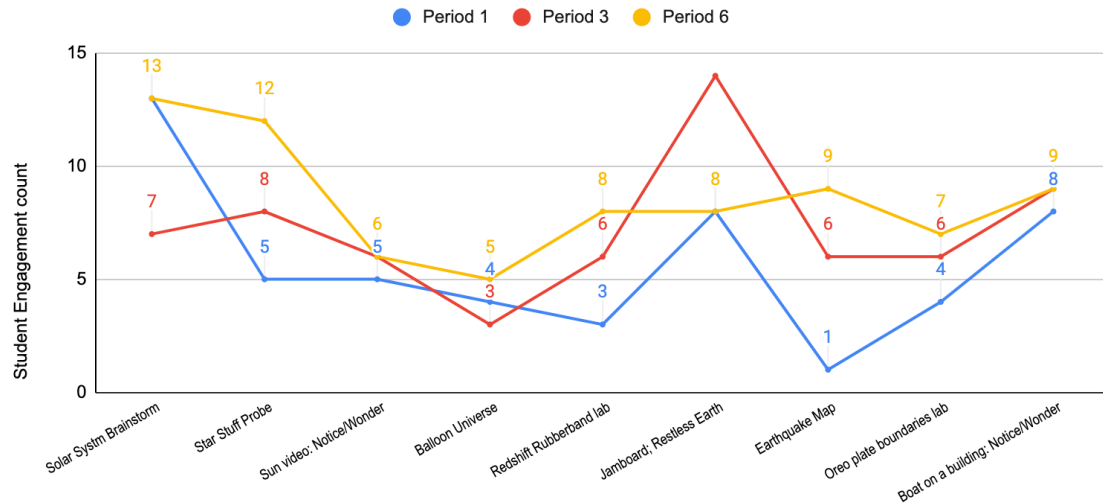


Figure 2. Student participation in modeling activities during synchronous class time, ($N=72$).

Student performance on the Build a Better Model: the Solar System and Why is the Earth so Restless? modeling assessments were evaluated using an NGSS-based rubric. The normalized gain across all class periods was 0.022, which indicates no gain ($N=72$) (Hake, 1998) (Figure 3).

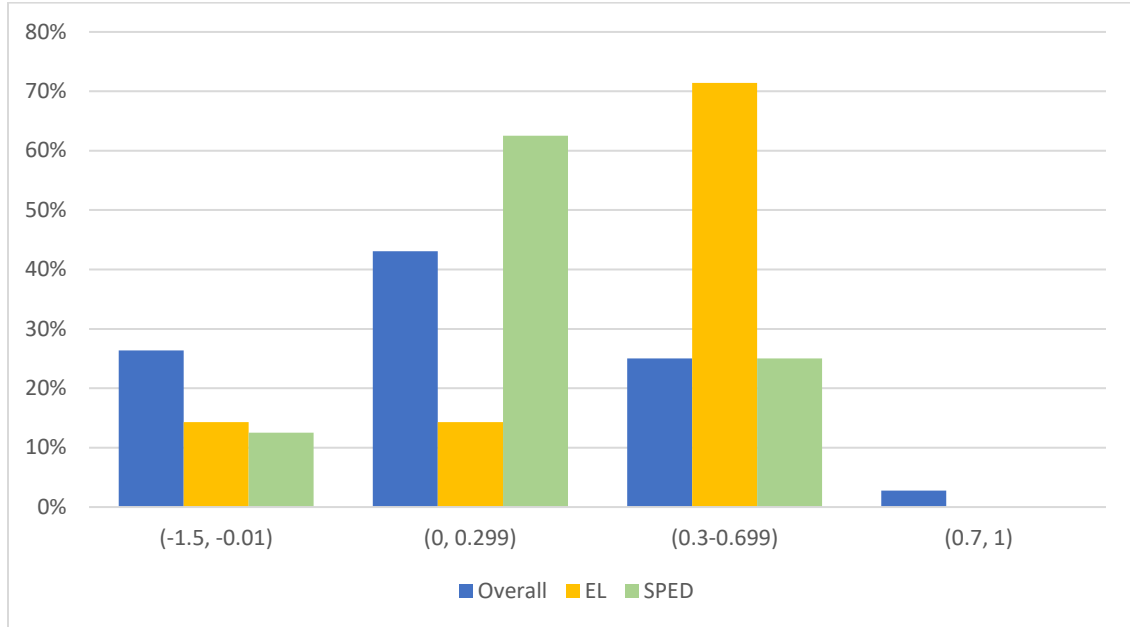


Figure 3. Distribution of normalized gains, ($N=72$).

