Maine Physical Sciences Curriculum Partnership (MainePSP) Sixth Year Research Report

Compiled by RiSE Center Faculty, Students, Partners, and Staff

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New Research Started in 2015-16

In the past year we began two new research projects in response to the launch of new MainePSP programs and activities to support pre-service teachers. We also began new research projects in areas of teaching and learning in K-12 and at the University; some of which built upon MainePSP studies that were previously conducted and are now complete. In addition, we began new research in response to data gathered from teachers and students in the MainePSP and our ongoing efforts to integrate research and implementation through partnerships between teachers, researchers, pre-service teachers, staff, and other stakeholders.

Pre-Service Teacher Preparation

Two new research projects started in the past year investigate aspects of pre-service teacher preparation. One investigates students' experiences in the RiSE Center's new Undergraduate STEM Education Professional (USEP) Program, and the other focuses on students' experiences in the Master of Science in Teaching (MST) Program, which continues to evolve and grow through ongoing integration with the Maine Physical Sciences Partnership.

Undergraduate STEM Education Professional (USEP) Program Research

The USEP program includes support for students – USEP students – to develop their skills in teaching and education research, with the goal of recruiting some of these students to become teachers. There are three major components to the program. USEP students will be:

- STEM majors, learning the content of their discipline.
- Maine Learning Assistants, acting as facilitators in STEM classrooms, and possibly also K-12 Teaching Partners, visiting K-12 classrooms to be teachers' assistants.
- education researchers, as they do the capstone project of their degree program.

Much of this work will happen in the context of two groups (which may combine into one): Teaching Pods, where the USEP student works together with a Master of Science in Teaching (MST) student and a K-12 teacher to develop professional knowledge and skills around K-12 teaching, and Research Pods, where the same USEP and MST student work with a UMaine faculty researcher, typically on topics related to the MST student's master thesis and the USEP student's capstone project (with the expectation that these be complimentary and related).

The goal of studying students in the USEP program is to understand:

1. how USEP students develop as teachers, researchers and STEM majors.
2. how the aspects of the USEP program influence this development.

Researchers
Erin Vinson, Michael Wittmann, Laura Millay, Adam Rogers, and Carolina Alvarado.

Project Dates
Recruitment selection, finished in May 2016.
USEP summer program, June-July 2016

Data collected
We have collected information from the accepted USEP students. The information includes their expectations of the USEP program, career interests, teaching experiences & attitudes. We have reached out to students to invite them to participate in the case studies.

Findings
From the six responses obtained so far from the survey, we know that the six students plan to apply to graduate school, two of them in an education related program, while the other four in a STEM discipline. Regarding their career interest, all of them show an interest (probably & definitely interested) in University teaching, while only three show interest in K-12 Teaching. Five students are interested in STEM Research and University Research. While four students were shown not to be interested in industry, and five students shown not to be interested in medicine. The population is divided in their school record, three attended all years of grade school and high school in Maine, while the other three studied outside of Maine. From the six students, three have participated as MLA, two have not, and one didn't provide such information.
This information will be considered to contrast the changes observed in the interviews regarding how USEP students develop as teachers, researchers and STEM majors. Some of the students have responded to the invitation to participate in the study, accepting to participate in the interview process.

Next Steps
To answer these two research questions, we will follow a small number of students (3-5) to develop longitudinal case studies of their experiences. We will gather a variety of information about each student, as described below, and use a rich description of their experience to help understand if, how, and in what manner USEP students develop as STEM majors, researchers, and teachers.
The case studies will include four interviews over the course of the next 12 months from the USEP Summer program; each interview will last about an hour. The interview would include a conversation trying to define: what are the USEP students doing as part of the USEP program? what influence does the program have on them? how are they thinking about their major? about teaching? about research?
The meetings will consist of four one hour interviews talking to one of the researchers about the questions and working through a series of "card sorting tasks" in which we give

them a bunch of note cards and ask them organize the cards according to whatever question we ask.

The first of these interviews would happen at the beginning of the summer (before the USEP summer program begins). The second would be at the end of the summer (before they start the Fall semester). The third would be either at the end of the Fall or beginning of the Spring semester. The last interview would be sometime next April, toward the end of the school year (if they are still here on campus).

The goal of these interviews would be to hear about their experience in the USEP program and how it is affecting their thoughts about their major, teaching (perhaps as an MLA, perhaps as they think about their career), and research.

Master of Science in Teaching Program Research: Investigating the transition from MST Program pre-service preparation to in-service professional practice

The University of Maine's Master of Science in Teaching (MST) program provides students who have undergraduate degrees in mathematics, science, or engineering with preparation to become science, math, and engineering teachers. The two-year program introduces future teachers to education research both as a resource that they can draw upon and also as a practice that they engage in as they prepare and defend a thesis that is required for graduation. The program seeks to prepare teachers to be reflective as well as effective practitioners.

This study seeks to understand how the reflective, research-oriented approach of the MST program intersects with the instrumental view—where teaching is assumed to be just a matter of having clear goals, knowing "what works," and applying proven methods to achieve intended goals—that some new teachers encounter as they move into professional practice. The study explores two conjectures:

1. Even though teachers trained in the MST program may experience dissonance arising from the need to adapt to a working environment that takes an instrumental view of teaching, they will, within a few years, begin to use and value the habits and tools to support reflection that they acquired through the MST program.
2. As science teachers or math teachers, teachers trained in the MST program will encounter and struggle with a relatively small, common set of issues related the intersection of subject matter and teaching.

To the extent that the second conjecture is borne out, identification of common issues will provide useful feedback into the design of the MST program.

<u>Researchers</u>
Bill Zoellick

<u>Project Dates</u>
November, 2015 – June, 2016

Data collected

17 intensive interviews with MST Faculty and alumni.

Findings

Findings at this stage are tentative. They suggest that the faculty do, as a group, focus on familiarizing prospective teachers with the goals and structure of educational research, recognizing that many of the students with backgrounds in engineering, mathematics, or sciences other than social sciences will be unfamiliar with the theory rich nature of educational research or with its sensitivity to context. In methods courses, many of the faculty also emphasize familiarity with important research articles.

Findings from interviews with MST alumni suggest that most students completing the program find that writing a thesis is useful for a wide variety of reasons, including, for students who have not had previous experience doing research, first-hand experience with the process of formulating researchable questions, collecting and analyzing data, and presenting results. In general, alumni value the reflective orientation of the MST program. As conjectured, many of them do find that the view of teaching that they encounter among some school administrators can be in tension with this reflective orientation, but they also report being able to accommodate the differences productively.

Next Steps

This summer, as planned, Mr. Zoellick will undertake repertory grid interviews (Fransella, Bell, & Bannister, 2004; Munby, 1984) with alumni who are teaching locally to identify constructs and beliefs that inform teaching. He will also interview 2016 MST graduates who plan to work as teachers and will begin coding and analysis of the interviews with the faculty and alumni that he conducted this spring. This fall he will observe and interview these alumni as they begin teaching.

Publications

None at this time.

References

Fransella, F., Bell, R., & Bannister, D. (2004). A Manual for Repertory Grid Technique (2nd ed.). West Sussex, England: John Wiley and Sons.

Munby, H. (1984). A Qualitative Approach to the Study of a Teacher's Beliefs. *Journal of Research in Science Teaching*, *22*(1), 27–38.

Teaching and Learning of Physical Sciences in K-12

- Energy
- Force and Motion
- Earth Sciences Instruction and Student Attitudes

Two new research projects began this year in areas of teaching and learning of energy and force and motion concepts. The new project focused on energy began when we examined data gathered over time in the MainePSP and found both that students, and even many teachers, demonstrated use of persistent misconceptions when responding to survey questions about thermal energy transfer. We noticed that one question seemed more difficult than another for students and teachers. We brought the data forward to teachers at the MainePSP Fall Summit, and based on discussions with teachers and an examination of existing research in this area, we developed a Collaborative and a research project focused on this topic. For Force and Motion, a new project began this year to focus on a specific difficulty demonstrated by students and teachers in the area of Force and Motion, with considering coordinate systems and directionality of motion, force, and acceleration. The difficulties to be examined and potentially addressed through the new study were identified in the Master's Thesis work recently completed by Gregory Kranich, with advisor Michael C. Wittmann. A description of each project is below.

Energy: Differentiation between Thermal Energy and Coldness (as an energy entity)

The MainePSP program includes a series of assessments of conceptual understanding to the teachers' students prior to and after instruction to measure the changes due to instruction. As part of the 8th grade materials, students explore the conceptual understanding of Energy, identifying the different forms of energy, its transformation into other energy forms, the transfer of energy among the objects in the system, and the conservation of the energy within the system.

The survey is designed to assess the topics covered in the Energy unit, by using mostly multiple choice items, it allows us to give feedback within a reasonable time to teachers regarding the performance of their class. A report of the results prior to instruction allows teachers to be aware of the ideas held by their students to be considered in their instruction. A comparison of the pre and post instruction responses allows the teachers to observe the students' conceptual change.

We explore the understanding of Thermal energy using multiple items in the survey to see if there is a coherent understanding of thermal energy when the item implies *warm*/*hot* items compared to when it uses *cold* items in the scenario studied.

<u>Researchers</u>
Michael Wittmann, Laura Millay, Adam Rogers, and Carolina Alvarado.

<u>Project Dates</u>
Collection of survey data and modification of the items Summer 2015
Collection and analysis of survey data Fall 2015 and Spring 2016

<u>Data collected</u>

We used the 2015-2016 data in order to inform our analysis of conceptual understanding, as well as data from the 2014-2015 for comparison in the response patterns.

Summit talk about coldness at the MainePSP Summit

We hosted two collaborative sessions with teachers to discuss the conflict observed in the data. In the meetings hosted on February 11th and March 30th, we collected energy models from the teachers exploring particular scenarios in order to track the different interpretations of thermal energy in a scenario that works with cold objects (i.e. snow in a bucket interacting with room temperature rods).

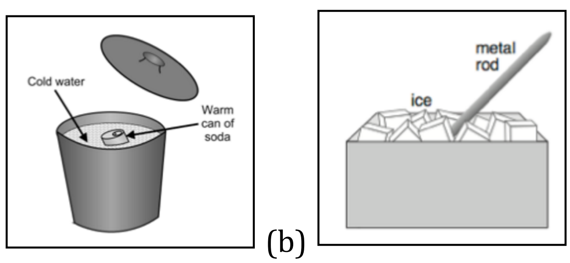
<u>Findings</u>

Students' Survey Responses

The survey has two items using similar objects submerged in ice or cold water. Both items are designed to assess the conceptual understanding of thermal energy being transferred as the submerged object lowers its temperature (Figure 1). There are some differences in the type of wording used as well as the details of the scenario itself that makes them different to each other.

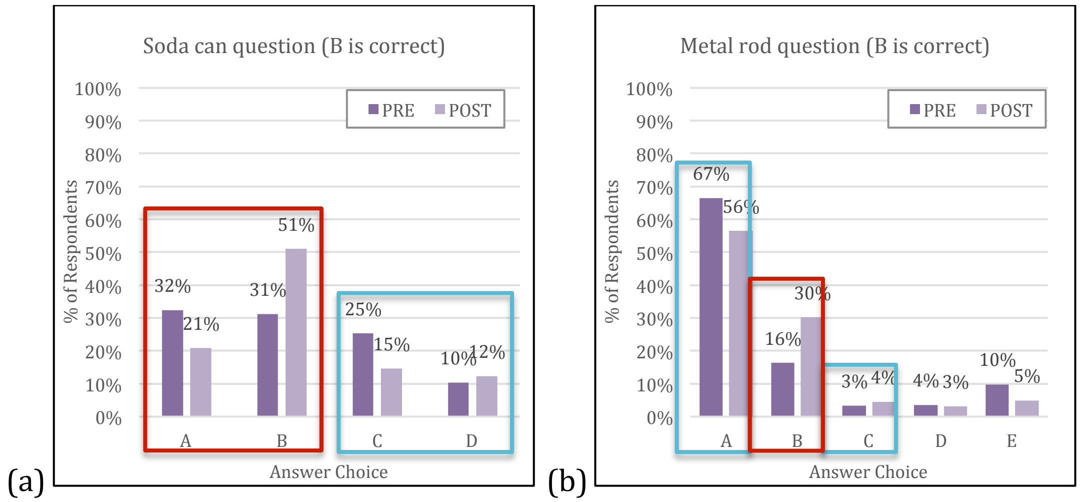
Figure 1. Scenarios used in the two items analyzed. They both includes objects at room temperature interacting with a colder substance, cold water or ice.

