CREATING AUTHENTIC AND RELEVANT SCIENCE CURRICULUM THROUGH PROJECT-BASED LEARNING

by

Brooke K. Laundon

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ABSTRACT

The focus of this project was to examine the effects of project-based learning on relevant and authentic science content, student collaboration, student self-regulate learning (SRL), and how the role of the teacher changed with project-based learning implementation. Traditional science teaching often asks students to be passive participants in their own learning. By learning through project-based learning students had the opportunity to construct their own learning of Newtonian physics by exploring the driving question, how can we, as museum designers, plan an exhibit that demonstrates Newton's Laws in urban design? To accomplish this task students, over a three-month period, explored the concepts related to each of the laws of motion and for each law created a working exhibit that connected the law to an urban design feature found in New York City. Students participated in labs, read books on urban design and engineering, visited museums, prototyped their exhibits and learned from experts in the field on urban engineering and museum design. Through the analysis of data collected, I was able to determine that students felt connected to their city and saw the applicability of physics in the real world. Students effectively collaborated throughout the unit, their SRL improved over the course of study, and the teacher was of more of a guide in the learning process than a lecturer.

INTRODUCTION AND BACKGROUND

As an independent school teacher one of the challenges I've faced is the lack of actual training and education I've had in my profession. I'm currently in my 11th year of teaching at independent schools, and before working towards my Masters of Science in Science Education at Montana State University (MSU) in the fall of 2012, I'd never taken any education classes. Like many teachers I'd always taught similarly to my favorite teachers, which was in a more traditional classroom where the teacher is the expert, often driving classroom discussions, and teaching students through lectures, question and answer sessions, and using summative assessments like tests to measure student understanding - the methodology wasn't creative and neither was the content. The process of teaching this way had become uninspiring because it lacked creativity and authenticity – students weren't learning science in a way that affected their daily lives. Additionally, I didn't feel as though I was teaching students skills that were useful for the 21st century and they weren't always engaged in their own learning. As I reflected on my teaching I realized that I wanted to push the boundaries of what it meant for students to learn, what it meant to be a teacher, and to work and learn along with students. I wanted students to develop critical thinking, problem solving, and collaboration skills, and for students to be engaged in authentic scientific issues driven by relevant issues in our world. In 2013 two things happened that helped me actualize my education and teaching goals.

The first was that the school I work at, the Berkeley Carroll School (BCS) in Brooklyn, NY, started to make monumental changes and address innovations in their pedagogy philosophy. The administrators at BCS wanted students to learn in a way that was more in line with the school's recently adopted mission:

> A passion for learning is at the heart of Berkeley Carroll. The school is a creative and intellectual community where devoted teachers challenge and engage talented students. Our demanding curriculum and vibrant civic life prepare our diverse graduates for success in college and for the greater endeavor - a life of critical, ethical, and global thinking (Berkeley Carroll School, n.d).

In order to develop students as "critical, ethical, and global" thinkers, teachers need to develop ways of teaching that are more in line with 21st century skills. Project Based Learning (PBL) is one such methodology that BCS started to examine and eventually implemented training for teachers to address pedagogical changes. Because I was frustrated with the more traditional ways of teaching and learning about inquiry-based teaching practices through my graduate program, I volunteered to receive training in PBL by Tim Kubik, a consultant with the Buck Institute for Education (BIE) and World Leadership School, which is one of the leading organizations in project-based education, to discuss and implement changes to my curriculum. Through working with Tim and under his tutelage I was able to convert units within the 8th grade curriculum to PBL and make small changes to the 7th grade curriculum that aligned with my education goals.

The second thing that helped me address how to teach a more authentic curriculum was the development of my action research-based classroom project at MSU, where I decided to focus my project on PBL. The combination of working with Tim and reading articles about PBL and writing about PBL for graduate school forced me to dive into the world of PBL research and implementation. Learning about and developing PBL curriculum was and continues to be challenging, but through the transition I can sense the ownership that students have over their own learning and their increased interest in their education. As a teacher, I feel like I'm learning with the students instead of being the expert, which has reinvigorated my interest in the profession. Conversations that I've had with other teachers in my department have prompted changes in their thinking, and they've also started to redesign units that have underlining principles of PBL. I think inquiry-based and a more student-driven curriculum is where education needs to move as our world becomes more connected. Skills like collaboration, critical thinking, use of technology, creativity, and communication are essential to a successful project-based unit and also essential to what students need as they move into adulthood in the 21^{st} century. In order to tackle some of the challenges that face our world like poverty, education for all, and environmental sustainability people, from around the world need to be able to work together to come up with creative and innovative solutions. The only way to do this is to teach students (and teachers) how to think differently and to be a source for their own learning – to teach relevant and authentic curriculum. I believe that PBL is a way to do that, and I'm proud and inspired by the work that I'm doing. I know my students and colleagues can feel the effects of that passion.

As I developed my action research-based classroom project I reworked my research questions several times to align them more closely with my goals as a teacher. I shifted the focus to questions that, in the spring of 2014 focused on students' academic performance, to questions that focused on curriculum design and student motivation. Therefore, with those goals in mind my primary research question for the project is: How does project-based learning teach students about relevant and authentic science content? My sub-questions are: What are the effects of PBL on student collaboration? How does PBL affect self-regulated learning (SRL)? What is the role of the teacher with the implementation of PBL?

CONCEPTUAL FRAMEWORK

A classroom where the teacher is the expert, the students listen to a lecture-based lesson, and the teacher drives content and context is the old way of teaching. Yet this type of pedagogy still exists today and doesn't connect learning to everyday life, which ultimately effects student recall and understanding (Marx, Blumenfeld, Krajcik, & Soloway, 1997). A new way of teaching is needed that educates the whole child and prepares students with skills that they'll need as they move toward adulthood in the 21st century and promotes meaningful understanding. Students need to be active members in constructing their own knowledge and have a reason to learn new information (Kanter, 2010). PBL is a teaching method that engages students in relevant and authentic investigations where students learn content and skills over extended periods of time in response to a complex real-world question, problem, or challenge (Buck Institute for Education, n.d., Kanter, 2010). This type of methodology creates a demand for students to gain knowledge, gets them excited about learning, and improves meaningful understanding.

Meaningful understanding allows students to make more sense of what they are learning and apply new knowledge to new situations in authentic ways. There are reforms specifically in science standards that are asking students to do this. Current research shows that social context plays a large role in learning and memory and that students need to be able to attach new information to what they already know, which builds connection between concepts and makes learning more relevant (Marx et al., 1997). This new knowledge growth depends on existing knowledge and beliefs, understanding that knowing and doing cannot be separated, communication of knowledge matters, social interactions, and the use of technology (Marx et al., 1997). What this means is that there has to be changes in instructional programs that are based on constructivism where students build their own understanding (Marx et al., 1997), which makes the learning more authentic. Because PBL asks students to be active participants in their own learning when engaged in relevant projects where they've constructed much of their own learning, students have a greater understanding of new knowledge than students in a more traditional classroom. For example, in a study of 131 students in their second term in an Executive MBA program, Capone & Kuhn (2004) wanted to demonstrate specific outcomes of PBL that were directly linked to instruction and understanding and if the mechanism behind a teaching methodology based in the constructivism ways of Piaget and Dewey were superior to more passive ways of learning. The authors believed that PBL is an active way of learning, which activates a mental mode that's responsible for superior acquisition, recall, and integration of new material. Results from the study show that there wasn't a difference between the groups with acquisition and recall. However, integration, student understanding, and sense-making was stronger for the PBL unit. The conclusion of the study was that students taught through a more student-centered PBL approach were better able to apply this new information to other situations (Capone & Kuhn, 2004).