To evaluate smaller subsets of this data, several specific ranges and student groups were isolated and evaluated based on submitted assessment categories. Across all class periods, 23% of students submitted no modeling assessments and therefore showed no gain. Four percent of students showed a high normalized gain (>0.7). However, this is because they did not submit a solar system assessment but did submit an Earth system assessment. Twenty-five percent of students showed medium gains (0.3-0.699), low gain (0.0-0.299) was 18%, and no gain (same score start and finish) was 3%. Eight percent of students submitted a solar system model, but no Earth science model. This group's negative normalized gain had a severe impact on the normalized gain data, drawing it far below the zero mark. Eighteen percent of students who submitted both a solar system and Earth science assessment also showed negative gains. Among my English Language Learners, 71% showed medium gains (0.4-0.65), 14% showed a low gain (0.13), and

14% showed a negative gain (-0.75). The average normalized gain for my EL group was 0.26, or a low gain ($n=7$). For my SPED and 504 designated students, 25% showed low gain (0.11- 0.22), 25% showed medium gains (0.5-0.67), 12% showed negative gains (-0.57,-1.0) and 6% scored the same on both assessments. No SPED/504 students showed high gains. Twenty-five percent of my SPED/504 students turned in neither modeling assessment. The average normalized gain for this group was 0.08 ($n=16$). Overall, the maximum score on the space assessment was a 90% and the maximum score on the Earth assessment was 85%. The overall low normalized gain and the regression in overall score percentage does not demonstrate a connection between the use of modeling instruction and increased assessment performance in these three classes during the research period.

Table 2. Average rubric scores for summative modeling assessments.

Assessment	Details	Predictive ability of model	Accuracy	Revisions	Clarity
Solar System Model	1.33	1	1.43	1.32	1.625
Why is the Earth so Restless? model	1.69	1.29	1.65	1.54	1.68

For their space models, the rubric scores show that students had the highest average scores on the clarity component (Table 2). This was supported by student reflection responses such as, “this helped me see and understand where objects lie in the

solar system,” and “it helped me understand how far things are compared to where we put them.” The area of least success for students was in the predictive ability of their models. This was reflected in student statements about their struggles such as, “the scale was a nightmare,” “the scale and sizes, and I did not really overcome it,” and “drawing Pluto’s orbit since it didn’t match.” While watching student videos and evaluating their models, most did not include direction of orbits or revolution periods, even though we had recorded that as a class as a necessary component of a complete solar system model during our brainstorming session.

For the Why is the Earth so Restless? modeling assessment, the highest average rubric score was for the inclusion of details (1.69/4) followed very closely by clarity (1.68/4) of the model (Table 2). Student reflections about this assessment support this data with statements such as, “this project helped me understand the workings of inside the Earth,” “it showed me how interesting volcanoes are and what is actually happening with them,” and “now I understand plate boundaries and mountains.” The models that students developed showed these details and the FlipGrid videos talked me through their understanding. The rubric area of least success was predictive ability of the model (1.29/4). Students struggled to show how their feature would change over time and how that change would be evident into the future. The checklist of required components for the model included a specific item for predictive ability, but many did not include it. One student reflection specifically called this out when they replied, “the part of the project that was the hardest was telling how old a plate was and what it would do in the future.”

The rubric component that showed the most growth from the solar system model and the Earth system model was in the details of the models, the rubric scores improved from an average score of 1.33/4 on the solar model to an average of 1.69/4 on the Earth modeling assessment. All of the areas of the rubric showed improvement from the first to the final modeling assessments, but the improvement was not enough to demonstrate even moderate normalized gains.

There were several major themes from the post-assessment student reflections that gave insight into the effectiveness and impact of using model-based assessments to help students demonstrate their learning. These themes included that the modeling assessments helped students learn the material better and that they enjoyed having a way, besides a test, to represent their learning. For the solar system project, 36% of students responded in the positive that the project helped their understanding of the material and 8% responded that it did not help. For the earth science assessment, 90% of students responded that the project helped their understanding and 3% responded that it did not. Several students responded that the assessments were too difficult and they had a difficult time understanding how to complete the tasks.

CLAIMS, EVIDENCE, REASONING

The 2020-2021 school year presented a myriad of challenges that I had never faced in my 12-year teaching career. Well-crafted research plans made in the 2019-2020 school year were overhauled or completely abandoned and new strategies and methods had to be immediately implemented in our new all-remote learning world. Using my experience with modeling during in-person instruction plus the demonstrated disengagement of students in the spring of 2020 during our mandatory district shutdown, I wanted to bring modeling to my remote instruction to see if it would help facilitate student learning and make our synchronous class time more engaging. The how and why science works is often lost in assessments constrained by multiple choice options or Google-able question formats, so this year was my chance to pull back from a heavy emphasis on more traditional testing formats and create opportunities for students to demonstrate their learning in a variety of digital formats that could be completed independently at home on school Chromebooks. I was concerned from the start of the year about student participation during virtual class sessions and my desire was to engage a higher percentage of students by using modeling-type activities. My intention was to use the data to support ongoing use of modeling in my teaching practice and to create a digital version of modeling activities and assessments that I could use in future years.