(a) (b)



The items have multiple choice answers that includes the idea of thermal energy or heat being transferred as well as coldness or cold being transferred. Students' responses show that the responses using coldness as an entity is attractive to students. There is a different tendency to use thermal vs. coldness to explain the two scenarios (Figure 2). Students use the idea of cold as an entity with a higher frequency to explain the thermal interaction between the rod and the ice (scenario b), even after instruction. In contrast, the use of coldness to explain the interaction of the soda and cold water decreases after instruction not being as popular as using thermal energy to explain the scenario.

Figure 2. Students' responses prior and post instruction from the two explored items. Answers within the red rectangle use the idea of thermal energy, while answers within the blue rectangle use the idea of coldness as an energy form.



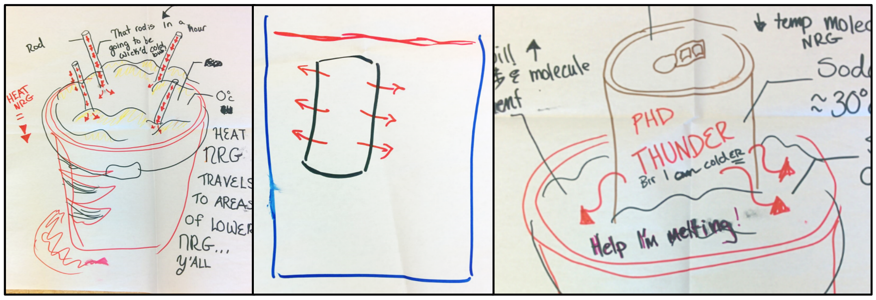
Given the results found, we decided to share this analysis with teachers and explore with them the different interpretations that could be made from both scenarios depending on the type of approach used, thermal versus coldness. As found in the literature, our students can hold both models simultaneously. While refining the understanding of thermal energy during the class, the idea of coldness hasn't been eliminated from the resources they use after instruction to answer the questions.

Teachers' Energy Diagrams

After presenting the data to the teachers participating in the collaborative sessions, we decided to engage them in an activity trying to model the energy interaction in the given scenarios (Figure 1), as well as a different scenario that uses a thermos with hot water. In small groups teachers worked on generating a diagram to explain the energy transference among the different objects involved in the scenarios. Three different categories were found from the diagrams used.

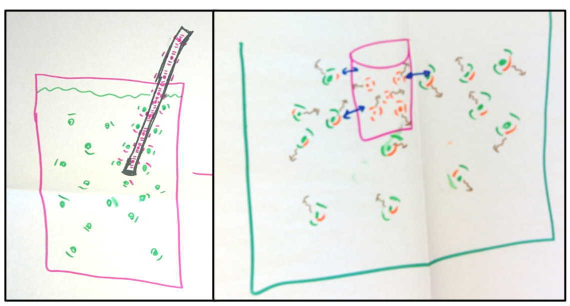
The first category of representations focuses on the thermal energy transfer direction, using thermal energy as a flow, see Figure 3. In the diagrams we can observe that the energy moves from the hotter object into the colder object. The representation doesn't allow us to know more details about the thermal interaction, is energy lost? Is the entire object (rod or can) changing its temperature at the same rate (same temperature on the top or bottom of the object)?

Figure 3. Representations focusing on thermal energy transfer as flow.



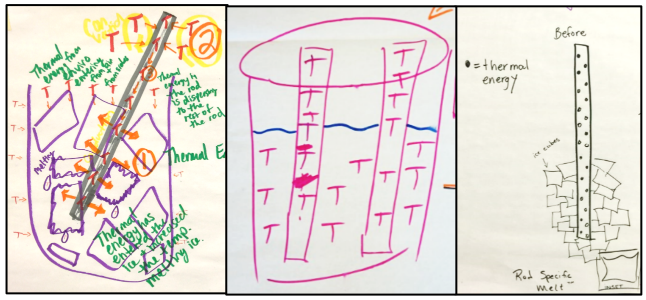
A second representation uses a molecular level to explore the thermal energy, using the vibration of the molecules as an indicator of thermal energy (Figure 4). The more vibration of a molecule the more thermal energy it has. By using a diagram to represent the scenario in two different moments we can observe the change in the thermal energy of the different objects involved. In some cases, colors are used to track the origin of the extra thermal energy. This representation may allow us to observe if the change in thermal energy is uniform in the objects or if it is gradual. The representation could indicate energy conservation if the number of lines used to represent the molecular vibration/thermal energy remains constant in both instances, or may indicate a lack of conservation if the number differs meaning energy was lost or added to the system.

Figure 4. Representations focusing on thermal energy as molecular vibration.



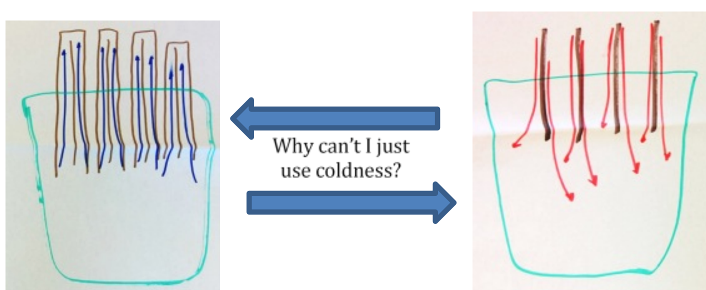
Finally, the third type of representation shows units of energy making an explicit reference to the type of energy involved in the scenario (Figure 5). This particular representation seems to share features with the previous two categories. Some of the teachers' representation of energy by units includes the transfer of those energy units individually, allowing to have a story among time of the energy. In other instances they use the relative amount of thermal unit energies in the objects to indicate whether one object is hotter than the other or if they reach thermal equilibrium.

Figure 5. Representations focusing on thermal energy as units.



These models allow us to understand the different approaches that can be used when talking about thermal energy in scenarios that use cold objects. The different categories emphasize different aspects of the energy interaction: direction of the transference, approaching thermal energy in a molecular level, and observing thermal energy as units to facilitate the idea of conservation of energy. Nevertheless, as one of the groups discussed it, this doesn't inform us how to discard the idea of coldness as something that is being transferred instead of thermal energy (Figure 6). While we know different ways to talk about this using thermal energy, it doesn't mean that the idea or tendency to use coldness as an entity if the options allow it will be eradicated.

Figure 6. Representation showing both models, thermal energy and coldness, can be held simultaneously.



<u>Next Steps</u>

In the literature we can observe an awareness of the misuse of *cold* as an energy entity rather than describing a "cold object" as something that has less thermal energy. This dual use of thermal energy can lead to complications when we try to keep the analysis of conservation of energy. Nevertheless, there is no follow up in the literature on how to address it, or a deeper understanding of this conflictive conceptual understanding.
We would like to write a paper exploring in detail the different models that students can hold when talking about thermal energy and using cold objects in the scenario explored. In this paper we will detail the implications of holding both energy forms simultaneously, and will explore the complications of instructions when trying to address it. We would like to eventually be able to propose specific strategies to help modify the student perspective,

allowing them to find the use of *cold* as an energy entity not useful and keep thermal energy as a model that works for both (warm and cold objects) scenarios.
We will also investigate the conversation among teachers while creating the diagrams in order to observe the features that were discussed while analyzing the scenario. This type of analysis would give us more detail on how they consider the thermal energy observed, how they define the story to tell, and whether or not they were including their students' perspectives while engaging in the activities.

<u>Presentations</u>

Wittmann M.C, Alvarado C., Millay, L. & Kumpa R. (2015) Keeping out the cold? Finding a gap in students' learning about energy transfer. Presentation at the Maine Partnership Summit: Evidence-based strategies for excellence in teaching. Carrabassett Valley, ME.

Rogers, A. (2016) The Persistence of Coldness: Exploring Students' and Teachers' Thinking about Thermal Energy. Presentation at the University of Maine Graduate and Undergraduate Research Symposium. Bangor, Maine.

Force and Motion: Developing the Geometric Model of Vectors through Kinesthetically Engaging Activities with 8th Grade Physical Science Teachers and Students

Focus of the Project: Research over the past 30 years has highlighted the struggles that students have with understanding vector quantities at all levels of education. Prior research has found that students are able to understand the vector nature of displacements, but fail to transfer that vector knowledge to quantities such as velocity and acceleration. To isolate issues about vectors from issues of algebra, I am studying this problem in 8th grade physical science students' conceptual understanding of vector quantities without the direct use of algebra. I am carrying out a design experiment around a modified course sequence; the proposed modification utilizes forces as an anticipatory model for which the students can begin to develop their sense of the properties of a vector in a kinesthetically engaging experience. This introduction of vectors, through the use of forces, provides students the ability to then reinforce their understanding of vectors in the environment of displacement vectors. This design should encourage students' abilities to transfer their understanding of vectors to the concepts of velocity and acceleration, and thus gain a deeper understanding of all vector quantities.

Researchers: Peter A. Colesworthy, Carolina Alvarado, Gregory Kranich, Elijah Tabachnick, & Michael C. Wittmann

Research Subjects: Maine PSP 8th Grade Teachers and Students

Project Dates: October 2015 - May 2017

Data Collected: Samples of student work through the adapted curriculum, audio recordings of students working through 3 lessons, Reflective student statements after completion of the adapted force and motion introductory lesson, and 20min. audio recording of debriefing meeting with piloting teacher

Findings: Early reports from the piloting teacher indicate that the lessons were highly effective at developing the concept of a vector arrow. The data that was collected is currently in the middle of being analyzed and with more data and findings to be collected soon.

Next Steps: An in-service teacher professional development is planned for August 2016. In this we will be focusing on preparing the teachers to understand this new vector arrow model of representation. The teachers will be the focus of the study, in particular how they think about the topic, how they think their students will think about the concept of a vector arrow, and finally, where the teachers think that students will have the most difficulty.

An Investigation into the Interrelationship of High School Student STEM Attitudes and Content Performance

In this study, we explored the possibility of an interrelationship between student content performance and attitudes toward STEM using data collected from three ninth grade Earth science classrooms within the MainePSP. Identifying such a relationship could give us ideas for how to motivate students to gain as much content understanding as possible. Likewise, we could also understand better how content understanding motivates student attitudes and STEM interest. However, this study only used a relatively small data set of 96 students and should be seen as a preliminary step as we wait for more data to be collected in the 2015-16 school year.

<u>Researchers</u>
Adam Rogers and Laura Millay

<u>Project Dates</u>
March 2016

<u>Data Collected</u>
This study utilized content and attitude survey data of 9th grade Earth science students within the MainePSP. The MainePSP designed and revised the content survey through multiple years, trying to adhere to NGSS standards and the curriculum while incorporating a variety of question styles which include misconception-based items. The MainePSP also created the attitude survey several years ago to elicit a variety of student attitudes toward

STEM, such as self-efficacy and STEM career interest. The data set for this study was collected in the 2014-15 school year from students who were administered the surveys pre- and post-instruction by their teachers. Students were matched across the post-instruction content and attitude surveys resulting in 96 matched students, 40 of whom could also be matched to the pre-instruction content and attitude surveys.