The ability to use new information and newly acquired skills outside of the classroom is essential in the 21st century and just one of the benefits of a successful PBL unit. With the application of new information and skills towards real-world and complex problems, the results are meaningful understanding that allows students to make more sense of the world. Kanter (2010) conducted a study during the 2002-2003 school year with 12 teachers and 652 6th, 7th, and 8th grade students to look at project-based science design and explore ways that design can promote more consistent meaningful understanding. For the study Kanter (2010) created a pre- and post- unit test designed to evaluate three levels of cognitive difficulty based on Bloom's Taxonomy. Level 1 questions tested students' ability to remember, as evidence that they learned the content. Level 2 questions tested students' ability to understand and apply information to similar situations that they learned in class, as evidence that deeper learning took place than revealed by Level 1 questions. Level 3 questions asked students to apply new knowledge to a new context and analyze and evaluate, as evidence of meaningful understanding. Results of the study indicate that in the design there were gains in meaningful understanding, which were 2.2 times the Bloom value and effect size (ES) = 0.51. The ability to apply newly learned information to a new context supports the idea that PBL teaches students skills that are relevant to the 21st century. However, student self-regulated learning (SRL) is needed for students to acquire new understanding and apply it elsewhere.

English & Kitsantas (2013) looked at a structural design of PBL that made a connection between PBL and SRL. SRL requires metacognition, motivation, and active participants and SRL students are able to set goals, plan a course of action, select appropriate strategies, self-monitor and self-evaluate their learning and performance. SRL must be present for PBL to be successful but teachers need to scaffold activities so students can build SRL skills. In their study, English & Kitsantas (2013) examined three phases of PBL and connected SRL skills to each of those phases. The first PBL phase was the launch of the problem or project. This included outlining a strong driving question that provided structure to the project, clearly stated learning goals, and launcher activities. SRL skills attached to this phase were goal-setting, strategic planning, and self-motivation. The second PBL phase was the inquiry and product/solution creation phase, which made student learning visible through white-boarding, formative assessment, journaling, and prompts for explanation. In this phase the teacher acted as a guide, encouraged students to ask for help, created reflection prompts and opportunities for revision, and provided instruction when student knowledge was lacking. In this phase the SRL goals were self-control and self-observation. The last phase outlined by English & Kitsantas (2013) was the conclusion phase where students held presentations, took part in role-plays, had poster and pin-up sessions, and gallery walks. For this last phase the SRL goals were student reflections on learning outcomes, strategies and resources that worked well or not well, and examinations of any unanswered questions. The connection between the three phases of PBL and the different SRL needed at each stage helped me develop the PBL outline and timeline of activities and assignments for the students. This study also prompted me to think deeply about the skills needed to complete a successful project and the importance of student skill acquisition.

If students are self-regulated learners then there is a greater possibility that the role of the teacher can change to develop into a more supportive role than the person with all the answers. Hixson, Ravitz, and Whisman (2012) conducted a study in West Virginia examining the role of the teacher and to assess whether PBL-trained teachers reported that they teach 21st century skills more than other teachers and what, if any, value is added by teaching PBL compared to more traditional and incidental instruction. The treatment population for the study was 42 teachers who had participated in a weeklong PBL training and the comparison group was 42 teachers from the same school district and programmatic level as the treatment group and coded as classroom teachers but didn't receive PBL training. To answer the first research question teachers were given a survey that asked about PBL use and teaching practices related to 21st century skills defined as critical thinking, collaboration, communication, creativity, innovation, self-direction, global connections, local connections, and use of technology as a tool for learning. The results of the self-survey showed that PBL teachers taught 21st century skills to a greater extent, specifically collaboration and critical thinking skills, they thought their students were taught what they needed to know for standardized tests, that students could apply new information to new tasks and situations, and that their students worked just as hard, were as well prepared, and learned as much as students in a more traditional classroom. To answer the second research question test scores from 821 PBL students and 821 non-PBL students were compared. The results showed that there were no significant knowledge gains in math, English, science, or social studies. This study shows that teachers that are trained in PBL are more likely to prepare students with 21st century skills and that PBL students are at no disadvantage in standardized test-prep. The results from this study impact my study in two specific ways. The first is that I'm examining PBL as a means of teaching relevant curriculum and I would argue that teaching 21st century skills are relevant. Secondly, I'm interested in seeing how PBL changes my role as a teacher and the results from this study suggest that teachers that are trained in PBL, which I am, are more likely to prepare students with the skills such as critical thinking and collaboration.

Even if a teacher has been trained in PBL there are challenges that exist with PBL design that can affect the amount of meaningful understanding for students. The Buck Institute for Education (n.d) outlines essential elements of PBL as significant content, 21st century competencies, in-depth inquiry, a driving question, a need to know for students, voice and choice among the students, revision and reflection, and a public audience that displays student work. Many PBL design approaches include the elements above however, there are other important elements to consider when designing a PBL unit. PBL units need to provide structure and guidance to students while also allowing a certain amount of freedom of choice. High Tech Middle, which is part of the High Tech Charter School organization in the San Diego, CA area, believes that "the consistent use of PBL grounded in the six A's of project design results in high levels of student engagement, innovative and responsive teaching practices, and a school community that is dedicated to learning" (Lattimer and Riordan, 2011, p. 22). The six A's of design are academic rigor, authenticity of the project, applied learning, active exploration, adult connections, and an action proposal. Lattimer & Riordan (2011) found that when PBL is designed in this structured manner there are positive teacher-student relationships clearly seen around school, impressive student work is displayed on the walls, and confident, poised students are proud to be members of the school community. PBL units are challenging to design and having a roadmap to work from such as the six A's of design is helpful. As I designed my PBL for this project I kept the six A's of project design in mind in order to develop an engaging project that motivated students.

There are additional challenges that exist outside of project design. For PBL to be effective teachers need to move away from the old ways of teaching and students need to understand a new way of learning. Teachers need training and professional development in order to learn how to teach PBL, and they also need to learn how to manage a different classroom because PBL encourages more freedom and talking from the students. Additionally, more time is needed for students to conduct in-depth investigations, students and teachers alike need to be comfortable with technology and challenges that arise with formative assessment and trying to measure student understanding, and teachers need to become comfortable with allowing students to grapple with information (Marx et al., 1997). Most teachers tend to focus on small changes in the classroom driven out of one of the above needs. For example, a teacher may want to include more technology in the classroom or have students working together more. Teachers tend to start with small changes and then work towards including all the other changes and this sometimes causes teachers to become novices once again (Marx et al., 1997), which can be overwhelming for any teacher. To tackle some of these challenges strong professional development and training is needed. Challenges of fostering change through professional development is aided by **CEER**; **C**ollaboration among teachers, administration, consultants, and other important constituents; **E**nactment in the classroom where teachers must try new things; **E**xtended effort because change takes a long time, possibly several years, and; **R**eflection, which can be both private and public acts (Marx et al., 1997). Additionally, the school can support teachers by making change an ethos that is valued, allow time for planning and collaboration, and having block scheduling (Marx et al., 1997). While the challenges of converting to a PBL curriculum are real and substantial, the benefits for student learning and meaningful understanding are tremendous. I've had to keep reminding myself of the above so that I don't get frustrated with the challenges of trying something new in my classroom.

The literature on PBL supports the idea that through this type of teaching students will be more prepared for the 21st century workplace. PBL engages students in activities that build confidence, teach responsibility, problem solving, and collaboration, develop communication skills, and promote creativity and innovation (Buck Institute for Education, n.d.). The old ways of teaching where students are told what to learn and often talked at rather than talked with, need to step aside for a classroom where students are active learners and are able to construct their own learning. Teachers are no longer the experts in their field and need to learn how to work together with students on projects that are rigorous and relevant in the real-world. PBL prepares students for standards that are focused on 21st century skills and meaningful understanding.