Claims of the Study

The first and last data collection tool I used with students was the Developing and Using Models survey focused on developing and using models in science. I based the

development of this survey on the language contained in the NGSS for Developing and Using models expectations for grades 9-12 (Willard, 2015). By using this survey twice, my goal was to see how initial modeling confidence would grow with the explicit use and application of modeling during class and on assessments. I gave the first survey prior to any modeling-based instruction with the intention that students would give me an honest assessment of their modeling experience and confidence. Unfortunately, student self-assessment showed very high confidence in developing and using models from that first survey. Open comments on the survey did not necessarily match the responses students selected about ability and confidence. One student commented from the first survey, “I did say agree on all but I’m also not that confident in what I know so I would need to know more before I could do something like this on a big project,” yet this same student selected Agree or Strongly Agree for all of the survey questions. Other similar comments included, “I haven’t really gotten to use models much,” paired with Agree and Strongly Agree selections on the survey. A third student responded, “I don’t have much experience with models, but I’m confident I can do them.” These type of comments and survey responses indicated to me an overinflation of skills assessment that was probably widespread among my students. After administering the survey a second time at the end of the treatment period, the data moved very little and students still rated themselves as quite skilled in their ability to both develop and use models.

The survey results were problematic as I was not able to accurately gauge where students’ skills and confidence with modeling actually started and ended. On the end of treatment survey, a student did comment, “at the beginning of the semester I wasn’t

confident and then we started doing more and now I feel much better about models.” The survey did not get to the depth of self-evaluation that I wanted. It would have been helpful to have students evaluate a model which would have given me a more accurate picture of their actual skills. I could have then used the pre- and post-survey analysis to determine changes in student ability in using models along with the confidence data from the original survey questions. The discrepancy between student’s perceived ability to develop and use models based on the survey and their performance on the summative assessment tasks also demonstrates the over estimation of skills as compared to the actual ability to produce a novel model based on a scientific phenomenon.

The data collected between the two modeling-based assessments for Earth and space science did not show a significant gain in student ability to demonstrate their learning in modeling-based formats for the overall student group, or smaller subsets of students, including those with IEPs/504s, and English Language learners. Using the same NGSS-based rubric to analyze the critical features of high-quality modeling was intended to eliminate bias between the two assessments and enable me to evaluate the models from the beginning to the end of the treatment period, regardless of the content required. After analyzing the data, several flaws in this method became evident. The variability in student experience with models could not be taken into account using the rubric. A student who scored equally well on both assessments, demonstrating a high level of skill with modeling, then showed the same normalized gain as a student who submitted no assessments. Additionally, the differences in content difficulty between the two units of study were intended to be eliminated; however, if students were discouraged by their

level of content understanding, they may not have persevered through the assessment task. In their reflection, one student stated, “I have a really difficult time getting all of the information a science model required. I learned so many new things, but it was stressful.” One of my EL students responded, “I would like to do something smaller, more simple to understand.” Modeling assessments are designed to be challenging, but if the design of my assessments created unnecessary barriers to completion due to their complexity, unclear instructions, or too many components then the data was not indicative of students’ actual abilities or knowledge.

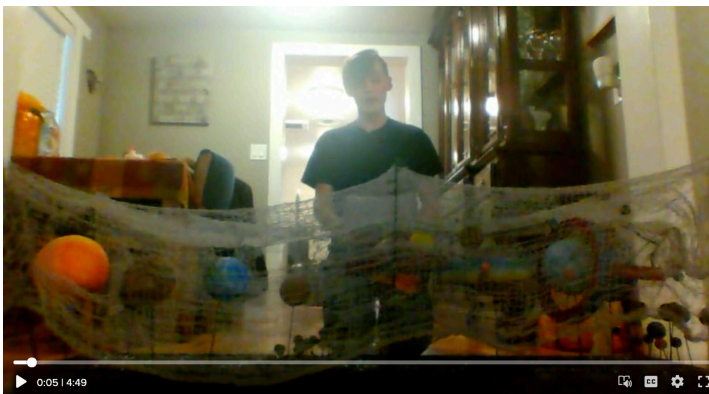


Figure 4. Student work sample from the Build a Better Solar System Model.

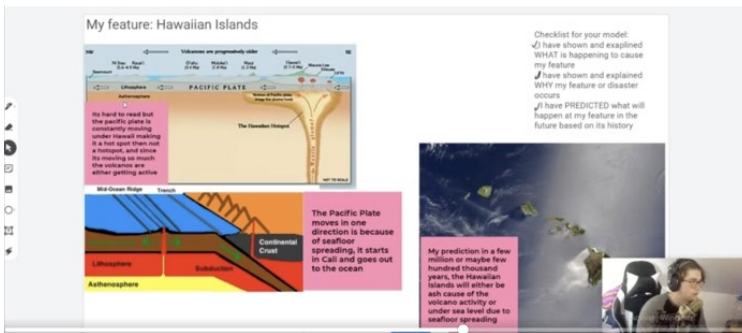


Figure 5. Student work sample from the Why is the Earth So Restless? Model.

The lack of assessment completion was the near undoing of my research. In a traditional in-person classroom, I would have been able to work with students on a daily

basis, answering questions, troubleshooting problems with understanding instructions, processing thinking in real time, working collaboratively in partners or small groups, all of the teaching strategies that I regularly employ did not translate into our virtual world. Students were reduced to small black squares on my screen that I saw a total of 90 minutes each week and, as can be seen in my tracking engagement data, using modeling-type activities during class did not improve interaction. I saw the same students being consistent with their engagement, and the same students did not participate. I was mindful of students' discomfort in an online school setting – giving them the freedom to have cameras on or off, using the chat or audio to make their voices heard, never singling out students. My fear of alienating students may have contributed to their lack of engagement because they knew I would not call them out. It was a predicament I could not solve and my solution each week was to just try new activities and strategies with the hope that more would join in for each class period.