Findings

When the students of all three teachers were aggregated, there was a significant correlation between their favorable attitude score and their content score, with a linear R^2 of 17%. However, once the students were split based on teacher (which I'll refer to as class), the relationships between attitude and content scores were highly variable. For two of the classes, there was no significant relationship, while the third class had a significant relationship with a linear R^2 of 45%. This hinted that class could be having a significant effect on content and attitude scores. Indeed, we found that class had a significant effect on both content and attitude scores. However, class explained 44% of the variation in content scores compared to only 10% for favorable attitude scores. These results suggest that student attitudes may have an effect on their content scores (or vise versa), but this relationship is very variable by classroom. Furthermore, which classroom students are from could have a relatively predictable effect on content scores but not attitudes, highlighting the difficulty of addressing student attitudes through classroom experiences alone.

We then investigated the effect of specific attitude questions on content score. We found that three attitude questions comprised the best ANOVA model:

- (Q12) Science is a hard subject
- (Q17) I look forward to taking science classes in college
- (Q29) Which of the following best describes yourself as a student in science?

The model showed that whether students were favorable or unfavorable on these questions was significantly related to their content scores with a linear R^2 of 37%. Seen in the table below, all three questions resulted in a mean content score gap >10% between those who were favorable or unfavorable.

	Mean Content Score of Favorables (MCS_F)	Mean Content Score of Unfavorables (MCS_U)	Content Gap Between Unfav and Fav (MSC_U - MCS_F)
Q12	66%	52%	-14%
Q17	68%	48%	-20%
Q29	66%	49%	-17%

Furthermore, all three of these questions experienced net unfavorable shifts for the 40 students that could be matched pre/post. These results suggest that students' perceptions of their self-efficacy and their abilities and futures in STEM could be related to their understanding of the content.

Next Steps

The most pressing next step would be the addition of 2015-16 data. The attitude survey questions were not altered for the 2015-16 year and only several questions on the content survey were altered, so the new data should be comparable to add to the 2014-15 data of this preliminary investigation. We'd also like to perform some validation tests on the surveys through student interviews to ensure our interpretations of student responses are realistic. We'd also like to extend the study to include content and attitude data from other curricula within the MainePSP. We'd like to extend it this way to test whether other grades have similar predictive attitude questions, especially since our other research into the attitude data show significant attitude differences depending on grade level.

Publications

Comparing Instructional Practices Across Middle, High School, and University Instruction

Observation-based description of secondary to post-secondary transition in STEM education

This study examines instructional practices of STEM instructors at different levels of secondary (middle and high school) and post-secondary (introductory and advanced courses). The researchers conducted observations of these courses utilizing the Classroom Observation Protocol for Undergraduate STEM (COPUS) which captures the actions of the students and instructor for every two-minute time interval for a given class period. For the analysis, both overall class time use and individual activities are being compared between educational levels. In addition, other variables such as class size are being used to sort and compare classes.

Researchers
Ken Akiha, Erin Vinson, Justin Lewin, MacKenzie Stetzer, & Michelle Smith

Participants
5-Post-Secondary, UCOP Teachers and UMaine Faculty

Project Dates
University Campus Observation Program (UCOP) Data Collection began in Feb 2014 and is scheduled to conclude in April 2017

Data collected
COPUS data was collected in person by either the researchers or secondary teachers participating in UCOP beginning in February 2014.

Findings

Our initial analysis shows many important differences between secondary and post-secondary STEM classes, highlighting important issues to focus on when considering the transition our education system asks students to make when entering college. For one, the amount of time students are asked to listen in a given high school class period is significantly less than the amount of time students are asked to listen in an undergraduate class, introductory or advanced. Similarly, the amount of time an instructor spends lecturing in a high school class is significantly less than an instructor in an undergraduate class, introductory or advanced. Within secondary and post-secondary levels, some differences can be observed. Middle school students spent a significantly longer time listening compared with high school students. In addition, introductory classes have a significantly higher percentage of student working codes compared with advanced undergraduate classes.

Next Steps
Ongoing analysis of data and publication in progress.

Publications
N/A

Teaching and Learning of Physical Sciences at the University Level

Evaluation of undergraduate chemistry students' understanding of greenhouse gases following a guided inquiry lab activity. (Undergraduate Students)

This study investigates how students learn about chemistry concepts through participating in a guided inquiry laboratory activity which is part of the General Chemistry Laboratory (CHY 123) curriculum at the University of Maine. In the lab titled "Building a Spectrometer to Explore Infrared Radiation and Greenhouse Gases (IR/GHG lab)," students investigate the thermal effects of molecular absorption of infrared radiation (IR), the driving factor of Earth's atmospheric greenhouse effect. Students use a simple spectrometer to measure and gather data that compares the absorption of IR by at least two different gas samples. In addition, students explore two online resources: 1) an interactive online resource in which users can simulate the interactions between atmospheric gas molecules and radiation (https://phet.colorado.edu/en/simulation/molecules-and-light), and 2) an authoritative resource on the scientific concepts involved in climate science (The American Chemical Society's "Climate Science Toolkit" at http://www.acs.org/content/acs/en/climatescience.html). One goal of the IR/GHG lab is to "provide information and tools such that students can identify atmospheric greenhouse gases."

The researchers hypothesize that performing all parts of the lab will help students improve their ability to identify greenhouse gases by describing one or more of the following charactersics: 1) structural properties of a greenhouse gas molecule, 2) molecular function of a greenhouse gas, and/or 3) temperature effects of a greenhouse gas sample due to IR absorption. To quantitatively evaluate the level of student improvement, the researchers gathered pre- and post-laboratory open-ended text responses to the question "*Please explain how you could identify a molecule that is a greenhouse gas.*" Researchers will conduct post-laboratory interviews in order to deepen qualitative understanding of student conceptions about greenhouse gas functions in the atmosphere.

Researchers

Mitchell Bruce and Tiffany Wilson

Project Dates

Data was collected in November 2014 and more data will be collected in June 2016. Analysis is ongoing.

Data collected

Open-ended text responses to pre- and post-laboratory questions were collected from students enrolled in the Fall 2014 offering of General Chemistry Laboratory (CHY 123) at the University of Maine using the InterChemNet course management platform. Audio-recorded interviews of students enrolled in the Summer 2016 offering of CHY 123 will be conducted in June 2016.

Findings

By focusing on molecular interactions between atmospheric gases and radiation, the goal of the IR/GHG lab is to build a solid foundation with which students can more fully understand the science behind the greenhouse effect. Analysis of pre- and post-laboratory responses of 191 students to the question "*Please explain how you could identify a molecule that is a greenhouse gas*" shows a strong improvement in students' ability to correctly identify and describe greenhouse gas structures and/or functions. The level of understanding provided by each response was evaluated as "correct," "partially correct," or "incorrect" based on a scoring rubric developed by the researchers. From pre-laboratory to post-laboratory, the number of incorrect responses diminished by 67% (94 to 31) while the number of correct responses increased by 111% (57 to 120). The results indicate that the lab provides a favorable learning gain of the physico-chemical mechanisms surrounding IR absorption by gas molecules in the Earth's atmosphere. The lab activity does not explicitly address all physical mechanisms relating to Earth's greenhouse effect, and preliminary analysis of the data shows that common misconceptions about the greenhouse effect occur and persist pre- and post-lab.

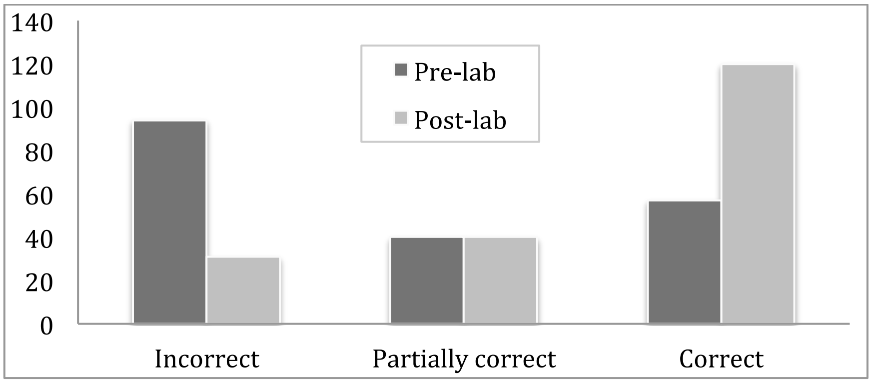


Figure 1. Quantitative assessment of pre- and post-lab conceptual understanding based on 191 student responses to the question "*Please explain how you could identify a molecule that is a greenhouse gas.*"

Next Steps

Ongoing analysis of pre- and post-laboratory data to assess the existence and persistence of common misconceptions associated with the greenhouse effect. Acquire interview data for analysis.

Citations related to this research

Bruce, M. R. M., Wilson, T., Bruce, A., Bessey, S. M., and Flood, V. (in review) A simple, student-built spectrometer to explore infrared radiation and greenhouse gases. *Journal of Chemical Education.*

Bruce, M. R., Wilson, T., Bruce, A. E., Bessey, S. M. Infrared Radiation and Greenhouse Gases: An Introductory Chemistry Laboratory Experiment. In *Abstracts of Papers, 249th ACS National Meeting & Exposition*, American Chemical Society: Denver, CO, March 22-26, 2015, CHED-1652.

Research Projects Completed in 2015-16

Teaching and Learning of Physics Topics: Force and Motion

Knowledge in Force and Motion (PBIS Student and Teacher, K-12)

Researchers

Thompson, Stetzer, Laverty

Focus

Investigating relationships between teachers' content knowledge, pedagogical content knowledge, and student learning in the context of Force and Motion in PBIS classrooms

Project Dates

Ongoing; began Summer 2011

Data Collected

2013-2014: A revised student survey was administered both pre-and-post instruction of the *VIM* unit to all PBIS students. The survey measuring content knowledge (CK) and pedagogical content knowledge/knowledge of student ideas (KSI) was also administered to all PBIS teachers in Fall 2013.

Findings from the student surveys

2013-2014 student surveys did not find overall learning gains of force and motion concepts among the PBIS students. Further analysis of the data grouped the survey items into five content categories to look at more specific topics (Newton's first law, second law, third law, uniform motion, changes in motion). Little shift was found in student understanding pre-to-post across any of the five content categories. The analysis indicates that students tend to relate net force with velocity, rather than net force with acceleration. Students infer that if an object is moving in a direction, then there must be a net force moving it in that direction, regardless of whether the object is speeding up, slowing down, or traveling at constant speed. Students additionally relate forces with motion rather than changes in motion, showing that they are lacking the connections between balanced forces and uniform motion. Survey items also show that students have difficulty in defining, and distinguishing between, different types of motion.

These findings from the student survey informed efforts to redesign the force and motion curriculum with a greater focus on achieving student understanding of force and motion concepts. A task force of teachers worked during the summer of 2014 to develop a set of student activities, with supporting teacher materials that would map a clear learning progression of Newtonian force and motion concepts while still maintaining the strong engineering design concepts present in the *VIM* curriculum. The task force, comprised of middle school teachers and researchers from the MainePSP, worked to identify the core force and motion concepts, align these concepts with national standards, and review research based curricula to develop a coherent progression that would support a learning progression towards an understanding of Newton's laws of motion. This revised set of materials was then piloted by the task force teachers in the fall of 2014. The task force reconvened in the early winter of 2015 to reflect and complete revisions to the curriculum. They then provided training and professional development to other PSP teachers for a second phase of piloting that occurred during the spring of 2015.

Findings from the teacher survey

Teacher surveys from 2013-14 showed some persistent gaps in content knowledge understanding, even after professional development. These misconceptions are congruent with findings from the literature base and previous studies measuring understanding of Newtonian force and motion concepts and have shown to be resistant to change.

Posters and Presentations

Laverty, D.P. (2016) *Investigating Teachers' Content Knowledge and Pedagogical Content Knowledge in a Middle School Physical Science Curriculum on Force and Motion*. Master's Thesis with advisors John R. Thompson and MacKenzie Stetzer, University of Maine, Orono, Maine.

D. P. Laverty, J. R. Thompson, and M. R. Stetzer (7/28/12). *Preliminary investigations of physical science teacher content knowledge and PCK*. American Association of Physics Teachers Summer Meeting. Philadelphia, PA.