METHODOLOGY

The methodology for this action research-based classroom project focused on implementing a PBL unit where students were actively engaged in their own learning. The unit was designed to teach students about Newtonian physics so that they learned and recognized the principles of Newton's Three Laws of Motion and how the laws impact their daily life. I conducted my project during the second trimester of the school year, which ran from the December 1, 2014-March 10, 2015. The driving PBL question for the unit was, how can we, as museum designers, plan an exhibit that demonstrates Newton's Laws in urban design? The PBL Project Overview and Design (Appendix A) outlines the project in more detail, but the basic premise for the project was that in order for cities to be constructed and for their impact on the environment to be minimized, the laws of motion need to be understood and applied. During the project students learned a few ways that Newtonian physics intersects with urban engineering. For the entry event to the unit students brainstormed concepts that they thought related to physics and then watched the PBS documentary "American Experience: The World that Moses Built". Robert Moses built bridges, highways, Jones Beach, Lincoln Center and the United Nations in New York City. Moses' projects were some of the most ambitious and controversial public work projects ever conceived and changed the face of the city. Students watched the movie and wrote down aspects of the movie that they thought related to the physics words they had previously brainstormed. Common words that surfaced were movement of dirt and general construction, cars, trains, bridges, tunnels, and cranes. After a discussion about the movie and its connection to physics students first explored the concept of inertia and Newton's First Law of Motion through several activities, readings, and assignments, and then explored the Second and Third Laws of Motion together in the same manner as the First Law. After students had a solid understanding of each law they used books about urban design and NYC to pick an urban design feature that had a connection to Newton's Laws of Motion and designed a working model of that particular feature. For example, after learning about inertia and Newton's First Law of Motion a Ferris wheel, a train, and a rollercoaster were all built by different groups. For Newton's Second and Third Law of Motion an elevator, a cable car, and a boat were all built. For each design students also wrote an essay on how their structure connected to a particular law and how the structure impacted NYC. In addition to making the structure, students had to make place cards that explained the structure's connection to physics. After students' first structures were completed second grade students from BCS, who were learning about the history of transportation in NYC, visited with the students to test the structures. After students built their second structure, which connected to Newton's Second and Third Law of Motion combined, the students visited each other's structures to give feedback. Students also visited two science museums to learn what makes exhibits fun and interactive. Additionally, we had an author of one of the main books the students used to research their urban design feature come and speak with the students to teach them more about their city, and we also had a science museum design expert speak with the students about her line of work and what makes a good exhibit. After all the feedback students received about their projects they picked one of the projects they had designed and improved upon it for the final exhibit, which was a two hour pop-up museum where the BCS second graders, parents, and faculty interacted with the students structures and learned about physics and NYC.

The participants for this study were my two 8th grade science sections at BCS. BCS is a pre-K through 12 private school located in the affluent Brooklyn neighborhood of Park Slope. BCS's student body is 78% white, 11% black, 6% Asian, and 4% Hispanic (Berkeley Carroll School, n.d). In an attempt to increase the school's diversity the admissions team at BCS does community outreach and the school works with organizations such as Prep for Prep, The Oliver Program, The TEAK Fellowship, Boys' Club NYC, and The Breakthrough Collaborative. At present BCS does not provide for Supplemental Educational Services. Tuition for BCS middle school students enrolled for the 2014-2015 school year is $38,995 (Berkeley Carroll School, n.d). Students at BCS are highly motivated students with lots of parental and outside support.

Each 8th grade section had 15 students in the class for a total of 30 students of which 20 are female, 10 are male, there are three black students, one Asian student, and the remaining students are white. There is one female with a learning plan that is entitled to flexible scheduling and extended time on tests based on 504 accommodations. Additionally, there is one female student and two male students that have learning plans and receive extended time on tests not based on 504 accommodations. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix B).

Before the physics unit began and after it finished students completed the

Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) (Appendix C). The survey is a Likert-scaled instrument designed in the early 1980's by McKeachie and Pintrich to measure student motivation and self-regulated learning. Using a published instrument helped to insure validity and reliability. The final MSLQ was completed in 1990 and published for the first time in the Journal of Educational and Psychological Measurement (Pintrich, et. al, 1991) and has been used in numerous correlation studies. The original version of the MSLQ has 81 questions however, I didn't use the entire questionnaire and instead focused on the parts of the questionnaire that pertained to my study. Additionally, I changed some of the wording on the questionnaire to make sure the language was 8th grade appropriate and connected to my classroom strategies. In the "Motivation Section" of the questionnaire, students answered questions pertaining to intrinsic and extrinsic goal motivation, task value, and control of learning beliefs. In the learning strategies portion of the questionnaire students answered questions pertaining to elaboration, critical thinking, time and study environment, effort regulation, peer learning, and help seeking. For each sub-category listed above, students' scores were calculated based on a 7-point Likert scale, where 1 represented "not at all true of me" and 7 represented "very true of me". The average of items within a category made-up the score for that category. For example, there were five questions in the critical thinking portion of the questionnaire so a student's critical thinking score was calculated by finding the mean of those five questions. There were some questions on the MSLQ that were negatively worded and students' scores were reversed before the mean was determined. This means that, for example, a student's score of two within critical thinking was reversed and the score was six. Pintrich, et al. (1991) recommended subtracting the original score from 8 to get the student's score on a reversely worded question. What follows are explanations of each of these scaled categories.

- *Intrinsic goal motivation* refers to a student's perception about why they are participating in a task. A student's perception and motivation to do the work comes from a place of wanting to partake in a challenge, is curious, or has interest in mastery.
- *Extrinsic goal motivation* refers to a student's perception about why they are participating in a task in relation to grades and other types of evaluations by others. As opposed to the intrinsic motivation, the learning task in extrinsic motivation is the means to an end.
- *Task value* pertains to a student's interest, importance, and value they've placed on the learning task.
- *Control of learning beliefs* is the idea that a student has the ability to make positive changes in their performance based on effort. Outcomes are a result of personal drive rather than external factors.
- *Elaboration* is the ability for a student to build connections between concepts discussed in a learning task and is connected to long-term memory. Student strategies for elaboration connect new information with prior knowledge.
- *Critical thinking* is the application of newly acquired knowledge to new and unfamiliar situations.

- *Time and study environment* refers to a student's ability to manage their time well in order to complete a task and the environment in which they study.
- *Effort regulation* includes a student's ability to manage their control and focus on a learning task when there are outside distractions and uninteresting facts.
- *Peer learning* is another way of saying collaboration, which reflects a student's ability to work with others.
- *Help seeking* refers to a student's ability to know when to ask for help and to know who to ask when help is needed.

The items compromising the 10 MSLQ categories (Appendix D) outlines which questions in the survey relate to which of the categories above.

Students completed the questionnaire on their iPads through a Google Form before the unit began and on a computer through Google Forms after the unit. Students took the motivation part of the questionnaire on the first day of the unit and the last day of the unit and took the learning strategies part of the questionnaire on the day after they took the motivation part of the questionnaire. After students completed both sections of the questionnaire (pre-unit) I calculated their individual score for each scaled category, gave them back their results, and had them read the strategies for improving. I gave students back their category scores over several days and had them reflect in their science journals after each score. I wanted students to process the information, understand the purpose, and think about how to put the suggestions into action.

To collect quantitative data from the MSLQ I graphed the pre- and post-unit scores on the questionnaire to compare any individual change in SRL and also overall class change. I correlated individual student pre- and post- unit MSLQ scores with their first and second trimester grades, respectively, to determine if students with higher SRL scores performed better in science. Additionally, the MSLQ scores from the task value helped evaluate the ability of PBL to teach authentic and relevant science content while the peer-learning questions added to greater understanding about student collaboration. At the completion of the PBL unit students took a unit test (Appendix E), which was used to evaluate students' SRL and students completed a project self-reflection (Appendix F), which was used as qualitative data to assess the authenticity and relevancy of the unit.