By the end of the treatment period, I had many zeros for the two modeling assessments, a situation that I have never experienced before. I could not get students to submit work even with frequent emails, meeting with students individually during class time in breakout rooms, and sending home progress reports. The lack of data skewed my normalized gains to almost zero. The student group who performed the best on the two summative assessments was my English Language learners, with a normalized gain of 0.26 ($n=7$). These students also had assistance during and outside of class from one of our paraeducators who could help translate and spend additional individual time with this smaller group. Their effort in completing the assessment tasks, which required them to

read, write, and present outside of their native language far exceeded the effort of my general population of students. My SPED/504 students also had the assistance of a paraeducator both during and outside of class, but factors including attendance and lack of engagement during class time meant both the paraeducator and I had a difficult time assisting students in completing the summative assessments. The SPED/504 normalized gain scores were still slightly higher than the overall class scores, although not enough to even qualify as moderate gains.

In retrospect, a better approach to the modeling format for the research period would have been for students to develop an initial model using the driving question for each unit and then a final model after all instruction was complete. This would have given me a source of comparison for before instruction and after instruction, instead of just a final model comparison across the two units. I have done this initial/final model approach on paper during in-person instruction, but I had thought that using a consistent rubric across two units would serve the same purpose since the solar system model was so early in the treatment period and the Earth's features model was at the very end. Doubling the required submissions for each modeling assessment also did not seem feasible when I struggled to get students to participate or submit their summative assignments. The sheer number of confounding variables during the research period makes drawing conclusions about the effectiveness of model-based instruction difficult. Although I did not see statistically significant improvement from the start to the end of my research, I was able to see improvement in all areas of the modeling rubric and I did see improved student confidence on the Developing and Using Models survey.

Value of the Study and Considerations for Future Research

The purpose of this study was to evaluate the impacts of using modeling with my 9th grade science students on their engagement in class and performance on assessments while we were in an all-remote learning setting. My goal was to provide a rich and robust science education to students during this new and challenging situation. My data was not as supportive of my goals as I had hoped. It was a year fraught with struggle, for my students and for myself as we all navigated a school set up that none of us had any experience with. We learned new technology, used real world science phenomena to learn science content, created a classroom culture and environment that was inclusive and collaborative, even if it was on Zoom. I was encouraged by the reflection response from one student who said, “I enjoy using models because they help me, but they are hard to create. Thank you for finding a way during this virtual learning to help all of us be engaged.”

As I look towards the next school year, there will be continued opportunities for modeling in the virtual learning environment. We may still be in a hybrid virtual/in-person learning setting with restrictions on social distancing, mask wearing, and classroom safety. If this becomes the case, my experience this year will help shape my plans and execution of modeling strategies. I have also been invited to pilot physics units from OpenSciEd for the next three years, which will bring a new level of modeling-based instruction to my classroom and the opportunity for world-class professional development for me. I will be collecting data from my classes for the pilot study and this

will provide further insight into my instruction and the learning that can take place when modeling and model-based instruction is the focus.

Impact of Action Research on the Author

My love for teaching science has always been around wanting students to dig deep and ask how and why things work the way they do. Modeling provides a robust foundation to work from as it forces these kinds of questions and interactions between student, teacher, and science learning. I am a die-hard believer in the potential that model-based instruction can bring to a classroom and there is a solid body of research that supports my ongoing endeavors to bring this instructional method to my classroom and engage my students in the practice. Throughout my research period, I kept a journal that documented the highs and lows that I experienced. The high points were the days where I could see and hear student voice in the work. I could see the value in my work on the day where we brainstormed all the things they knew and learned about what was really out in the solar system and how we could show that in a model. The list got so long we needed more rows in our Google Doc table. Another highlight was the day when students worked on a Jamboard to notice/wonder with digital sticky notes about why a boat would end up on the roof in the middle of what looks to be a wasteland of garbage. Even though I couldn't "see" students, their excited sticky-note activity was evident when they figured out there had been a tsunami. They had just learned that tsunamis were caused by earthquakes, and this meant plate tectonics at work. The lightbulb moments that are created when we are all in class together were further and farther between this year, but they still happened and most often during our class time modeling activities.

It was a semester full of frustration and many days I closed my computer discouraged. It was painful to feel as though I was only teaching to a minority of my class each day and I did not know if the black boxes on the screen were at their device(s) for the period. So much of the work done this year had to be created from scratch as my original plans needed me to be face-to-face with students. The days it took to develop the assessments and activities that some students never even attempted, left me feeling like a failure. My journal entries are full of questions such as, were the assessments too complicated, how can I get kids to read instructions, or even just watch the videos of me explaining the instructions, why won't kids come to office hours to ask for help? I wanted to feel like I was making a difference in students' science education, but I am left feeling disappointed. It is difficult to compare this year to my previous eleven. It is also difficult to give myself permission to not have everything go as planned. Model-based instruction and assessments are a continual work in progress, just as teaching is a dynamic process. Moving forward, I am confident that I will continue to improve my modeling practice and that I can engage students in working with, developing, and using models to apply their learning in my science classroom.