Teacher-Generated Common Formative Assessments For 8th Grade Force and Motion

Researchers
Gregory Kranich, Michael Wittmann, Carolina Alvarado

Research Subjects
PSP Teachers

Focus of the project
We're examining a group of teachers in the process of creating common formative assessment items for an 8th grade unit on force and motion. In particular, we are interested in how the conceptual understanding of the individuals in the group shapes their interactions and informs the development of an assessment item.

Project Dates
October 2014-January 2015

Data collected
We have collected video from six planning meetings and the four module assessments created by the group.

Findings

Kranich, G. D., Wittmann, M. C. & Alvarado, C. (2015). Formative Assessment Efficacy as Affected by Teachers' Conflicting Conceptual Models.

We have studied a group of middle school teachers as they modified curriculum and developed common formative assessments on force and motion concepts. While discussing assessment goals for student understanding of acceleration, two of the teachers held opposing models about the implications of the sign of acceleration on the direction of an object's motion and whether it is speeding up or slowing down. Failing to resolve the inconsistency between their individual models, the resultant assessment item was such that both models would provide the same correct response, albeit for different reasons. The potential for correct answers for incorrect reasons perpetuated ambiguity into its classroom use as a formative measure of student understanding. More specifically, the item had limited ability both to accurately inform teacher instruction, interventions, and feedback that would support students in identifying their mistakes and refining their thinking.

<u>Contributed Publications/Presentations</u>

G. D. Kranich, M. C. Wittmann, and C. Alvarado, Teachers' conflicting conceptual models and the efficacy of formative assessments, 2015 PERC Proceedings [College Park, MD, July 29-30, 2015], edited by A. D. Churukian, D. L. Jones, and Lin Ding, doi:10.1119/perc.2015.pr.040.

G. D. Kranich, 2016, "inconsistent conceptions of acceleration contributing to formative assessment limitations (Master's thesis)," University of Maine, Retreived from: http://digitalcommons.library.umaine.edu/cgi/preview.cgi?article=3445&context=etd.

RiSE Conference 2015: Teaching, Learning, and Assessment in the Context of the Next Generation Science Standards and the Common Core State Standards in Mathematics, University of Maine, Orono, ME, June 2015, "Using Data to Talk about Assessment," Carolina Alvarado, Gregory Kranich (Workshop).

The Summer 2015 Meeting of the American Association of Physics Teachers (AAPT), University of Maryland, College Park, MD, July 2015, "Consequences of teachers' content difficulties on planned instruction and assessment," Gregory Kranich, Michael Wittmann, Carolina Alvarado (Presentation).

The Summer 2015 Meeting of the AAPT, University of Maryland, College Park, MD, July 2015, "Teachers' pedagogical decisions when facing gaps in content knowledge," Gregory Kranich, Michael Wittmann, Carolina Alvarado (Poster).

The Summer 2015 Physics Education Research Conference (PERC), University of Maryland, College Park, MD, July 2015, "Data-centered teacher professional development," Michael C. Wittmann, Carolina Alvarado, Gregory Kranich, Alex Axthelm (Workshop).

Studies of Instruction and Instructional Strategies for Teaching Middle and High School Physical Sciences

Productive Talk: Does Productive Talk Improve Students' Abilities to Use Evidence to Support Claims in their Written Work?

<u>Researchers</u>
Rachel Martin, Susan McKay, Molly Schauffler, Mindi Summers

<u>Research Subjects</u>
7th and 9th grade Earth Science students at rural Maine schools

<u>Focus of the project</u>

Researchers and teachers collaborated to research the connection between different classroom discussion protocols and student written argumentation skills. Seventh and ninth grade Earth Science students at central Maine schools answered two questions. For the first question, students wrote their answers with no discussion beforehand. For the second question, classrooms were assigned a discussion protocols—no discussion, discussion without Talk Science, or discussion with Talk Science. Students wrote their answers using the Claim, Evidence, Reasoning (CER) framework. The responses were evaluated using a CER and Content rubric to determine improvements made with each discussion protocol. Finally, students wrote reflections about classroom discussions.

Project Dates
10/2015—present

Data collected
Student written responses, audio of classroom discussions, student discussion reflections

Findings
Following a Talk Science discussion, ninth graders improved their scores on evidence, reasoning, and content and seventh graders improved their scores on claim. Audio recordings suggest that the teachers focused on different moves and, thus, structured their discussions differently. Most students valued the discussions either for obtaining information to include in their answer or for gaining further knowledge of concepts.

Next Steps
Results of this study will be used to influence classroom instruction and professional development within the MainePSP. Because of the positive results, other teachers should be encouraged to use Talk Science and CER in their classrooms. Though teachers often report that classroom discussions are not beneficial, it is apparent here that students do value discussion.

Presentations

Martin, R. A. 2016. Influence of productive talk discussions on written arguments in middle and high school science classes. University of Maine Graduate and Undergraduate Student Research Symposium, Bangor, ME.

Martin, R. A. 2015. Does discussion affect students' written arguments? Maine RiSE Center Research Group, University of Maine, Orono, ME.

Posters

Martin, R. A. 2015. Using Productive Talk to improve students' written work in middle and high school science classes. 2015 RiSE Partnership Summit. Sugarloaf Mountain Resort, Carrabassett Valley, Maine.

Martin, R. A. 2015. Does Productive Talk improve students' abilities to use evidence to support claims in their written work?: A pilot study. No Question Left Behind: Teaching, Learning, and Assessment in the Context of the Next Generation Science

Standards and the Common Core State Standards in Mathematics Conference. University of Maine, Orono, Maine.

Place-Based Education: Evaluation of the Collaborative Design Process and Classroom Implementation of a Place-Relevant Lesson in Ninth Grade Earth Science Classrooms

Researchers
Marina Van der Eb, Susan McKay, Sara Lindsay, Molly Schauffler

Research Subjects
Ninth grade Earth Science students

Focus

Ninth grade Earth Science teachers in the Maine Physical Sciences Partnership (Maine PSP) and researchers at the University of Maine identified a lack of student engagement in the science classroom as a serious problem and have sought to improve engagement by making science classroom experiences more relevant to students' daily lives. To test a possible approach for solving this problem, teachers and researchers worked together to co-design and implement a lesson focused on a Maine topic in rural Maine schools. The design process was documented and data was collected to provide insight with respect to the impacts of the lesson. These data include recorded class discussions, student written work, and follow-up interviews with teachers.

The first goal of this research is to describe and assess the collaborative process of designing a new lesson with a Maine focus and how successfully this lesson was implemented in the classroom. The second goal of this research is to understand how a Maine-based lesson impacts student engagement and students' ability to synthesize information. The design and implementation process was very successful as a result of the collaboration. However, it was difficult to measure classroom impacts due to small sample sizes. Findings show that students likely appreciate, and prefer, place-relevant material and find class more interesting when it is focused on issues related to where they live. This research is intended to guide and inform the long term goal of making science content more relevant to students in Maine schools.

Project Dates
December 2014-August 2016

Data Collected
Video/audio recordings and classroom observations
Student written worksheets
Student pre- and post-attitude survey responses
Teacher interviews

Findings

The design and implementation of the place-relevant lesson was successful from both the researchers' and teachers' perspectives. The collaborative process ensured that the lesson design was targeting the persistent problem of engagement while also aligning with Next Generation Science Standards and the instructional resources teachers are currently using in their classrooms. While small sample sizes limited the ability to fully assess the impact of the lesson on the student population, attitude surveys indicate that students likely prefer, and appreciate, place-relevant material in their classes and would enjoy science class more if topics were focused on locally relevant issues.

Presentations

Van der Eb, M. 2016. Quality of group discussion during place-relevant lessons. Maine RiSE Center Research Group, University of Maine, Orono, ME.

Van der Eb, M. 2015. Place-relevant education in the ninth grade MainePSP. Maine RiSE Center Research Group, University of Maine, Orono, ME.

Posters

Van der Eb, M. 2015. A case study looking at use of a place relevant lesson in an ocean science module of the Maine Physical Science Partnership (MainePSP) ninth grade global climate change instructional resources. 2015 RiSE Partnership Summit. Sugarloaf Mountain Resort, Carrabassett Valley, Maine.

Van der Eb, M. 2015. Place-based education in the Maine Physical Sciences Partnership (MainePSP) ninth grade global climate change instructional resources. No Question Left Behind: Teaching, Learning, and Assessment in the Context of the Next Generation Science Standards and the Common Core State Standards in Mathematics Conference. University of Maine, Orono, Maine.

Next Steps

The next step is to generate a concise set of recommendations for incorporating place-relevant material into science classrooms for teachers and researchers. Ideally this will lead to the creation of a template that educators can follow that will allow them to efficiently connect locally relevant issues to national science standards and increase student engagement in their classrooms.

Learning about Modeling and Energy Through an Embodied Modeling Activity (K-12, PSP Teachers and Earth Science Students)

This study investigates learning about science content through participating in an embodied modeling activity (Energy Theater or ET). The researchers conceptualize ET as an activity in which participants engage in the practice of modeling and the research is focused on the kinds of learning about science content that is supported through this practice. For the analysis the Knowledge in Pieces perspective on conceptual change and learning is being utilized.

Researchers
Lauren Barth-Cohen & Michael Wittmann

Project Dates
Data collection began in February 2014 and analysis is ongoing.

Data collected
Video and audio of PSP teachers participating in ET through a Wednesday collaborative, and video and audio of the 9th grade students participating in the same ET activities in their classrooms. Also, in this data the participants were doing ET about both topics in earth science and topics in physics.

Findings
The new science education standards foster interest in understanding how scientific practices contribute to learning science content. Here we contribute to this discussion in the context of an embodied modeling environment. Four classrooms of high school science students each self-organized themselves to use their bodies to represent the dynamic equilibrium of the earth's energy, as energy joins and leaves the earth at relatively equal rates. Through qualitative data analysis using coordination class theory we show that the students used their conceptual understanding of dynamic equilibrium to generate and then to revise their models. We show that there were mismatches between what content students represented within their model and what other students expected to be represented within their peer's model. These mismatches led students to modifying the conceptual content that was being represented in the model and to modifying how they represented that content. We argue that these mismatches function as a mechanism to drive model revision and this result affirms the synergistic importance of both the conceptual content and the particular representation of that content in the modeling process.

Publications
Barth-Cohen, L. A. & Wittmann, M.C. (2016) *Expanding Coordination Class Theory to Capture Conceptual Learning in a Classroom Environment.* Paper Presented at the 12th International Conference of the Learning Sciences in Singapore.

Barth-Cohen, L.A. & Wittmann, M.C. (Under Review, 2016) *Aligning Coordination Class Theory with a New Context: Applying a Theory of Individual Learning to Group Learning.* Submitted to Science Education.

Elements of Productive Clicker Conversations (K-12 Students)

There is growing interest in using classroom response systems or "clickers" in science classrooms as it is widely viewed as a promising technology by both university and K-12 instructors. The existing literature on this technology has largely focused on the efficacy of clicker implementation, however few studies have investigated discourse in the context of students' clicker conversations. This study is motivated by an expectation that using clickers can lead to productive student conversations about relevant science content. Some have been skeptical about clickers due to concerns that students will be off-task during clicker discussions or that one student will tell peers the correct answer without further discussion. We asked middle school students to answer a physical science clicker questions individually, talk to their peers, answer the same questions again, and then subsequently answer matched-pair questions. We analyzed students' learning gains on each question and audio taped the peer conversations. From the analysis we found that neither of these concerns were manifested in our data and a subsequent grounded analysis is used to characterize the nature of students clicker conversations with a focus on four elements: revision of ideas, asking questions, science content and multiple individuals contributing. The later analysis was connected to the analysis of learning gains on each question and we find that the more elements in a conversation, the better the conversation.

Researchers
Lauren Barth-Cohen, Michelle Smith, Daniel Capps, Justin Lewin, Jonathan T. Shemwell, MacKenzie Stetzer

Project Dates
Data was collected in 2011-12. A peer-reviewed journal article from this work was published in 2016.

Data collected
Audio of middle school students' clicker conversations and quantitative data of learning gains from clicker questions.