In addition to using the MSLQ to evaluate the effect of PBL on student collaboration, I used a collaborative group checklist (Hendricks, 2013) (Appendix G) and individual student interviews (Appendix H) to collect both quantitative and qualitative data, respectively. Anytime students were collaborating I collected data by using the checklist. Individual student interviews were conducted outside of class time with five students after the completion of the unit. The student interviews provided information on student collaboration as well as student opinions regarding the relevancy and authenticity of the unit and my role as the teacher. In order to gain further insight into the relevancy and authenticity of the unit and my role as the teacher, and I wrote weekly journal reflections (Appendix I) and I videoed myself three times over the course of the unit to further reflect on my role as the teacher in a PBL unit.

All of the data instruments used throughout the unit are summarized in Table 1. There were several data sources for each research question in order to triangulate data for reasons of validity and credibility.

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Primary Question: 1. How does project-based learning (PBL) teach students about relevant and authentic science content?	Pre- and Post unit MSLQ	Student Project Self-Reflection (Post Unit)	Student interviews
Secondary Questions: 2. What are the effects of PBL on student collaboration?	Pre- and Post unit MSLQ	Collaboration observational checklists	Student interviews
3. How does PBL affect student self-regulated learning (SRL)	PBL Project Grade	Pre- and Post unit MSLQ	Physics Test
4. How does the role of the teacher change with the implementation of PBL?	Teacher video	Weekly reflection journal	Student interviews

Below is a timeline (Table 2) for the use of the instruments outlined in Table 1.

Table 2
Timeline of Instruments

Instrument	Date
MSLQ Survey (Pre-Unit)	Week of December 5
MSLQ Survey (Post-Unit)	Week of March 8
Student Self-Reflection	Week of February 22
Student Interviews	Week of March 2
Collaboration Checklist	Throughout entire unit
Teacher Journal Reflections	Once a week for entire unit
Video	Week of: December 20, January 20, February 20

DATA AND ANALYSIS

Using a project based learning approach, which incorporated a unit on Newtonian physics, allowed students to see the relevancy of physics in their daily life and connected them to the city they live it. Student collaboration was a major component of the project and students frequently worked with a group of students recognizing the importance of working with others in the learning process. Additionally, the project-based learning unit improved student SRL and the role of the teacher was seen as more of a guide then a purveyor of information.

Authenticity and Relevancy

I used three instruments to evaluate whether PBL teaches students relevant and authentic science content - the task value questions from the MSLQ, student project self-reflections, and student interviews.

In examining the data from the task value questions on the MLSQ there wasn't a large shift in student perspectives pre- and post-unit. Student pre-unit results averaged 5 on the 1-7 Likert scale and post-unit results were 5.2. A 0.2 difference is an increase in the value placed on the task but not a significant one. However, looking at individual student ratings 33% (*N*=10) of the students' task value scores went down from pre- to post-unit, whereas 67% (*N*=20) of the students' scores increased from pre- to post-unit. This is an indication that students' opinion on the value of what they were learning, which is associated with relevancy and authenticity, increased during the PBL unit.

Question 13 on the MSLQ is associated with task value and asked students to respond to the prompt, "I think the course material in this class is useful for me to learn."

The unit before the physics unit was not a PBL unit therefore, when students completed the pre-unit MSLQ their responses were in conjunction with a more traditional unit on climate change. A student that answered question 13 with a 4 on the pre-unit MSLQ wrote,

> I'm not sure how useful the course material is to me, because while knowing about global warming is important, I knew most of it already, and I don't ever see myself having a job or an interest that involves me using soil pH or the species in Jamaica Bay.

Post-unit the same student answered question 13 with a 6 and wrote, “I chose number 6 because I believe I can take what I learned from this unit, and apply it to other topics.” Other students that responded with a 6 or higher on the post-unit MSLQ wrote similar comments to these two students, “I think the material in this class is useful for me to learn because it can be applied in the real world” and “It is useful because physics is used in a number of different professions, and is very prevalent in the world at large.” Additionally, the student that had the largest increase (20%) in their motivation score from pre- to post unit wrote in response to question 13 pre-unit,

> Because there are times when I think to myself (and not just in this class, in other classes as well), why do I need to learn this? When am I going to use this in my daily life when I grow up? Why do I need to know how much force is exerted on an object or what nitrogen does for soil?

However, post-unit they wrote, “Because I can take what I learned in science and apply it to life, because if you think about it, we see what we learn in science pretty much anywhere and in everything.” This particular student struggled all fall to make sense of the material and engage with her classmates. During the PBL unit they came alive and performed beautifully with their peers and on all the assessments, and had a strong handle of the material – it was exciting to watch the shift.

However, students that responded on the post-unit survey in the 3-4 range on the Likert scale wrote similar comments to these two students, "I answered with a 4 because I think that urban design only matters for people that want to work in urban design" and "I'm not sure how useful the course material is, and I think it depends on what you want your career to be later in life." As the unit develops for next year, it will be important to address the concerns of the students that don't see the unit as relevant to their lives and try and make more connections between to the applicability of physics in the real-world.

In addition to the MSLQ students wrote a project self-reflection at the completion of the PBL unit and were asked to evaluate the most important thing they learned in the project. Thirty students completed the self-reflection and 67% (*N=20*) of the students wrote something similar to these students, "The most important thing I learned was how Newton's Law of Motions connect to real-life situations," "The most important thing learned was that physics is applied and important to everyday things, and if we didn't understand how motion worked, much of urban infrastructure would not be possible," and "The most important think I learned through this project is that everything on earth connects to Newton's Three Laws of Motion…even when it's not right in front of you." Additionally, during the five student interviews I conducted I asked students to reflect on how closely they thought the concepts they were learning about in physics related to the real world and the responses from all students (*N*=5) ranged from "very closely", "pretty closely", "it all applies to…literally everything moving", "really relates", and "it relates to the real-world so much because we see it every day in buildings, bridges, and cars". And when asked if it was important to connect science to everyday life 100% of the students said it was important to make those connections.

By participating in this project students were able to connect what they were learning in the classroom to the outside world and understand how physics impacts their city through urban design.

Self-Regulated Learning

In order for students to work as a scientist in authentic ways in the classroom and to learn about relevant topics, students need to be motivated and have learning strategies that allow them to examine real world problems in a meaningful way. A student with strong SRL is able to set goals, plan a course of action, select appropriate strategies, self-monitor and self-evaluate their learning performance (English & Kitsantas, 2013). A good PBL unit asks students to solve complex problems, think critically, analyze and evaluate information, work cooperatively, communicate effectively, and develop flexible thinking. SRL must be present for PBL to be successful and teachers need to scaffold activities so students can build SRL skills if they don't already have them.

Three instruments were used to evaluate how PBL affects SRL - pre- and post-unit MSLQ scores, student grades on the test for the non-PBL and PBL unit, and student grades on the first and last physics exhibit.

Figure 1 provides a simple overview of how students (*N*=30) rated themselves in the two scales that the 47 questions on the MSLQ measured – motivation and learning strategies.