REFERENCES CITED

- Campbell, T., Zhang, D., & Neilson, D. (2010). Model based inquiry in the high school physics classroom: An exploratory study of implementation and outcomes. *Journal of Science Education and Technology*, 20(3), 258–269. doi: 10.1007/s10956-010-9251-6
- Cheng, M. -. F., Lin, J. -. L., Lin, S. -. Y., & Cheng, C. -. H. (2017). Scaffolding middle school and high school students' modeling processes. *Journal of Baltic Science Education*, 16(2), 207-217.
- Carrejo, D. J., & Reinhartz, J. (2014). Facilitating conceptual change through modeling in the middle school science classroom. *Middle School Journal*, 46(2), 10–19. doi: 10.1080/00940771.2014.11461905
- Gray, R., & Rogan-Klyve, A. (2018). Talking modelling: Examining secondary science teachers' modelling-related talk during a model-based inquiry unit. *International Journal of Science Education*, 40(11), 1345–1366. doi: 10.1080/09500693.2018.1479547
- Gouvea, J., & Passmore, C. (2017). 'Models of' versus 'Models for.' *Science & Education*, 26(1-2), 49–63. doi: 10.1007/s11191-017-9884-4
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74.
- Krajcik, J., & Merritt, J. (2012, March). Engaging students in scientific practices: What does constructing and revising models look like in the science classroom. https://static.nsta.org/ngss/resources/201203_Framework-KrajcikAndMerritt.pdf
- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. The National Academies Press.
- NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. The National Academies Press.
- OSPI Report Card Bremerton High School. (2019). <https://washingtonstatereportcard.ospi.k12.wa.us/ReportCard/ViewSchoolOrDistrict/101674>

- Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). *Helping students make sense of the world using next generation science and engineering practices*. NSTA Press, National Science Teachers Association.
- Relevant Strategies. (2013). Washington State science learning standards transition project: A comparison of the Next Generation Science Standards to the 2009 WA science learning standards.
<https://www.k12.wa.us/sites/default/files/public/science/pubdocs/sciencestandardscmparisonanalysisreportfinal.pdf>
- Willard, T. (date). *NSTA quick reference guide to the NGSS – K-12*. National Science Teachers Association.
- Windschitl, M., Thompson, J., & Braaten, M. (2018). *Ambitious science teaching*. Harvard Education Publishing Group (HEPG).
- Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, 92(5), 941–967. doi: 10.1002/sce.20259

APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION



**INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165**

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MEMORANDUM

TO: Emily Wise and John Graves

FROM: Mark Quinn *Mark Quinn CJ*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 30, 2020

RE: "How Does the Use of Modeling in Remote Learning Impact Student Engagement, Performance on Modeling-related Tasks, and Explanation of Phenomena?" [EW103020-EX]

The above research, described in your submission of October 30, 2020, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- ☒ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☒ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).
- ☐ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- ☐ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- ☐ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- ☐ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

DEVELOPING AND USING MODELS SURVEY

Developing and using models in science

Answer the following questions to the best of your ability and understanding! This survey is part of my graduate school research at Montana State University. Participation in my research is voluntary and participation or non-participation will not affect your grades in any way.

* Required

1. Name (First AND Last) *

2. Class Period *

Mark only one oval.

☐ 1

☐ 3

☐ 6

3. How would you define a "model" in science? *

Mark only one oval.

☐ A model is only something you build, like a bridge.

☐ A model is only something you draw, like the solar system or an atom.

☐ A model can be both something you build with materials and it can be drawings/pictures to show how something works.

☐ I don't know what a model is in science.

4. When presented with a scientific phenomenon (ex: a challenge/big idea/system), I am confident in my ability to create a complex model to show how it works. *

Mark only one oval.

☐ Strongly agree

☐ Agree

☐ Disagree

☐ Strongly disagree

5. When I create a model for a scientific phenomenon, I am confident in my ability to collect data using the model I have created. *

Mark only one oval.

- ☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

6. When I create a model for science, I can change it if I learn new information. *

Mark only one oval.

- ☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

7. I am confident in my ability to compare two (or more) different models about a scientific phenomena to determine the most accurate one. *

Mark only one oval.

- ☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

8. I am confident in my ability to test a model for its reliability (does the model represent all of the supporting evidence). *

Mark only one oval.

- ☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

9. I can use a model to make predictions about related scientific ideas and systems.

Mark only one oval.

- ☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

10. I am confident that I can identify ways that a model is a good representation and ways that it is limited in what it shows. *

Mark only one oval.

- ☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

11. I can identify multiple types of models that can represent scientific phenomena. *

Mark only one oval.

- ☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

12. Is there anything else you would like me to know about how you have used models in science before? Experiences you have had?

APPENDIX C

SOLAR SYSTEM MODELING PROJECT



BUILD A BETTER
MODEL:
THE SOLAR SYSTEM

PHASE 1: THINKING BACK ~10 min.

Let's look at the models that you evaluated at the start of the year!

YOU KNOW MORE NOW!



Models of the Solar System

As in the best of your ability, with the knowledge you currently have!