Next Steps
This project is complete.

Publications
Barth-Cohen, L., Smith, Michelle K., Capps, Daniel K., Lewin, Justin., Shemwell, Jonathan T., Stetzer, MacKenzie R. (2015) *What are Middle School Students Talking About During Clicker Questions? Characterizing Small-Group Conversations Mediated by Classroom Response Systems.* Journal of Science Education and Technology. 25:1, 50.

New Assumptions about the Pace of Science learning: How Will Teachers React? (K-12 Teachers)

The field of science education has increasingly acknowledged that the most valuable learning in science develops over the long term and cannot be reduced to the steady acquisition of concepts and skills that are taught one day and assessed the next. However, in seeking to make systemic changes to teaching practice, it is easy for the rhetoric of reform to be preoccupied with changes in what gets taught, so that the organizing idea of reform is seen as a shift from shallow treatment of many topics to deeper treatment of a few. This rhetoric can easily obscure changes in assumptions about how learning occurs that call for reduced emphasis on short-term acquisition of knowledge and skills, and increased emphasis on longer-term development of intellectual capacities. The contribution of the present study is to underscore and illustrate the impact on teachers of shifting to more developmental approaches to instruction. The study followed 12 experienced middle-school teachers who enacted a developmentally-oriented curriculum, which we call MDC, for the first time. Quantitative and qualitative evidence from teacher journals and interviews showed that many teachers enacting MDC expressed appreciation for its focus on developmental learning. This appreciation was often paired with disfavor of acquisition-centered instruction of the past. However, many of these same teachers also expressed ideas in favor of acquisition learning, showing that they had not let go of acquisition approaches to instruction. These results illustrate how reforms that steer teachers toward more developmental learning will demand fundamental changes to how teachers think about science learning and act to promote it. These changes will likely require extended time, support, and experience to develop.

<u>Researchers</u>
Shirly Avargil, Jonathan Shemwell, Daniel Capps,

<u>Project Dates</u>
Data collection started in September 2011and ended in June of 2012. An article from this work was published in 2015.

<u>Data collected</u>
Teacher journals, audio files of teachers interviews

<u>Publications</u>
Shemwell, Jonathan T., Avargil, Shirly, Capps, Daniel K. (2015) *Grappling with Long-Term Learning in Science: A Qualitative Study of Teachers' Views of Developmentally Oriented Instruction.* Journal of Research in Science Teaching. 52:8,1163.

Studies of Instruction and Instructional Strategies for Teaching Middle and High School Physical Sciences

University Classroom Observation Program (UCOP)

<u>Researchers</u>
Michelle, Erin, Justin, and MacKenzie

<u>Research Subjects</u>
K-12 Teachers observing UMaine classes

Focus

Because of the national call-to-action to reform undergraduate STEM instruction, there is increasing interest in collecting information on the range and frequency of teaching practices at department-wide and institution-wide scales. To help facilitate this process, we helped to develop a classroom observation protocol known as the Classroom Observation Protocol for Undergraduate STEM, or "COPUS" (Smith et al., 2013). This protocol allows observers, after a short 1.5-hour training period, to reliably characterize how faculty and students are spending their time in the classroom.

At the University of Maine, local middle and high school teachers have been using the COPUS observation protocol to collect snapshots of the types of instructional techniques used in STEM classes. During the past year, teachers completed 194 classroom observations in 101 courses, taught by 96 different instructors and attended by more than 8000 students. These courses spanned 23 different STEM departments. In 2013, Drs. Michelle Smith, MacKenzie Stetzer, Susan McKay, and Jeff St. John--who were awarded an NSF WIDER grant (DUE 1347577) to explore how to use the observation data to develop meaningful campus-wide professional development opportunities at the University of Maine--have been implementing additional new professional development programs under the WIDER program.

Project Dates

The project began in 2011, but has been modified over the four-year period. The project is currently ongoing. Observations take place during both the fall and spring semesters. Observation results were shared and discussed with the observed UMaine instructors in one-on-one meetings with the program coordinator.

Data collected

1. COPUS observation data of faculty- 194 observations during the 2014-15 academic year (37 in Fall 2014 and 157 in Spring 2015).
2. UMaine faculty filled out a survey about their teaching practices. This survey is called the Teaching Practices Inventory (Wieman and Gilbert, *2014* CBE-Life Sciences Education).
3. UCOP teachers completed two post-observation surveys for each class observed. One survey was completed as an observation pair and another was completed by each teacher individually. Both surveys were developed by MST student, Justin Lewin.
4. Middle and high school teachers filled out feedback surveys about their observation experience and a revised Teaching Practices Inventory for middle- and high-school teachers.
5. All 18 participating middle and high school teachers were individually observed using the COPUS protocol.

Findings

As described in a recent publication: **Smith MK,** Vinson EL, Smith JA, Lewin JD, Stetzer M. A Campus-Wide Study of STEM Courses: New Perspectives on Teaching Practices and Perceptions. **CBE-Life Sci Educ**. 2014*, 13:624-635.*

We have found:
1) Faculty members teaching STEM courses cannot simply be classified into two groups--traditional lecturers or instructors who teach in a highly interactive manner--but instead exhibit a continuum of instructional behaviors between these two classifications.
2) Student behavior differs greatly in classes with varied levels of lecture.
3) Although faculty members who teach large-enrollment courses are more likely to lecture, we also identified instructors of several large courses who use interactive teaching methods.
4) Faculty members are generally self-aware of their own practices when filling out the TPI survey.

For data collected during Fall 2014 and Spring 2015, we are interested in exploring the following question: Are there differences in how active-learning tools such as clickers are used, and how does this variation reflect the diversity of overall teaching practices?

Next Steps
We will be analyzing the data to answer the research questions above, and plan to submit a manuscript on the use of clickers in the fall.

List of publications or presentations directly related to this project

Smith MK, Vinson EL, Smith JA, Lewin JD, Stetzer M. A Campus-Wide Study of STEM Courses: New Perspectives on Teaching Practices and Perceptions. **CBE-Life Sci Educ***.* 2014*, 13:624-635.*

Michelle Smith Interviewed as part of a video on the Festival of Learning in Teaching in Adelaide, Australia:
http://www.adelaide.edu.au/festival-lt/

Michelle Smith Guest on RRR FM Australian science radio show Einstein A Go Go:
http://rrrfm.libsyn.com/einstein-a-go-go-16-november-2014

UCOP teacher blog post:
http://www.hurricaneisland.net/science-for-everyone/2015/4/24/improving-stem-teaching-through-course-evaluation

Invited talk by MacKenzie Stetzer:
"Two projects focused on undergraduate STEM education: The University Course Observation Program and an investigation of the role of metacognition in student reasoning in physics," Center for Teaching and Learning Seminar, Technischen Universität Hamburg–Harburg, Hamburg, Germany, July 2, 2014.

Invited talks by Michelle Smith:

NSF, March 2015, "Strategies that Promote Institutional Transformations in STEM Education"

Dartmouth, March 2015, "Using Student Learning and Observation Data to Guide Changes in STEM Classrooms"

Festival of Learning and Teaching, Adelaide, Australia, November 2014
Documenting the Importance of Active-Learning and Using Data to Guide Institutional Change

Ongoing Research Continued in 2015-16

Teaching and Learning of Scientific Practices

Argumentation: Students Understanding About the Syntactic and Epistemic Function of Reasoning in Argumentation

Researchers working on this project
Grace Gonnella, Ethan Geheb, Dan Capps, Jon Shemwell, Justin Dimmel

Research Subjects
6th grade SEPUP students

Focus of the project
Student learning in argumentation
Contrasting cases
Explicit reasoning

Project Dates
September 2014-Present

Data collected
Audio, artifact: activity packet

Findings
Combining Sir Francis Bacon's Method of Induction and the concept of Contrasting Cases (also known as Inventing), a contrast matrix was designed and refined to promote the greatest understanding of reasoning's functional role and effect in an argument. Once the final version was solidified, it was implemented in a 6th grade class at Hermon Middle

School, a rural school in Maine. The students were learning about rocks, minerals and erosion. Twenty students participated in pairs to complete the activity packet designed by the research team.

These are the tentative findings:

Research Question 1: When using the contrasts…

A: How did students think about the

(i) syntactic role of reasoning?

- Students did not go beyond a basic understanding of the syntactic role
- Not all students reached a basic understanding (vague)
- Frequently, students' contextual expressions had more information than their general expressions
- Expressing with multiple arguments creates an implicit generalization.

(ii) Epistemic role of reasoning?

- Students did not go beyond a basic understanding of the syntactic role
- Not all students reached a basic understanding (vague)
- Cases of informative generalized descriptions

B: To what extent could students understand the syntactic role of reasoning without understanding the epistemic role and vice versa?

- Generally, the two forms (syntactic and epistemic) of understanding co-vary
- Understanding one role does not mean students will understand the other role.
  - Some students understand reasoning's syntactic role in an argument, but may not understand reasoning's importance [epistemic]
  - Students reverted to explaining the syntactic role
    - (*Prompt 2 – Leaving off the importantly sentence makes Pat's arguments [lacks the essence] not as convincing as they should be. Why?*
    - [students answer to question 2] *"So if you leave the important part off, then you might not know why their thought is that. [referencing one of the arguments] You wouldn't know why you think you're going to get sick."*

Research Question 2.

What were informative ways that students processed the contrasts to learn about reasoning?

Syntactic

- Students always used the absent case (Students emphasized the consequence of reasoning's absence)
- Students sometimes used the present case (Students explicitly said what the present case contained (in contrast to the absent case))

Epistemic

- Again, the absent case was important.

Next Steps:

- The next steps are to finish writing my results section and verifying my findings with the data.
- I plan to defend early Fall 2016.

Argumentation: Organization of Contrasting Cases to Support Student Learning About Reasoning within Argumentation

<u>Researchers</u>

Grace Gonnella, Ethan Geheb, Dan Capps, Jon Shemwell

<u>Research Subjects</u>

6th grade SEPUP students (Dedham, Orono, Belfast, Hermon)

<u>Focus of the project</u>

Student learning in argumentation
Contrasting cases
Explicit reasoning

<u>Project Dates</u>

September 2014-Present

<u>Data collected</u>

Audio, artifact: activity packet

<u>Findings</u>

Combining Sir Francis Bacon's Method of Induction and the concept of Contrasting Cases (also known as Inventing), a contrast matrix was designed and refined to promote the greatest understanding of reasoning's functional role and effect in an argument. Once the final version was solidified, it was implemented in a 6th grade class at Hermon Middle School, a rural school in Maine. The students were learning about rocks, minerals and erosion. Twenty students participated in pairs to complete the activity packet designed by the research team.

The analysis of my research is three parts: 1) to analyze student deficiencies in learning about reasoning using the contrast matrix, 2) what changes were made to address these deficiencies in subsequent protocols' revisions of the contrast matrix, and 3) what effects the changes had on student learning. The goal of the activity was student learning about the functional role and effect of reasoning in an argument.

What I've done so far is determine the two major changes made throughout the refinement of the contrast matrix activity protocol, specifically in the presentation of the contrast matrix to students. For each major change, I analyzed the student interviews of protocols before and after a major change was implemented, and determined if the quality of student understanding was changed.

The first variation was making the reasoning statement in an argument less obscure. There was little evidence of increased ability to isolate the reasoning statement, but there was an increased understanding of the role and effect of reasoning. I now know that obscuring the reasoning statement within an argument does not inhibit student ability to identify it, and has a positive effect on student ability to understand the role and effect of reasoning.

Next Steps

The second variation was withholding arguments' pairs until students requested them for use in their comparison. The results of this variation are still under analysis. I am hoping that if students use more arguments to talk about reasoning, their understanding of reasoning will increase when using all given arguments.

Professional Knowledge for Teaching Middle School Physical Sciences

Knowledge for Assessment (K-12, SEPUP Teachers)

This study examines teachers' assessment knowledge (AK), knowledge of student ideas (KSI), and the specialized content knowledge (SCK) that guides instructional and assessment decisions within earth science content areas.