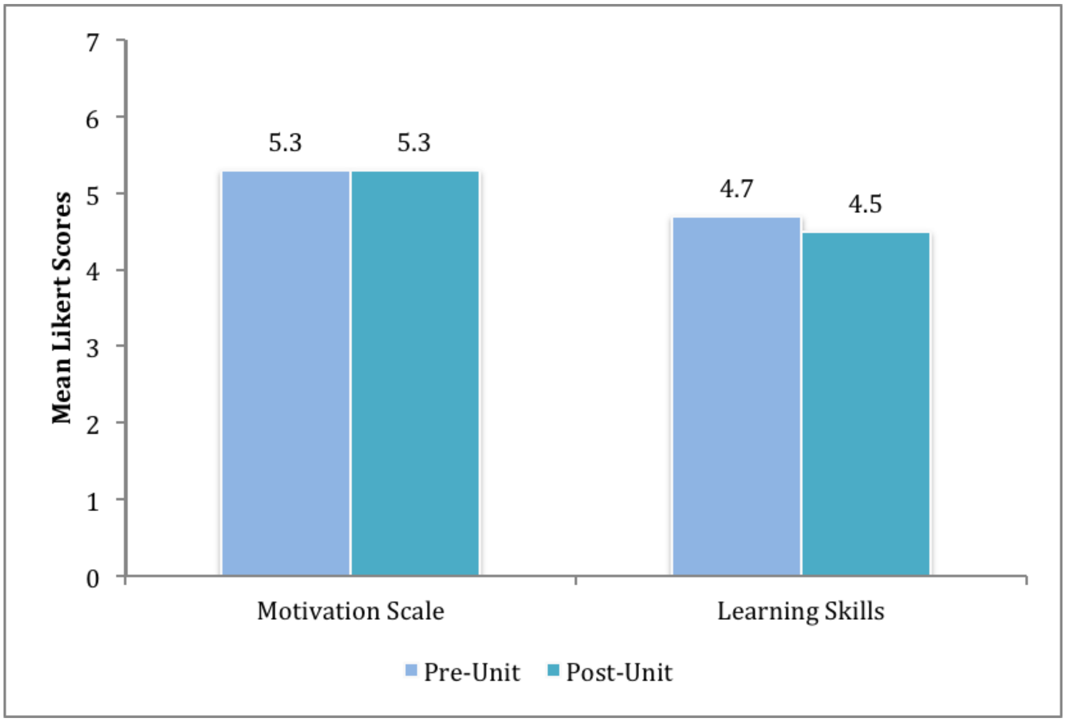


Figure 1. Pre- and Post-Unit mean scores of student responses to the two overarching themes of the MSLQ, motivation and learning strategies, (*N*=30).

For both the motivation and learning strategies scales the pre- and post-unit mean scores were on the higher end of the 1-7 Likert scale, 5.3 for motivation and an average 4.6 for learning strategies. Student scores on the motivation scale are slightly higher compared with scores on the learning strategies scale, which fits in with what I see in the classroom. There's not a significant difference in the scores (0.7) but I do notice in class that students are generally motivated learners, but don't always have the strategies to manage their work and effectively learn the material. In comparing the pre- and post-unit scores there isn't a difference in motivation and there is a 0.2 decrease from the pre-unit learning skills score to the post-unit learning skills score. Neither of these scores reflects a significant change.

Figure 2 breaks down the MSLQ into the 10-scaled categories.

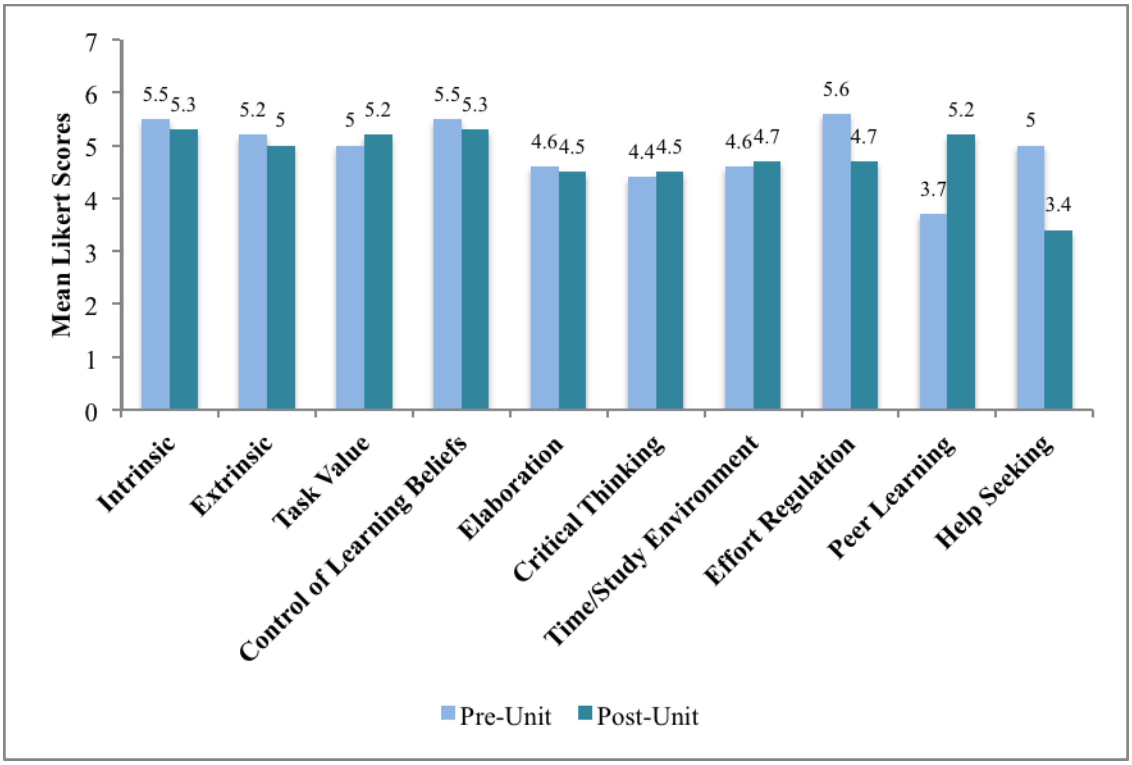


Figure 2. Pre- and post-unit mean scores of student responses to the 10-scaled categories on the MSLQ, (*N*=30).

On average, in all categories students identified themselves as having strong SRL skills - leaning more towards the 7 on the scale and the "very much like me" aspect of the survey. As I mentioned in my introduction, students at BCS are highly motivated students that want to do well and the data indicate this. As a teacher, I couldn't ask for anything more – students that want to work hard and have the ability to stay focused. This combination opens up endless opportunities for creative curriculum such as PBL.

Some of the more interesting results came when I looked at individual scores for specific questions on the survey. Question nine on the MSLQ survey, which is associated with intrinsic goal orientation asked, "I prefer course material that arouses my curiosity, even if it is difficult to learn." For this statement the average score was 6 for both the preand post-unit survey, which is an indication of how motivated the students at BCS are. When asked to elaborate on their answer a common answer from students that rated themselves a 6/7 was, “I answered that way because I enjoy being challenged in science and I want to learn about interesting and difficult topics rather than boring but easy topics” and “I (and most other people) enjoy learning about things that they find interesting. Even if I must push myself, it's worth it.” The student that had the largest drop in the motivation scale from pre- to post-unit scored themselves at a 2 on this same question and wrote, “Because sometimes I don't like to try as much as I should.” This particular student consistently holds the lowest grades in class and struggles with motivation and focus.

The most interesting results I found while analyzing the data in Figure 2 was not the overall scores for the 10-scaled categories. The mean scores don’t indicate a large shift in SRL because all the means are relatively close. The most interesting information appears when I’m able to link student quotes to questions and then compare both of those pieces of information to their overall scores in the motivation and/or learning strategies scales. It was illuminating, and yet not surprising, that there were often strong correlations between a student’s individual score on one question and their overall score on one of the two scales. For example, a student that had the second largest drop in scores from the pre- and post-unit motivation survey also ranked extrinsic motivation at a 7 on both the pre- and post-unit survey. I also happened to interview this student and when asked to talk about her general thoughts on the unit they responded, “The unit is a little boring, but I like the project aspect of it…but I would prefer to take notes on the topic so I could really get it into my head." With a shift in pedagogy I've found that certain students aren't used to the type of learning and need more scaffolding in terms of skills and direction. It's an important aspect of PBL teaching that needs to be kept in mind when teachers are thinking about making the shift in pedagogy. In the long run, I think PBL is a good teaching methodology for this type of student because there's student choice allowed in PBL. I've found that when there's more freedom in learning student intrinsic motivation increases but it takes time for students to understand how to become more self-regulated and to learn with less structure and more freedom. Hopefully, PBL will get students that aren't as naturally motivated and don't always think about their learning to grow because the idea behind PBL is that it's authenticity and relevancy is motivating and in order to have success there has to be strong SRL.