Name (Last)

or First

100

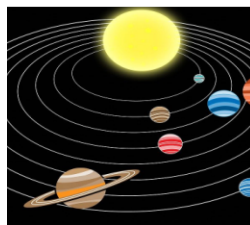
1 Visit [THIS Google Form](#) (yes, it should look familiar!).

2. Take a few minutes to evaluate the models again - which one is more accurate? Which one is the worst? Why?

PHASE 2: RETHINKING THE MODEL ~30 min.

Reimagining the Solar System

LET'S FIX THE MODEL...



NONE of the four models in the Google Form are really complete. Even the solar system in the desert was missing all kinds of things!

Task: Whole Class Brainstorm - what parts **MUST** be in a more accurate solar system model? How can you show these things?

****Find the brainstorming document in Google Classroom! (you can type right on it)

PHASE 3: BUILD A BETTER MODEL ~2 days on your own

Putting all of your ideas and knowledge to work!

1. Create a new, better, improved, and more complete model of how the solar system works with your improved understanding of it!
2. You have options for how to "build" your model (choose one choice from below):

Digital Model:	Physical Model:
1) Use Google Keep to do digital drawings, labels, and explanations of your new model of the solar system. OR 2) Create a new blank document in Kami where you can draw, label, and explain your new model. You will probably need multiple pages in your Kami document, that's okay. OR 3) Use a drawing/modeling app of your choice to create an amazing solar system model! Be sure your app will let you put all the stuff you want in it!	1) Use items from around your house to model the solar system based on your brainstorming sheet. Think about objects you can use to represent all the "stuff" in the solar system! You will need to label/describe the items in your model. Think about using small pieces of paper or sticky notes. OR 2) Hand draw and label all the parts of the solar system from your brainstorming sheet. This could be on pieces of blank printer paper that you tape together or a poster board you get at the Dollar Store.

3. Remember - the original models were all missing many things! Your new model should fix those missing parts - use the brainstorming sheet from class to help you put all the pieces together in your new model.

But wait...there's more! Keep reading for how to present your new model!

PHASE 4: TAKE ME ON A TOUR! ~30 min on your own

I need you to tell me all about your work!

SHOW ME WHAT YOU MADE!



1. Use FlipGrid to take me on a tour and show me what you created! Whether it is a digital model or physical model, I want to see your work.

Record up to 10 minutes using FlipGrid.

- a. The link to record is posted on Google Classroom! (each period is a unique link)
- b. If you made a digital model: you can allow FlipGrid to show me your screen and then you narrate what I am seeing.
- c. If you made a physical model, show me what you made and narrate your explanation.

PHASE 5: IF YOU NEED IT...COME GET HELP! ~Office Hours

Stuck? Having tech issues? Come see me!

DON'T STRUGGLE ALONE!



If you get stuck, if you are having trouble generating ideas, if you want me to walk you through Screencastify - come on in during office hours!

Mon/Tues/Thurs/Fri - 2:30-3:30pm
Wed - 11:45-12:30

Zoom Link is posted in Google Classroom!

APPENDIX D

WHY IS THE EARTH SO RESTLESS?: EARTH SYSTEMS MODELING PROJECT

History of Earth: PSE 9

Why is the Earth so Restless?



Let's go on a tour of the Earth and all of the amazing geologic features and historic events that have taken place! Why do the features like volcanoes and deep sea trenches exist? Why do events like earthquakes and tsunamis happen?

Read through each section. When you come to ●, stop and do the activity connected with the section.

Performance Expectations for this project:

1. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. HS-ESS1-5
2. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. HS-ESS2-1

ENGAGE



WHOA! Why is the boat on the building? What could have caused this?

Use this [Padlet](#) to record your ideas, your noticings, and wonderings about what is happening here.

EXPLORE

We are going on a FIELD TRIP! On your Chromebook!

We will be using Google Earth to create a field trip and we can "fly" all over the globe from the comfort of your house!

- Follow the instructions for putting your spot on the map.
 - 1) Choose a feature on the Earth or a major geologic event [from the list](#) posted in Google Classroom - only ONE person per location! No typing over each other!

My feature/disaster:

- 2) Open the [Google Earth Project for your class period](#) (it is linked in Google Classroom)
- 3) Click "New Feature"
- 4) Use the "search to add place" feature and type in your location. Let Google "fly" you to your place on the globe.
- 5) Click the "add to project" button.
- 6) You can save your location for now, but there will be more to add!

- There's lots to learn about your location on the map and you want to teach your classmates about this amazing place that you chose! Let's do some research...

- a. Describe the location (mountain range? In an ocean? An island arc? Major metropolitan city?) :

b. Where is it located on Earth (if you were telling someone where this is, how would you direct them there)?

c. What plate(s) is it on or near (Go back to our Plate Overlay project!)?

d. Based on the tectonic boundaries near this location, what is happening geologically (briefly describe the plate boundary type/interactions)?

e. What disasters have occurred here? If none, what is super interesting about your feature? (Why did I put it on the list of cool Earth features? What would make you want to visit your site?)