Researchers

Millay, Bruce, Avargil, Wittmann, Shemwell, Gallagher

Project Dates

Ongoing; started Summer 2011

Data Collected

Baseline interviews with four SEPUP teachers, multiple cycles of pre-assessment interviews, pre-assessment classroom observations and video/audio during teaching, post-assessment interviews, and classroom artifacts.

Findings

Analysis to date has focused on one assessment cycle (pre-and post-assessment interviews with the teachers, and classroom audio/video analysis of teaching of the material related to the studied assessments) with each of two teachers. Findings from one cycle showed that the teacher focused on assessing a specific student "misconception" without considering the relationship between the student misconception and the target earth science content that she had intended to teach. In the process, the teacher's assessment goals were not met. Analysis of an assessment cycle with another teacher showed that during classroom discussion, the teacher responded to students in ways that were closely aligned with her goals for instruction and assessment. A tentative finding through the case comparison is that assessment planning that explicitly relates key science content, goals for student learning, and ways to work with student ideas may help teachers to align their implementation of instruction and assessment with their goals for teaching and learning. In addition, the research suggests some possible descriptions of the relationships between teachers' knowledge, their planning process, and the outcomes of their implementation of assessment.

The findings have been presented in two talks to teachers and researchers through RiSE Center conferences, one in Summer 2012 and the other in Summer 2013 and was also presented at the MainePSP Summit in May 2012.

Next Steps

Findings will be written up as Millay's Master's thesis.

Presentations

Millay, L.,"Beyond Misconceptions: Honoring Student Ideas While Teaching Science." Invited talk at RISE Center NQLB, Northport Maine, June 2013.

"Opening a can of worms," Wittmann, M.C., Millay, L.A., Avargil, S., Bruce, M.R.M., and Shemwell, J., Science Teaching Responsiveness Conference, Seattle, WA, 2013 July.

Content Knowledge for Teaching Energy (PBIS teachers)

This study investigates teachers' knowledge of energy and of their students' ideas. The goal of this work is to better understand the role of teacher knowledge (of content, of students, and of content as focused on teaching and learning) on classroom actions and student learning.

Researchers

Michael C. Wittmann, Lauren Barth-Cohen, Alex Axthelm. Primary outside collaborators are from Rutgers University (PI: Drew Gitomer, also Eugenia Etkina), Seattle Pacific University (PI: Stamatis Vokos), Facet Innovations (PI: Jim Minstrell), ETS (PI: Geoffrey Phelps, also Courtney Bell), and Horizon Research, Inc. (evaluator: Sean Smith)

Project Dates

The project began September 2012 and is ongoing

Data Collected

The project is collecting artifacts from several teachers who volunteered to participate in the study. From these teachers' students, we are also gathering classroom data on student work, collected by teachers from homework and in-class assignments and tests. Finally, we are surveying students in this class with a specially designed survey that is independent of other surveys on energy that have been used in the project in the past.

Findings

Because data only started to be gathered in the past few months, we have not arrived at findings. One overall observation is that the design with collaborators at Rutgers, SPU, ETS, Facet Innovations, and Horizon was focused on high school teachers, and that the concepts used to design the teacher assessment and student knowledge assessment are very often beyond the knowledge that is needed to work in middle school physical science classrooms.

Next Steps

Based on our preliminary findings about survey and assessment design, we need to make more efforts to recruit high school teachers to participate in the study. This will provide an excellent opportunity for the MainePSP to extend the question of vertical alignment to the high schools, much like the MaineESP has extended the question of STEM learning into the elementary schools. For middle school teachers, the concepts of energy used in Earth science and physics courses in high school seem as horizon content knowledge – what needs to be known next – suggesting a valuable interplay between teachers at different grade levels. To study these interactions, we will conduct professional development activities in which middle and high school physical and Earth science teachers will come together to develop their content knowledge for teaching energy and study this environment as part of a larger study.

Correlations between students' performance on assessments and teachers' knowledge of students and energy (K-12, PBIS Students and Teachers)

The project looked at teachers' knowledge of both content and student ideas using written assessments. The responses on these assessments were used as a proxy for teachers' knowledge, and correlations between this knowledge and student performance on a written assessment about energy were made.

Researchers
Levi Lucy, Michael Wittmann

Project Dates
January 2011 until December 2013

Data collected
Written assessments for both teachers and students, and audio data for the validation study on both teacher and student assessments.

Findings
For limited circumstances in the data (where it was possible), correlations were found between teachers' knowledge as demonstrated on a written assessment and student performance. Teachers who gave a more detailed response on a free response question had students who also gave more detailed responses. Teachers who gave more detailed responses also had students who performed better on the multiple choice portion of the written assessment. Furthermore, teachers who could better explain a wrong student answer to a particular question, had students who performed better on that questions.

Next Steps
The project will be continued by graduate students Greg Kranich and Oai Ha.

Publications and Presentations
The findings from this project have been written up as Levi Lucy's Master's thesis, and may lead to one or more publications.

Analysis of teachers' energy understanding and refinement over time

Researchers
Carolina Alvarado and Michael Wittmann

Research Subjects
PBIS Cohort teachers

Focus of the project

Analyze how the teachers' understanding of energy as well as teaching/learning energy has changed while being involved in the MainePSP activities. We are looking for an individualized assessment of teachers' growth in their content knowledge, recognition of students' ideas and pedagogical strategies regarding energy while participating in the PD designed by the MainePSP.

Project Dates

September 2014, ongoing process

Data collected

Teacher Energy survey (block and the ramps open-ended question) and video of a cohort meeting

Findings

By using the data of those teachers who had responded to the Teacher Energy survey in more than one year, we were able to make comparisons of their understanding of energy concepts, how they recognize their students' ideas and the type of pedagogical intervention they would do if they find those ideas in their classroom. We observed that teachers had evolved in the way they consider energy; they are valuing the details of the energy transformation and transference more than in the earlier stages. In **Error! Reference source not found.** we observe the differences in the responses. We show how teachers' responses have a more detailed story regarding the energy involved in the scenario analyzed. Teachers tend to include the indicators of energy as part of a complete answer in their later stage responses, rather than just considering the recognition of the different energy types as a complete answer.

Table 1. Teacher's response regarding a complete answer in two different years while participating in the MainePSP program.

2012-2013	**2013-2014**
In pic 1 there is **GPE** and **thermal**. In pic 2 there is **kinetic** (mechanical) energy, **thermal** and **light**.	In picture there is **potential** energy due to the position of the block and some **thermal** due to the friction. In picture 2 there is still **potential** as well as **kinetic** (mechanical) as well as some **thermal** due to the friction between the block and the surface. The total amount of energy does not change. The energy types only changes form. Energy is not created or destroyed.

Teachers also show a positive change regarding the identification of students' ideas prior to instruction, observed in **Error! Reference source not found.**. By being able to identify the intuitive ideas students bring to the classroom before a formal instruction, the teacher is better equipped to identify the ideas that need to be changed during instruction and what possible strategies to use.

Table 2. Teacher's response regarding their students' ideas prior instruction in two different years while participating in the MainePSP program.

2012-2013	2013-2014
Because they **do not have an idea of energy** other than it is something that they here in the news and costs money. Energy makes things warm or move.	The student would equate **energy with movement**. If there is no movement then there must be no energy. the amount of energy will decrease as the object comes to the end of it's journey [...]

Finally, we observe teachers including more active learning strategies while planning an intervention with their students. They value active learning in earlier stages but show a more aligned plan in the later stages, indicating that teachers have more resources to implement an actual active learning experience in their classrooms. In **Error! Reference source not found.** we can observe the changes in the type of verb usage in two different years. While the earlier response implies a passive role for the student and the teacher as the provider of the knowledge, the later response paints the student in an active role facilitated by the teacher.

Table 3. Teacher's response regarding what would they do if their students still holds an alternative idea in two different years while participating in the MainePSP program.

2012-2013	2013-2014
I would begin by **offering** the scientific definition of energy, then **introduce** the concept of potential energy by stretching rubber bands [...] I would then **explain** how any kinetic energy, the energy of motion, has to result from the presence of potential energy to begin with.	I tend to use **group discussion** a lot and I'm sure we would hammer out a lot of the details in that format. For **demonstrations** I would use the coaster cars to demonstrate how starting higher on the ramp gives the car the potential to travel further

Given the population analyzed (experienced science teachers), we consider that the changes observed can be due to their participation in the MainePSP program. The three dimensions analyzed reflect the design of the pedagogical development activities teachers are involved in to strengthen their teaching about energy.

We designed a cohort meeting where teachers were discussing four responses given by their colleagues in earlier years. This exercise allowed us to observe in a larger population what they consider relevant or valuable in the areas of our study (energy content, and pedagogical strategies). The video of the session shows how teachers intertwined the three dimensions as exploring the two dimensions independently. We consider this as a reflection on how the conceptual understanding of the content for teaching also requires the recognition of the students' ideas.

The analysis of teachers' discussion while exploring previous years' responses shows a progression in the focus. They pass from evaluating how correct an idea is into recognizing the pieces from each response (rather than evaluating it as a whole). There was an interesting distinction between misconception and omission, which demonstrates an empathy towards the ideas of others, recognizing that missing pieces don't necessarily mean holding a wrong conception. Finally, teachers generated their own version of a complete answer mixing different pieces of the responses given after engaging in productive conversations as a group.

Next Steps

We have found these changes in all of the teachers who have answered to the Teacher Energy Survey more than once, which is the only population that allow us to assess changes while participating in the MainePSP program. Given the useful analysis on teachers' growth found with this type of assessment format, we plan to use this format for further exploration of teachers' changes in the three areas discussed. If possible, we would like to be able to observe if the responses given in the survey actually reflect the teachers' practices in their classroom. We are working on the publication of two papers, one addressing the methodology of the set of questions regarding one particular physical phenomenon and the changes observed in the teachers' responses, while the second paper will address the use of given data for a pedagogical development session with teachers who are familiar with the item.

Publications/Presentations

Alvarado, C. (2016) K-12 pedagogical development courses based on the teachers' survey data. Invited Oral presentation at the American Association of Physics Teachers Winter Meeting, New Orleans, LA.

Wittmann, M.C. & Alvarado, C. (2016) A Model for Data-Centered Teacher Professional Development. Workshop at the Physics Teacher Education Coalition Conference, Baltimore, MD.

Wittmann, M.C., Alvarado, C., & Millay, L. (2016). Teacher responses to their multiple goals for teaching energy. Conference proceeding from the Physics Education Research Conference 2015. College Park, MD.

Alvarado, C. (2015) Desarrollo de cursos para profesores de nivel medio basado en investigación (Development of middle school teacher pedagogical development courses based on research). Invited Oral presentation at the III Coloquio Internacional en la Enseñanza-aprendizaje de las Ciencias, Universidad de Guanajuato, Mexico.

Wittmann, M.C., Alvarado, C., & Kranich, G. (2015) Data-centered teacher professional development. Workshop at the Physics Education Research Conference, College Park, MD.

Alvarado, C., & Kranich, G. (2015) Using data to talk about assessment. Workshop at the No Question Left Behind: Bringing Guided-Inquiry Curricula into Science and Mathematics Classrooms, Orono, ME.