However, two students that had the largest increase (20%) in pre- to post-unit scores on the learning strategies scale wrote comments in response to the MSLQ question, "I try to apply ideas from one class to other classes", which is connected to the SRL skill of elaboration, that indicate growth in making connections between classes and seeing how subjects are intertwined. One student wrote pre-unit, "Sometimes in my mind I'll relate two classes, but I don't go totally out of my to relate ideas because I don't find it necessary to combine two class ideas" and post-unit wrote, "I like to make connections, it exercises my brain and I feel smarter." And, the other student wrote pre-unit, "Because I have specific studying habits to help me in different classes, and I have different goals for different classes" and post-unit wrote, "It depends if the topics relate and are helpful when understanding the course." The PBL unit on physics combined science, math, art, design, history, and outside experts. These two students' scores indicate that their opinions of interdisciplinary work, which improves SRL, improved with the implementation of PBL.

In addition to looking at the survey as a stand-alone instrument I wanted to see if there was a relationship between the motivation and learning strategies scales and student grades. I calculated correlations between the pre-unit motivation scale and learning strategies scale with students' 1st trimester grades and correlated the post-unit motivation scale and learning strategies scale with students' 2nd trimester grades. There wasn't a strong correlation between students' first trimester grades and their pre-unit motivation scale (0.3) but there was for the post-unit motivation scale and their second trimester grade (0.6). This is an indication that for the non-PBL unit there wasn't a relationship between motivation and grades but that during the PBL unit this relationship was stronger, which is great to know as a teacher and helps support the idea that PBL motivates students, which is connected to learning. For the learning strategies portion of the MSLQ there was a strong correlation between both the pre- and post-unit survey and students first and second trimester grades, 0.6 and 0.5, respectively. This indicates a relationship between the learning strategies students have and their trimester grades, which makes sense because the way students learn impacts their grades. I also correlated the pre-unit motivation and learning strategies scale scores with the post-unit motivation and learning strategies scale scores. The pre-unit correlation (0.4) was not as strong as the post-unit correlation (0.7). This difference is an indication that during the PBL unit there was a stronger association between student motivation and their learning strategies and that students were motivated and attempting to make decisions that allowed them to find success in class.

An important aspect of SRL is elaboration, critical thinking, and ability to manage time. These skills are beneficial when studying for and taking a test. From year to year when teaching the same content I use a version of the same test and this year wasn't any different for the physics test. However, this year I made the physics test harder than in years past by asking students to take the information they learned throughout the unit and apply it to other situations as an indication of meaningful understanding. As I graded the test, I was incredibly impressed with the students' answers and their understanding of Newton's Laws of Motion. I don't have students' grades from years past, but I'm confident that past student responses weren't as strong as the responses this year. Test scores from the non-PBL unit averaged 90% and the average for the PBL unit was 95%, an increase of 5%, and 63% (*N*=19) of the students did better on the physics test than they did in the non-PBL unit. Additionally, there were five students that struggle with test taking that improved their scores from 10% to 19%! These were the most surprising (and rewarding) test results I've had the pleasure to experience as a teacher and confirms my belief that PBL teaches students how to think critically, elaborate on their understanding, and manage their time better.

Another important aspect of SRL is that students can self-monitor and self-evaluate their learning performance (English & Kitsantas, 2013). A large aspect of the PBL unit was students building exhibits, getting feedback on their work, learning how to do it better, and then making another exhibit with the new information. As students moved through the unit they were constantly evaluating their work. Students made a total of three exhibits and the average grade on the first exhibit was below standard at 80% and the average grade on the final exhibit was at standard at 90%. This increase is evidence that students were able to learn and that self-reflection was important and useful, and helped them raise the quality of their work, which is an important part of SRL. Additionally, without prompting two students during the interviews indicated that they liked doing the same thing more than once,

> I like how we were given the law and then kind of explored it on our own a little before we got into the big project, and how one project helped improve the next project. You could kind of build on what you had learned.

Another student said, “I really liked how we’re doing the same project for every different law because we kind of learn from our mistakes…” One of the challenges with doing things multiple times is the time it takes to reflect, learn, and do over. Students also reflected that they wished they had had more time to complete their work. It’s important to keep in mind that when doing a PBL unit less content is covered (in potentially more time) so teachers have to be prepared for that. However, I think skills gained in other areas are more valuable than content lost.

Collaboration

In addition to SRL skills being an important aspect of PBL, successful collaboration skills are essential for students to complete an authentic project. For data collection on collaboration I used the collaboration checklist, the MSLQ, and student interviews to gather data.

Students in both sections worked in groups (*N*=14) and were asked to design three interactive museum exhibits over the course of three months that related some aspect of Newton's Three Laws of Motion to an urban design feature in NYC. Some examples of student work included a rollercoaster, wrecking ball, urinal, and elevators. Throughout the PBL unit there were a total of 61 class periods between the two 8th grade sections (30 classes for one section and 31 for the other section) and students collaborated during 67% (*N*=41) of those classes, which indicates that students were working with others throughout much of the unit. Breaking down the unit into three stages, students collaborated 38% in the beginning third, 62% in the middle third, and 100% of the time during the last third. This indicates that as the unit went on students were working more with one another than on their own, which makes sense that as the project grew over the three months and the date got closer for the public exhibition students were locked into working together on their presentation.

Table 3 outlines the average percentage of groups that completed each of the collaboration behaviors over the 41 class periods.

Table 3
Student collaboration behaviors for physics PBL unit

Collaboration Behaviors	Average
All members actively participate.	93%
Group members are respectful of one another.	99%
Group members attempt to complete work on their own before asking questions.	80%
Group stays on task.	92%

Note. (*N*=41).

In looking at the percentages of collaboration behaviors all the numbers are relatively high, which indicates that students were effective collaborators, which is an important skill for PBL. In fact, 99% (*N*=40) of the time all groups were respectful of one another and 92% (*N*=38) of the time groups stayed on task. Over the course of the 41 periods 80% of the pairs attempted to complete work on their own before asking. When students were designing their exhibits there were a lot of questions about how to fix problems with their designs, where to get supplies, and how to write place cards for their exhibit so it makes sense that this collaboration category is the lowest. Overall, the data from the checklist on collaboration suggests that the students were effective collaborators during the PBL unit.

A second source of data for examining the effects of PBL on collaboration was the questions on the MSLQ that pertained to peer learning and students' ability to work with others. The average score of the peer learning questions before the PBL unit was 3.7 and after the unit the average score was 5.2, which is a 20% increase. On the MSLQ students were asked to elaborate on question 25, which asked them to rate themselves on a scale from 1-7 on the following statement, "I try to work with other students to complete course assignments." Students that recorded answers above a four wrote ideas similar to these two student responses, "I like to work with other students because it lets me see their point of view, which might be different than mine" and "I can learn from other students and it's always good to share knowledge." Students that recorded an answer below three on the survey wrote something similar to "I rarely work with another student on course assignments. The only time I do is when we are supposed to." There was an increase in the average score on the MSLQ for value placed on peer learning but there are indicators in the survey that students would still prefer to work alone and only collaborate when it's part of an assignment or project.