 Go back to your Google Earth selected site on the Google Earth Project...(we will do this step together in class if we need to. It's a little complicated)

- 1) Hover over the name of your site in the list.
- 2) Click the little pencil icon to be able to edit your site.
- 3) Click "Replace"
- 4) Click the camera icon. Use the Google Image search to find a picture that you like. Click the correct image and "select." You can select more than one image.
- 5) Copy and paste the information from your research into the text box.
- 6) Your edits are auto-saved!
- 7) You can preview your image and text by clicking "preview presentation"
- 8) Click the backwards arrow (<--) at the top of the editing box to return to the project.

EXPLAIN

Time to go deeper...like inside the Earth Deeper...

Your feature or event happens for a reason. There are processes happening inside the Earth that cause (or did cause) the formation, the destruction, or the ongoing changes at your site.

Vocabulary you may need to use for your answers (not all words apply to all features): convection, lithosphere, asthenosphere, mantle, core, isotope decay, heat, density, oceanic crust, continental crust, ocean floor spreading, trench, convergent, divergent, hot spot

- 1) What is the plate boundary/interaction that is causing your geologic feature or disaster? What specific plates are under or meet at your feature?

Use this link to see the plates and find your location on the Earth: <https://bit.ly/38eMO5l>

Check out this map: https://drive.google.com/file/d/15zVG_xH5VETUiE-2fgbMRbDjXOnwNEWs/view?usp=sharing

- 2) What is happening in the Earth that causes this boundary interaction to occur?

Use this link to review and identify what happens at the boundary types: <https://bit.ly/2HWY3nv>

	3) How old is your feature? How has it changed over time? What will happen to it in the future?
APPLY	Time to put all of your learning about the processes within the Earth together. ● Use the sample Jamboard (make a copy to make it yours) to tell me all about your feature on Earth. Follow the instructions on the first Board to help guide your project. Jamboard Link: https://jamboard.google.com/d/16VZcdeUwHmKREpRaPWbq_ftmzUHViboCt8WAtaFByeE/edit?usp=sharing
SHARE	Share your creation (with me!) ● Create a ten (10) minute or less FlipGrid that takes me through your Jamboard. Find the FlipGrid link in your Google Classroom (it is with this project assignment). This is just like the “tour of the solar system” you did before. Be sure to explain IN DETAIL about your location - not just the surface feature, but also what is happening under the surface. REMEMBER! This project takes the place of a big test over the systems of Earth. Your video and explanation need to show me AND tell me all about what you learned and what you put in your model.
REFLECT	● Reflect on your work in a Google Form OR FlipGrid OR by writing to me. The Google Form is also linked on your Google Classroom.
EXTEND	An opportunity if you finish early. Have more fun with the topic! Visit ALL of the field trip sites on our Google Earth Earth's Features trip. 1) Which one was your favorite? Why is it your favorite? 2) Which site would you be least likely to visit? Why?

APPENDIX E

MODELING ASSESSMENT RUBRIC

Modeling Rubric

Name: _____

Per. _____

	4	3	2	1	0
D E T A I L S	Many details are present in the model to explain both observable AND unobservable mechanisms, model shows inputs/outputs to increase clarity.	Details are present in the model to explain observable and unobservable mechanisms, model shows inputs/outputs to increase clarity	Some details are present in the model to explain observable and unobservable mechanisms, model shows input/output to increase clarity.	Minimal details are present in the model to explain the observable and unobservable mechanisms, model shows input/output to increase clarity.	No details to show science behind the phenomenon.
P r e d i c t i o n s	The model can predict many situations that have not been encountered yet by the student	The model can predict situations that have not been encountered yet by the student.	The model can predict only some situations that have not been encountered yet by the student.	The model includes predictions completely unrelated to the phenomenon.	No predictive capability.
A c c u r a c y	The model is an accurate representation of the phenomenon at an expert level.	The model is an accurate representation of the phenomenon.	The model is an accurate representation of the phenomenon at a basic level.	The model is NOT an accurate representation of the phenomenon even at basic level.	The model is incomplete and/or fails to show any accurate representation of the phenomenon.
R e v i s i o n s	The model has been revised to include new understandings and/or new evidence. In the revision process the student is systematic about selecting a type of model to <i>best</i> represent the phenomenon.	The model has been revised to include new understandings and/or new evidence.	The model has been revised, but <i>is missing some of</i> the new understandings and/or new evidence.	The model includes some revisions, but <i>fails to include</i> new understandings and/or new evidence.	The model includes no revisions.
C l a r i t y	The model <i>clearly</i> communicates the student's thinking to others.	The model communicates the student's thinking to others.	The model communicates <i>some of</i> the student's thinking to others.	The model <i>attempts to</i> communicate the student's thinking to others.	The model does <i>NOT</i> communicate any student thinking.