Wittmann, M.C., Alvarado, C., & Kranich, G. (2015) Using data to talk about teaching. Workshop at the High School Physics and Physical Science Teachers meeting, Orono, ME.
Alvarado, C., Wittmann, M.C., & Millay, L. (2015) Professional development promotes deeper understanding by teachers analyzing teacher responses. Poster presentation at the American Association of Physics Teachers Summer Meeting. College Park, MD.
Wittmann, M.C., Alvarado, C., & Millay, L. (2015) Teacher growth in pedagogical knowledge of energy in the MainePSP. Poster presented at the American Association of Physics Teachers Summer Meeting. College Park, MD.
Alvarado, C., Wittmann, M.C., & Millay, L. (2015) Change in Teachers' Views about Energy in the MainePSP. Poster presentation at the Foundations and Frontiers of Physics Education Research. Bar Harbor, ME.
Wittmann, M., & Alvarado, C. (2015) Measuring Change in Teachers Views about Energy in the MainePSP. Poster presentation at the Physics Teacher Excellence Coalition (PhysTEC) Conference 2015, Seattle, WA.
Alvarado, C., & Wittmann, M.C. (2015) Change in Teachers' Views about Energy in the MainePSP. Oral presentation at the 2015 American Association of Physics Teachers Winter Meeting, San Diego, CA.
Reconociendo las ideas de energía en estudiantes (Recognizing energy ideas in students). Alvarado, C. II Coloquio Internacional en la Enseñanza-aprendizaje de las Ciencias, Universidad de Guanajuato, Guanajuato, Mexico. November 2014.
Alvarado, C., & Wittmann, M.C. (2014) Entendimiento de Energía en profesores de nivel secundaria (K-12 teachers' understanding of energy). Oral presentation 2014 Annual Reunion of the American Association of Physics Teachers – México Chapter, Universidad de Guanajuato, Guanajuato, Mexico.

Studies of Teaching, Learning, and Professional Development in Chemistry at Middle School, High School, and University Levels

Teacher Professional Development using Iterative Inquiry-Based Chemistry Activities

<u>Researchers</u>
Mitchell Bruce, Clint Eaton, Stephanie Virgilio, Somnath Sinha, Laura Millay.

Research Subjects
Middle school Chemistry Teachers; 7th and 8th grade students

Focus of the project
In order to address the overall goal of the PSP to reform and vertically align science education in rural school districts, this chemistry project focused on improvement of teachers' instructional strategy with regards to scientific inquiry and subsequent learning gains of students. With regard to teachers, there was one week long intensive professional development workshop during summer (2014) besides other year round workshops. This particular project focused on the week long professional development of middle school science teachers during June, 2014. The overall goals of this project are: (i) to promote teachers' understanding of scientific inquiry, (ii) to enhance their skills of scientific communication, and (iii) to help teachers with instructional strategies in alignment with scientific inquiry.

As an extension of this above study and to gauge the impact of teachers' learning, we also looked on students' understanding of various scientific concepts. In that regard, we focused on two years of survey data from classes which followed the Science Education for Public Understanding Program (SEPUP) Chemistry curriculum. The purpose of this survey was to study the students' understanding of major Chemistry concepts and their misconceptions.

Project Dates
Teacher data: Started June, 2014 and is still ongoing.
Student data: 2013, 2014

Data collected
- Teacher Interviews, Teachers' clicker responses, Teachers' pre/post surveys, Teachers' poster presentation
- 7th and 8th grade student survey data (survey was aligned with SEPUP chemistry curriculum)

Findings
Teachers' understanding of scientific inquiry increased. Teachers increased their skill in scientific communication as evidenced by sophistication of posters they created.
One of the characteristic features of the professional development workshop – *iterative cycle* seemed to be contributing towards teachers' educational gains.
Significant student learning gains across multiple chemistry concepts were found. For example, with regards to 'conservation of mass,' 52% of the students answered with the correct response post instruction with an overall learning gain of 28%
Several persistent misconceptions were also identified. For example with regards to the 'conservation of mass,' one third of the student population selected a response that reflected a common misconception.

Next Steps

To investigate how the learning gains of these teachers get transformed into their classroom instruction by specifically observing their classroom instruction.
To investigate how teachers address a persistent misconception among students.

List of publications or presentations directly related to this project

Sinha, S., Eaton, C., Virgilio, S., Bruce, M. R. M., & Millay, L. A. (2015, February) *Teacher growth during chemistry professional development and middle school student learning of chemistry content through innovative science partnership in the Maine PSP.* Poster presented at the 2015 meeting of International Teacher-Scientist Partnership Conference. San Francisco, CA.

Bruce, M.R.M., Eaton, C., Bruce, A., Sinha, S., Millay, L.A., Haynes, B, & Kumpa, B. (2016 April) *Teacher Professional Development Using Iterative Inquiry- Based Chemistry Activities.* Present white paper at the 2016 meeting of National Association for Research in Science Teaching (NARST). Baltimore, MD.

Students' Understanding of Middle School SEPUP Chemistry Curriculum

Researchers

Stephanie Virgilio, Clint Eaton, Mitchell R. M. Bruce, Somnath Sinha, Laura Millay

Research Subjects

7th and 8th grade SEPUP Students from Rural Schools in Maine

Focus

A survey was developed and revised after a discussion with in-service teachers who participated in a week-long chemistry workshop. The goal was to align a survey with the Science Education for Public Understanding Program (SEPUP) Chemistry curriculum that studied the students' understanding of major Chemistry concepts and their misconceptions. Within the 13-question survey the major concepts covered were conservation of matter, structure and properties of matter, and chemical reactions.

Project Dates

The first iteration of the survey was distributed in the 2013-2014 academic year, which was then revised for the 2014-2015 academic year. The findings reported in this research are from the most recent survey data collection. This project is currently ongoing.

Data collected

A pre- and post-Chemistry-instruction 13-question survey focused on chemistry concepts included within the SEPUP curriculum with some classroom observations that included video and audio recordings.

Findings

The preliminary findings listed below reflect 250 7th and 8th grade students from 7 different teachers that completed both the pre and post surveys.

- Our students outperformed the reported AAAS and MOSART results for every question that we incorporated into the survey across multiple concepts including conservation of matter, structure and properties of matter, and chemical reactions
- Of the 10 multiple choice questions there were 7 questions with a learning gain above 25%
- When the questions provided more context and answer choices for the students they had more difficulty arriving at the correct answer and more of them retained the misconception

Some misconceptions that remained present in the student population:

- In the event that there is a biological decomposition in a closed system, the total mass decreases (Mitchell et al., 2009). 19% of students retained this misconception after instruction in Question #8
- Length, shape, and mass/weight are characteristic properties. 11% of students chose the misconception before and after instruction in Question #6
- Small objects float, possibly with the belief that the smaller piece will weigh less and therefore float (MOSART, 2007). Only 3% of students stuck with this misconception in Question #12
- When there is a formation of gas after the mixture of substances a chemical reaction has not taken place (MOSART, 2007). 28% of students answered with the misconception before and after instruction in Question #11; this was one of the highest percentages and one of the more difficult problems students encountered

Next Steps

The next steps in this project is to take a more in depth look at the written responses and also the implications that our findings have on the curriculum, students' understanding of chemistry concepts, and teaching methods.

Figures and Tables

Examples of data analysis of chemistry survey questions are below:

Question 2: Is there evidence that a chemical reaction has occurred?

Answer Choices	SEPUP Survey 2014-2015	
	Pre-Instruction	Post Instruction
A. No, because there was no color change when the polyvinyl alcohol and sodium borate were mixed to form slime.	7%	9%
B. Yes, because the volumes are different.	22%	13%
C. Yes, because the denisty and ease of pouring Slime are different than the polyvinyl alcohol and sodium borate.	54%	63%
D. There is not enough information	15%	15%
No Response	2%	0%

Normalized Learning Gain: 20%

Question 4: Choose the correct response: Which statement describes the molecules of a gas?

Answer Choices	SEPUP Survey 2014-2015		AAAS Results
	Pre-Instruction	Post Instruction	Grades 6-8
A. The molecules are soft.	5%	2%	11%
B. The molecules do not move.	5%	5%	8%
C. The molecules are far apart from one another.	63%	80%	61%
D. The molecules are often in contact with one another.	27%	12%	19%
No Response	0%	1%	

Normalized Learning Gain: 45%

The Influence of a Multi-Modal Exercise on Conceptual Problem Solving in Chemistry

Researchers working on this project
Dr. Mitchell Bruce, Samantha Dunton, Clint Eaton, Stephanie Virgilio.

Research Subjects
Undergraduate General Chemistry Course Students

Focus
We were looking at the effect of an interactive learning environment on problem-solving. While exploring this, we began to explore the effects of multiple modes within students' free responses.

Project Dates
Data collection occurred Spring 2014, analysis of the data occurred Summer 2015, and writing of the results is ongoing.

Data collected
Tests (multiple choice, free response, clicker data).

Findings
When comparing the group of students that answered all stages of questioning there were in fact high normalized learning gains. This suggests that an interactive classroom environment is beneficial for student learning. Within students' free responses, there was an interesting trend. We found that out of 63 students that used one mode to respond to Q3, only 28 students were successful (44%). Out of the 41 students who responded with 2 or more modes, 38 students were able to reach a correct answer (93%). This suggests the more modes a student has included within the response, the more likely the response was correct.

Next Steps
We are in the process of writing up the research for publication.

Publications/Presentations
Sam Dunton's SURA presentation (Summer 2014); Dr. Bruce's FIG presentation at Maine PSP summit (Fall 2014).

Research in Community and Leadership

Study of teacher community structure through social network analysis (Grade 6-9 science teachers)

This study is a multi-year, longitudinal, social network analysis of changes in the structure of the cross-system, multi-district teacher community that the MainePSP developed over the course of the project. The research focuses on the development of social capital--what Michael Fullan (Fullan, 2005) refers to as "lateral capacity"—that might serve to sustain the community beyond the end of funding. It investigates how program design and governance impact creation of social capital.

<u>Researchers</u>
Bill Zoellick

<u>Project Dates</u>
July, 2015 – June, 2016 (this year); July, 2010 – June, 2016 (overall).

<u>Data collected</u>
Primarily, responses to an annual survey of teacher advice-seeking serve as the basis for social network analysis. The social network analysis is supported by an analysis of notes and minutes from meetings, a survey of teacher concerns, and interviews with teachers that assist in analysis of the drivers behind changes in network structure. Mr. Zoellick has continued to collect social network data for the year ending in 2015 and for the current school year. These data may be useful for a future analysis of community structure beyond the end of full-scale program funding and operation.

<u>Findings and Outcomes</u>
As reported last year, the social network analysis of the MainePSP community indicated that, over the first three years of the project, there was a steady decrease in lateral capacity, which is the social capital that ties the cross-system community together. Then, in the fourth year, lateral capacity rebounded. Analysis of social network and other data suggested that this rebound was not inevitable, but was likely due to actions taken by the program's leadership. These findings were presented in a conference paper in 2015 (Zoellick, 2015).

During the current reporting year (July, 2015 – present) Mr. Zoellick has focused primarily on preparing these findings and analyses for peer-reviewed publication. A paper titled, "Sustaining Educational Improvement: A Framework for Study of Cross-System Networks and Lateral Capacity" was submitted to the *Journal of Educational Change* during the fall of 2015. In the course of peer review, it has gone through two revisions that have sharpened the theoretical focus and general applicability of the work. The most recent editorial feedback, received in early June, 2016, is, "I would like to reiterate that you've done solid empirical work, with fine methodology and review of the network literature to back it up. We'd now like to ask you to stretch your thinking a bit further, perhaps exploring some of the broader sociological theories of networks that have been advanced in recent years, to build in a more critical conclusion." Mr. Zoellick agrees with the editors that the article could usefully support a more critical view of Fullan's thinking about cross-system networks and lateral capacity and so will revise the article to include such critique and its implications for thinking about program sustainability.

Next Steps

In the near term, Mr. Zoellick will complete the revision of the article that is currently in review to incorporate more attention to extending theoretical foundations for sustainability of systems that work across multiple systems. In the longer term, inspect and consider data regarding community structure over time.

Publications

As noted above, a publication emerging from this work is in the later stages of peer review and may be published over the coming year.

References

Fullan, M. (2005). Leadership and Sustainability: System Thinkers in Action. Thousand Oaks, CA: Corwin Press.

Zoellick, B. (2015). Teacher Community Structure and Rural Science Education Reform. Presented at the NARST Annual International Conference, Chicago, IL, April 11-14, 2015.

Study of teacher leadership (Grade 6-9 science teachers)

This study examines the development of teacher leadership as teachers participated in a leadership academy developed and offered by the MainePSP and as they participated in the overall MainePSP program. Because the MainePSP provided an organizational structure that parallels and complements the organizational structures within the participating teachers' schools, it provided an opportunity to examine the emergence of teacher leadership that reflects the teachers' own views and concerns rather than leadership in service of a school's administrative priorities.