During student interviews when students were asked to reflect on collaboration and if it's an important skill to help them learn 100% (*N*=5) of the students responded that it is an important skill and that they were frequently asked to work with others during the PBL unit. Two of the students said that learning to work with others is important because adults in their jobs are often working together so it's an important skill to have. One student discussed the important of leadership as part of the collaboration process,

> It's really important to learn how to work with someone else, and…what type of leader you are, and I think that really comes into play in a lot of things that you do. So, working with other people and experiencing what type of a leader they are, and how you can work together to make all of your leadership skills come together to make the project better than it could be by yourself is important.

There are always challenges involved when working in groups and although much of the data suggest that students enjoyed the process of collaborating and learning from others, there is still work that needs to be done by the teacher to make sure all members are contributing equally and all students feel supported in their groups.

Role Of Teacher

An important aspect of this action research-based classroom project was examining how PBL affects the role of the teacher. I want my classroom to be more student-directed and inquiry-based where students are doing a lot of the learning and exploring on their own and I act as their guide. Three instruments were used to collect data on how PBL affects the teacher's role in the classroom – video sessions, student interviews and journal reflections.

Video sessions focused on how much time I was in front of the classroom compared to the amount of time students are working independently or in a group. I videoed myself three times throughout the course of the unit, the beginning, middle, and final third and found that as the unit went on my time in front of the class decreased from 32%, to 17%, to 5%, respectfully. The trend in the amount of time I spent in front of the classroom is indirectly related to the increase in student collaboration throughout the PBL unit. As my time leading the class decreased the amount of time students spent working together increased, not surprisingly. My journal entries also indicate a shift in my role as the unit continued. On December 17, which was in the beginning of the unit I wrote,

> Students watched a movie about Robert Moses to learn how New York City (NYC) has changed over time. My role was to introduce the topic of physics and how it can be connected to the city. Students watched the movie, while I paused it periodically to discuss NYC and brought light to a potential physics connection. Also, I wanted to make them appreciate all the changes that have occurred and occur to make a city function properly.

I wasn't lecturing during the entire class but I was directing the course of study and the discussion. However, towards the end of the unit in early March I wrote:

> "This was one of the best classes I have ever had the pleasure to be a part of. Students were working on their exhibits, some were in the classroom, some were working with the shop teacher, some were going around school getting supplies like paint from the art room, etc. Students were working in their teams but really working on their own without much direction from me - I was just kind of sitting back and watching all of the amazing building that the kids were doing. Both the science department chair and the Middle School Head walked in and were blown away by what they saw. The Middle School Head took a moment to talk with one of the students about what she was making and learning about and I was so impressed with the science that the student knew about Newton's Laws and how it connected to the subway/train car that her group had made. There was tons of creativity, problem-solving, self-directed learning, collaboration, etc. going on. It was very cool to sit back and watch."

I don't think I'll ever forget that class because the energy was so positive and productive and it was such a pleasure to witness it.

During student interviews I asked the students to reflect on my role as a teacher in the class. I specifically told them that they didn't have to provide an opinion as to whether my teaching was good or bad, just to think about my role. Students responded to the prompt with a range of ideas all similar to the following, "I felt like you really guided us through what we were doing. You weren't telling us what so do" and,

> I think you weren't exactly trying to tell us stuff so we wrote it down. I think you were trying to make us think more for ourselves and you guide us. So you set the boundary, but you really let us express our own ideas and opinions.

It is my experience from being in education for 11 years and talking with colleagues that teachers generally like to have control of their classroom and giving that up can be challenging. I'm incredibly comfortable with it but not everyone is and there's a fine balance, especially in the middle school years, between too much self-directed learning and not enough. There are students who need and crave structure and that need more support in PBL curriculum compared to students who are self-starters and very comfortable with choice and making decisions on their own. Differentiation is a skill that I need to work on but I know that every day during the PBL unit I was excited for class to start to see what the students were going to learn and create and, for the most part, the students were excited as well.

INTERPRETATION AND CONCLUSION

This action research-based project was designed to see how an 8th grade physics PBL curriculum impacts student perspective on the authenticity and relevancy of the curriculum, affects student collaboration, self-regulated learning, and my role as a teacher.

In response to my driving question for this action research-based project about relevant and authentic curriculum, I found that through student interviews, project self-reflections, and task value questions on the MSLQ students felt that applying physics to urban design and NYC connected them to the city, making the curriculum more relevant and authentic. Sixty-seven percent (*N*=20) of the students task value scores increased from pre- to post-unit and 67% of the students wrote in their project self-reflections that the most important thing they learned in the physics unit was how physics connect to their daily life and to the real-world. The self-reflection comments were supported by 100% (*N*=5) of the students during interviews reporting that the unit closely or very closely related to their daily life. The most common theme reported by students that felt like the unit wasn't relevant and authentic was that they didn't think they were going to be engineers or architects and therefore, had a hard time connecting to the curriculum. In the future, I think it will be important to communicate to the students that I'm not expecting them to go into this line of work but that it's one medium for them to explore physics. Also, as the project develops I think there is room for more freedom and choice for the students in picking subjects they're more interested in exploring, for example sports, and how it's connected to Newtonian physics. In addition to students creating exhibits through the unit, students were connected to a local author that writes about urban design and engineering in NYC, and a museum design expert. Additionally, students visited two museums to learn how to communicate challenging scientific concepts in a simple way for a range of audiences. Furthermore, an individual assessment during the PBL unit were two essays where students connected their exhibits to the history of New York City and how their urban design feature impacted the city. Unfortunately, I didn't collect data on any of these learning moments, which is something I'd like to do in the future, but I think that each activity impacted the connection students felt between what they were learning in the classroom and the real-word, which added to the authenticity and relevancy of the unit. Learning from a range of sources is an integral aspect of PBL and can open up students' minds to informational resources.

In response to my sub questions about self-regulated learning, the quantitative data collected from the MSLQ to measure SRL, didn't show a large change pre- to post unit, 0% change for the motivation scale and 0.2% decrease in scores from the pre- to post-unit. At the very least, this is an indication that PBL doesn't decrease students' SRL. When student motivation scores were correlated with students' grades, the pre-unit correlation was 0.3 and the post-unit was 0.6, which indicates that there was a stronger relationship between the motivation of students and their grades post-unit. Additionally, there was an increase in correlation between motivation scores and learning strategies scores from pre-unit (0.4) to post-unit (0.7), which is an indication that these two factors are more in line with one another during a PBL unit compared to a non-PBL unit. The data indicate that students are motivated by the connection to the topic, driven by their own choices, and because of this their learning strategies are more self-directed. Additionally, students took a test at the end of the PBL unit and 63% (N=19) of students did better on the physics test compared to the test they took in the fall during the non-

PBL. Furthermore, student grades on the PBL projects increased from the first project average of 80% to 90% for the final project. The increase in grades on both the test and projects is an indication of students strong grasp of the material and their ability to reflect and learn from their mistakes – all key concepts in SRL.

In response to my sub question about collaboration, I discovered that over the course of the three-month unit students collaborated 67% (*N*=41) of the time, increasing the amount they collaborated from 35%, to 62%, to 100% throughout the unit. There was a 20% increase on the peer-seeking questions of the MSLQ pre- to post-unit (3.7 to 5.2 on the Likert scale) and in student interviews 100% (*N*=5) of the students said that working with other helped them learn and they were asked to work with others a lot throughout the unit. Collaboration is a large component of PBL so it's not surprising that students were asked to work together and that as the final project got closer, that the amount they collaborated increased. Understanding how to work with others is a key aspect of living and working in the 21st century. A curriculum that encourages and, in some cases, forces students to work together is important to implement in the classroom.