APPENDIX F

ENGAGEMENT TRACKING FORM



Modeling Engagement Tracking Sheet



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A1	Activity Name/Date:				
	A	B	C	D	E
1	Activity Name/Date:	students with cameras on	students participating in the chat	students with audio participation	Total
2	Brainstorming for solar system model	Bryson	Jomar	Nevaeh	
3	Oct . 8th	Konnor	Mason	Olivia	
4		Drago	Oliva	Bryson	
5			Sarah	Konnor	
6			Zoe	Drago	
7	Total	3	5	5	13
8	Are we made of star stuff probe	Drago	No one :(	Konnor	
9	Oct 19th	Konnor		Drago	
10		Olivia			
11	Total	3	0	2	5
12	Sun video	Konnor	Olivia		
13	Oct 22nd	Bryson	Sarah		
14			Amber		
15	Total	2	3	0	5
16	Balloon Universe	Olivia	Konnor		
17	Nov. 16th	Drago	Jomar		
18	Total	2	2	0	4
19	Rubber Band - redshift				
20	Nov 19th	no one	Olivia	Peter	
21			Jomar		
22	Total	0	2	1	3
23	Jamboard - restless Earth brainstorm	no one	Oliva	no one	
24	Nov. 30		Drago		
25			Guillermo		
26			Zech		
27			Mayte		
28			Konnor		
29			Bryson		
30			Jomar		
31	Total	0	8	0	8
32	Earthquake Map				
33	12/10	None	Olivia	None	
34	Total	0	1	0	1
35	Oreo Cookies				
36	12/14	none	Olivia	Drago	
37				Bryson	

APPENDIX G

SAMPLE STUDENT REFLECTION FORM

Build a Better Solar System Project Reflection

How did the project go? What went well? What was a struggle? This part of the project will not affect your grade on the project and your participation is voluntary.

*** Required**

1. Name (First AND Last) *

2. Class Period *

Mark only one oval.

☐ 1

☐ 3

☐ 6

3. Did the modeling project help you better understand how the solar system works? *

Mark only one oval.

☐ Yes

☐ No

☐ I didn't finish the project.

4. Why did you select the answer above? How did it help? Or why didn't it help? If you haven't finished, what is your plan to finish? *

5. What was your favorite part of the project? Or what part of the project did you feel like you were most successful with? If you haven't finished, what parts are you done with? *

6. What part (or parts) of the project were difficult or were a struggle to finish? How did you overcome your struggle to finish? *

7. What will you do differently for the next modeling project we do (yes, there will be more!)? Examples could be about time management, or reading the rubric, or coming to office hours to ask for help. *

8. Is there anything else you would like me to know about your project or feedback about the project in general?

APPENDIX H

SAMPLE TEACHER REFLECTION JOURNAL ENTRIES

10/10 Journal

Yesterday I finished brainstorming for the solar system modeling project. Kids looked at the models from the very start of the year and then we whole class brainstormed ways that a new model could be made better. I also started the period by creating a class-generated list of collaboration norms. I had not done norms yet, so this was important. The brainstorming time absolutely flew by. I still only have a few kids with their cameras on, but a few more were willing to turn their mics on and/or participate in the chat. It was a great kick-off to the project. Olivia came by office hours to show me her beautiful foam planets - maybe there is hope for kids doing projects at home this semester!

10/23 - Grading day - first quarter over
- I got a little more than half of the S.S. models turned in on time. They are models of things, not of processes. Only 1-2 of them talked about the function of the SYSTEM, all the rest just told me

about the things you find in the solar system and rattled off loads of facts. Not what I was looking for, but it's the depth of understanding that they have and the depth of explanation that they can come up with. I had a few really creative videos and models using stuff they could find at home. A couple of beautifully built systems, but the ability to talk about the function of the pieces within the system was almost zilch. Nowhere to go but up I guess.

Nov. 20th

Nope. Things can get worse. Attendance is way down. Participation in the two modeling activities ~~is~~ was the worst it has been all year. In talking to other teachers, I am not alone in what is going on. I am running on fumes. When I give short, shallow assignments, I can get more kids to do their work. If I give more intensive, deeper, critical thinking assignments,

they don't turn anything in. Then their grades fall, and I spend all my time chasing down work, calling home, emailing kids, and being frustrated. Kids are not doing work asynchronously. This means all they are learning/doing happens in our Zooms. 90 minutes of science a week is just abysmal. I am at a loss.

Dec. 10th Today we used mapping data of Earthquakes to talk about the processes of plate tectonics. I had ZERO participation in 1st period. Well, one student was in the chat, but only chatting with me. She won't chat with the class. NO ONE else would interact - no response to questions, prompts, nothing. 3rd period went on a roll and we talked and looked and wondered and took up almost all of the work time. What a difference. So here's the problem - what did 3rd period gain from their period that 1st period did not? ~~Nothing~~ Anything? I was a happier person during/after

3rd period. Maybe that is only an impact on me. Can I change my 1st period? Was today an anomaly? Even my usual speakers/chatters were silent. It wasn't a good feeling "modeling" day, at least for 1st. This activity is usually a good one (mapping, data, analysis, long-range data, dynamic Earth surface.)

1/4 Back from break. I am not feeling like the new year is any different from 2020. Same garbage, different day. We have four weeks to the end of the year semester. The Big earth sci. project is still to come and I am so worried about getting kids to actually DO IT.

1/5: 1/6 Did our Jamboards about the Boat on the Building and actually got quite a few kids to participate! Was good to actually tie everything back to a phenomenon of the restless Earth. I cannot get ~~any~~ kids to stop thinking that