Questions about how this form of teacher leadership emerges and how it functions are important because: (1) in the rural schools that are the focus of the MainePSP there is a high level of administrative turnover, with the consequence that teachers sometimes emerge as a source of continuity in support of improvement; (2) in many schools, improvement of science teaching and learning is not a key administrative priority, with the consequence that improvement depends on a teacher's collaborative pursuit of their own improvement goals; and (3) as the professionals who are in closest contact with students and the day-to-day constraints and opportunities in classrooms, teachers' understandings of priorities are sometimes in tension with the perspectives driven by school administrators.

The question of how teacher leadership develops and acts independently of administrative directives is under-studied and under-theorized. The present study contributes to addressing the need for better understanding of teacher leadership as an expression of teacher concerns and beliefs.

<u>Researchers</u>
Bill Zoellick. Somnath Sinha (previous reporting period)

<u>Project Dates</u>
Ongoing after start of Leadership Academy in April, 2013. For this period, July, 2015 – June, 2016.

<u>Data collected</u>
Data were collected through interviews with teachers and observations of teacher interactions. The research uses data collected the previous year, consisting of 40 interviews, totaling 22 hours, with the eleven teachers in the second cohort of the MainePSP leadership Academy. These data were supplemented by additional interviews during the current reporting period with four teachers who emerged as case studies that are particularly relevant to the research questions.

<u>Findings</u>
The data provide evidence that the science teachers in this study do act as leaders to engage other teachers in pursuit of concerns and objectives of their own, apart from priorities set by school administrators. The evidence also suggests that the teachers use administrative support strategically, when it is consistent with the teachers' objectives. Mr. Zoellick has found that analyzing these phenomena through a theoretical frame that attends to power relationships (Clegg, Courpasson, & Phillips, 2006; Foucault, 1978; 1982; Hardy & Clegg, 2006; Heller, 1996) rather than just as leadership--which is typically interpreted as action in service of administrative objectives (Donaldson et al., 2008; Johnson & Donaldson, 2007)--opens new perspectives on the interactions. In particular, such analysis suggests that the dynamics of change should be analyzed from the teachers' viewpoints as well as from the administrator's viewpoint, which is the more traditional perspective. Such a shift in viewpoint appears to be useful not just from a research perspective, but also from an implementation perspective, suggesting that administrators might usefully attend to teachers' perspectives as a legitimate, important source of power or, alternatively, of resistance.

Mr. Zoellick presented an early version of these findings, focused more on the empirical results and less on the theoretical implications, at the 2016 AERA conference (Zoellick & Sinha, 2016).

Next Steps

The presentation at AERA provided an opportunity for interaction with colleagues that deepened Mr. Zoellick's thinking about the theoretical implications of the findings. The next step is to write a theoretically focused paper that uses the empirical work to argue for a more teacher-centered perspective on teacher leadership. Mr. Zoellick will propose such a paper for presentation at AERA in 2017 and will also, before next spring's AERA, prepare an article that summarizes this work for peer-reviewed journal submission.

Presentation

Zoellick, B., & Sinha, S. (2016). Teachers, Leadership, Collaboration, and Power. Presented at the Annual Meeting of the American Education Research Association, Washington, D.C.

References

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Donaldson, M. L., Johnson, S. M., Kirkpatrick, C. L., Marinell, W., Steele, J., & Szczesiul, S. A. (2008). Angling for Access, Bartering for Change: How Second-Stage Teachers Experience Differentiated Roles in Schools. *Teachers College Record*, *110*(5), 1088–1114.

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Research Completed Prior to 2015-16

Paying Attention to Theory in Science Classroom Argumentation (K-12 Teachers)

This study examined teachers' knowledge of the role of theory in scientific arguments and growth in knowledge through professional development in argumentation.

Researchers

Gurschick, Shemwell, Capps, Avargil, Meyer

Project Dates

Fall 2012-2015

Data Collected
Data collected included video, audio, and artifacts from teacher professional development activities over a five-month period.

Findings
Impetus for the project came from examination of student work by Capps and Shemwell, and noticing a lack of generalization to theory from observations. Initial video, audio, and artifacts collected during Phase 1 provided baseline data on teachers' knowledge in argumentation, showing that in general the teachers did not make generalized claims, but rather made localized claims based on observations. During Phase 2, a worksheet was introduced into professional development that guided the teachers to generalize claims based on observed evidence. Analysis of data collected during Phase 2 indicated that through use of the worksheet, teachers began to construct more generalized claims. During Phase 3 teachers piloted the worksheet in their classrooms, classroom observations were conducted and student work collected, and teacher PD included analysis of student work. Findings from data analysis of Phase 3 showed that, although teachers were constructing more generalized arguments in their own work, they were less able to identify differences between student work with higher or lower levels of connection to theory. Overall findings of the research showed that with the curriculum modification (a scaffolded argumentation worksheet) teachers' understanding of how to generalize claims increased. They included more theory in their own arguments, and they began to think generatively about why and how to support students in theory construction in argumentation.

Outcomes
This work was published in a journal article last year.

Evidence Construction in a Field Geology Environment (K-12, SEPUP Teachers)

This study examines how aspects of scientific practices (e.g. modeling, evidence construction, argumentation, etc.) support learning in a field geology environment.

Researchers
Lauren Barth-Cohen, Daniel Capps, Jonathan Shemwell

Project Dates
Data collection started in June 2013 at summer academy and there is ongoing analysis of the 2013 data. Data was collected at the 2014 Summer Academy.

Data collected

Video, audio, drawings, and survey's from teachers at summer academy

Findings

Evidence is key to many scientific practices including argumentation, explanation, and modeling. For learners engaged in scientific practices, often we aim for them to construct scientific evidence from observations in the world, but the details of how learners go from observation to verbal accounts of evidence in support of a claim in a complex environment has been overlooked. Here we argue that much can be learned about scientific practices from examining how evidence is constructed from human sensory data while interacting with an environment. Using theoretical machinery from coordination class theory we model the evidence construction activity, specifically how observations as connected with prior knowledge turn into evidence for a claim. Using this model we illuminate one case of a middle school earth science teacher constructing evidence as part of a professional development workshop. The focal teacher constructed evidence to support a claim about the relative ages of two rocks(granite and basalt) and she attempted to construct hypothetical evidence for an alternative claim. We describe how her observations connected with her prior knowledge to turn into evidence to support both her initial claim and the alternative claim. We also argue that for her this process of evidence construction led to some learning. The contribution of this work is to highlight the evidence construction process as an important aspect of scientific practices and as supportive of learning.

Next Steps

This work has been published in ICLS conference proceedings.

Papers, Presentations, and Abstracts

Barth-Cohen, L., Shemwell, J. & Capps, D. (2014). Learners' Intuitions about Geology*. To be presented at the International Conference of the Learning Sciences: Learning and Becoming in Practice. (ICLS, 2014).* Boulder, Colorado, USA / ISLS

> Many principles in geology are intuitive to geologists who already understand those principles, but little is known about learners' intuitions in geology. We apply existing theoretical machinery about learners' intuitions in physics to learners' intuitions in geology, and we present several examples of geology intuitions from teachers' reasoning about relative age relationships during field instruction. Implications are discussed for how to productively harness learners' intuitions in geoscience education.

Barth-Cohen, L., Capps, D. & Shemwell, J. (2014). Modeling the Construction of Evidence Through

Prior Knowledge and Observations from the Real World*. To be presented at the International*

Conference of the Learning Sciences: Learning and Becoming in Practice. (ICLS, 2014). Boulder,
Colorado, USA / ISLS

Evidence is key to many scientific practices including argumentation. For learners engaged in scientific practices, we aim for them to recognize scientific evidence from observations in the natural world. Here, we provide an early depiction of evidence construction, namely how evidence is constructed from one's prior knowledge and one's observations. We illuminate instances of teachers constructing evidence while engaged in a professional development workshop where they are tasked to reconstruct the geological history of a national park. We illustrate four cases, some of which involve the successful construction of evidence and some of which involve embedded challenges with constructing evidence, such as difficulties with background knowledge and individuals "seeing" different information in the same phenomena. This analysis illustrates the role of prior knowledge in scientific practices that rely on evidence construction in field-based complex environments.

There was also an honors thesis by Jean Stevens that was completed in May 2014 within this project. The title of her thesis is: SITUATIONAL INTEREST IN PROFESSIONAL DEVELOPMENT. Lauren Barth-Cohen was the thesis advisor and Dan Capps was the co-advisor.

In this case study we look at three cases of situational interest during a teacher professional development workshop. The cases were selected because they illustrate events where multiple teachers exhibited spontaneous interest in a geologic feature or phenomena. This research was conducted at a three-day professional development workshop on the seashore in the northeastern part of the United States. The professional development involved 17 middle school teachers who spent the three days at three different locations learning about the geologic history at those locations. In this study, we express the signs of interest shown by the teachers in each case and then compare and contrast the commonalities in the cases themselves. The study ends with a list of implications for future professional development to increase situational interest

Barth-Cohen, L., Capps, D., Shemwell, J. (2014, April). Profiles in Learning by Argumentation. Poster presented at the National Association of Research in Science Teacher (NARST) 2014 Annual Conference, Pittsburg PA.

Capps, D., Shemwell, J. Barth-Cohen, L. Avargil, S. (2014, April). From using models to developing models: Professional development that pushes on teacher thinking. Paper presented at the National Association of Research in Science Teacher (NARST) 2014 Annual Conference, Pittsburg PA.

Stevens, J. Barth-Cohen L., Capps, D. (2014, April). Capturing Teachers Engagement with Scientific Modeling. Paper presented at the National Association of Research in Science Teacher (NARST) 2014 Annual Conference, Pittsburg PA.

Barth-Cohen L., Shemwell, J. T., Capps, D. K. (2013, October). Using the Knowledge in Pieces to Understand Teachers Productive Knowledge in the Field. The Geological Society of America (GSA) 125th Annual Meeting, Denver, Colorado

Findings from Work to Identify and Support Struggling Students in Introductory Biology (Undergraduate Students)

During the 2012-2013 academic year, 3 sections of introductory biology students were identified as potentially "struggling students" at risk for low grades or for dropping the course by a low first exam grade. These 3 subsets of potentially struggling students (n=310) were offered one of three help options - either the normal university resources (no additional help); weekly sessions facilitated by Maine Learning Assistants (MLAs) to go through problems and help with homework; or a one-time help session with the course instructor. Students' help-seeking behaviors were analyzed, along with work habits and course grades, as part of a statistical analysis. The researchers found a significant difference among students who participated in the interventions offered and those who were invited to participate, yet declined and never sought out extracurricular help of any kind (ANOVA, $p<0.0001$, $CI=0.031\pm0.07$). Students who declined participation showed a negative improvement score, indicating that they never recovered from the first initial low score and continued to decline. However, there were no significant differences in grade improvements among the remaining groups of students (those who sought some type of help on their own such as university tutoring, those who participated in MLA help, those who participated in instructor help) who participated in the interventions. Researchers attribute this finding in part to inconsistent training for MLAs and to overall low participation in the help sessions, and plan to increase support and professional development for the MLAs who run the help sessions and find ways to increase student participation in the offered help.

Another aspect of the analysis looked at the reliability of first exam grade as a predictor of struggling students, and found that improvements could be made in identifying students who truly are struggling. Refinements are being worked out and will be tested in the coming year. Finally, the researchers found that students who chose to attend the offered help sessions did better than their peers who did not seek help, and as well as the high-achieving students in the class on effort-based elements of their course work, such as lab reports, in-class clicker questions, and homework. However, the help sessions did not seem to help them improve their exam grades, suggesting a need for more help with rigorous content. This finding will be incorporated into the new help sessions in the coming year.

This work was presented with a poster at the 2013 National Meeting of the Society for the Advancement of Biology Education Research, and is written up as a completed Master's thesis by Zachary Batz. The work is now a published journal article.