In response to my third sub question about the role of the teacher, I found as student collaboration increased, my role as the person in front of the classroom decreased from 32%, to 17% to 5% from the first third, middle, and last third of the trimester, respectively. My journal entries also indicated that I was leading the discussion more in the beginning of the unit compared to the end. During the interviews students frequently referred to me as a guide, which is another indication of what my role was as a teacher. Students have an incredible amount of access to information to learn from and the jobs that are available to people today probably won't exist or will certainly look different in the future. Students need to be able to make choices, learn from their mistakes, and problem solve on their own and with their peers. These lessons can't be learned if the teacher is conducting the class through lectures and feeding students information that they could easily Google. Teaching and what teaching looks like needs to shift and PBL is one way in which the teacher can ask more of their students and help them learn the skills that will be of value to them moving forward.

In looking at all the pieces of evidence from the different instruments there is strong evidence that points towards PBL teaching students about relevant and authentic curriculum, encourages collaboration, improves SRL, and forces teacher away from the center of attention in student learning.

VALUE

The process of diving into one topic (PBL) over an extended period of time has been an incredible learning experience. I've learned a tremendous amount about why PBL is a teaching methodology that can work well for adequately preparing students for their future. Through reading about PBL and having many discussions about it I believe in its purpose, and am excited about continuing to develop my skills as a PBL educator. I've also learned a lot about the skills students need in order to complete a successful project and that they need to be taught those skills – it cannot be assumed that they know them. Students that are more comfortable with the traditional ways of teaching, learning from rote memorization, and taking notes for most of class are challenged with the open-endedness of PBL and the level of choice that's allowed. Understanding the importance of teaching skills, like collaboration and critical thinking, and spending time reflecting on those skills with students is one of the biggest takeaways from this project. It is my opinion that the students at Berkeley Carroll are very comfortable reading and writing and learning a lot of traditional content from their teachers. They're not as comfortable recognizing that there are other aspects of learning that are as important as loads of content. However, that message needs to be communicated to students and reflected on often in a way where students have a voice in the process and feel heard. One way to do this is to have students involved in the rubric-making process so they know what they're being evaluated on and including more formative checks so students can check their progress. Talking more to students about the process of learning, through more formal check-ins, is something that I'll take away from this experience.

Designing a PBL unit is one aspect of PBL that comes easily to me but actually implementing it in the classroom is an entirely different experience and incredibly challenging. It's been helpful to read literature about the challenges of implementation and to learn that this is a common issue – sometimes a successful PBL unit can take years to fully develop. I had a lot of hard days during the PBL unit where I questioned what I was doing and needed encouragement from my colleagues who are also doing this type of work. Having support from others who understand this type of learning and support from the administration is crucial because there will be failures and there will be parents, students, board members, and other members of the community that don't support this type of learning because they don't understand the merit of it or the reasons for the shift in pedagogy. The work is rigorous but in a different way and that change is sometimes hard to grasp and believe in.

I’m lucky in that the students at BCS are highly motivated and already have well-developed learning strategies so the transition to PBL hasn’t been as hard as it could be for teacher with a different student body. Therefore, teachers with students whose SRL skills and collaboration skills aren’t as well-developed might have to work more with students on skill development. However, bringing relevant and authentic curriculum into the classroom would work anywhere.

I know that as I’ve leaped head first into exploring PBL over last two years I’ve faced a lot of long, exhausting days in the classroom and a lot of late nights planning and thinking about my classes. But I also know that all of those hard days were less frequent compared to the days when I saw students learning in new and exciting ways, and producing work that was far and above what I’ve see in the decade before I started on this PBL journey. Learning about and implementing a “learning by doing” curriculum is not a new idea - progressive education came about in the early 1900’s - but somewhere along the way it got lost and I’m not sure why. As our world continues down this technological journey, as new jobs become old jobs, and as people around the world are more and more connected, the way that students are asked to learn needs to be in line with an unknown future. Students need to learn how to problem-solve, make mistakes and rebound from them, and how to work with others and use multiple resources to learn information. Teachers are a large component of a student’s learning process but we also need to learn to give students freedom and push them to make their own choices. The largest lesson I’ve learned from this journey is that along with struggle, mistakes, and failure comes growth, perspective, and inspiration. I've been reinvigorated by learning how to give up control and give students choice, and I'm looking forward to continuing along this path.

REFERENCES CITED

The Berkeley Carroll School. (n.d.). Mission. Retrieved April 6, 2014, from http://www.berkeleycarroll.org/aboutus/berkeley-carroll-mission-statement/index.aspx.

Buck Institute for Education. (n.d.). Project based learning - BIE. Retrieved April 4, 2014, from http://bie.org.

Capon, N., & Kuhn, D. (2004). What's so good about problem-based learning. *Cognition and Instruction*, *22*(1), 61-79.

English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem- and project-based learning. *Interdisciplinary Journal of Problem-based Learning*, *7*(2), 128-150.

Hendricks, C. (2013). *Improving schools through action research: A reflective practice approach* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Hixson, N. K., Ravitz, J., & Whisman, A. (2012, September). *Extended professional development in project-based learning: Impacts on 21st century teaching and student achievement*. Charleston, WV: West Virginia Department of Education, Division of Teaching and Learning, Office of Research.

Kanter, D. E. (2010). Doing the project and learning the content: Designing project-based science curricula for meaningful understanding. *Science Education*, *94*(3), 525-551. http://dx.doi.org/10.1002/sce.20381.

Lattimer, H., & Riordan, R. (2011). Project-based learning engages students in meaningful work: Students at High Tech Middle engage in project-based learning. *Middle School Journal*, *43*(2), 18-23.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1997). Enacting project-based learning. *The Elementary School Journal*, *97*(4), 341-358.

Pintrich, P. R., Smith, D. A.F., Garcia, T., & McKeachie, W. J. (1991). *Manual for the use of the motivated strategies learning questionnaire (MSLQ)*. Ann Arbor, MI: The University Of Michigan.

APPENDICES

APPENDIX A

PBL PROJECT OVERVIEW AND DESIGN

<table>
<tr><td colspan="6">P R O J E C T   D E S I G N :   O V E R V I E W</td></tr>
<tr><td colspan="5">Name of Project: The Physics of New York City</td><td>Duration: 8 weeks</td></tr>
<tr><td colspan="4">Subject/Course: Science</td><td>Teacher(s): Kosnik/Laundon</td><td>Grade Level: 8</td></tr>
<tr><td colspan="6">Other subject areas to be included, if any: Engineering, Robotics, Urban Design, Museum Design</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Significant Content
(CCSS and/or others)</td><td colspan="5">• Forces: Balanced vs Unbalanced, Gravitational, Electric, Magnetic, Friction, Impact on motion, Impact of mass and acceleration
• Motion: Vectors, Speed, Velocity, Acceleration, Graphing, Force, Oscillation
• Machines: transfer of mechanical energy, how to maximize simple machines (Atwood machine or pulley for elevators)
• Newton's laws: first, second, third
• Graphing velocity vs acceleration
• How subways, elevators, skyscrapers work</td></tr>
<tr><td rowspan="3">21st Century Competencies
(to be taught and assessed)</td><td>Collaboration
• Works productively with others to solve problems and create new ideas and products
• Assumes shared responsibility for completing work</td><td>X</td><td colspan="2">Creativity and Innovation
• Designs a museum exhibit to teach others about physics in urban environments</td><td>X</td></tr>
<tr><td>Communication</td><td>X</td><td colspan="2">Other:</td><td></td></tr>
<tr><td>Critical Thinking
• Examines the structures in cities and applies principles of physics to these structures</td><td>X</td><td colspan="2"></td><td></td></tr>
</table>

Project Summary (include student role, issue, problem or challenge, action taken, and purpose/beneficiary)	In order for cities to be constructed and for their impact on the environment to be minimized, the laws of motion need to be understood and applied. Students will learn about NYC in order to learn about a few of the ways that physics intersects with urban engineering. Students will also learn about museum exhibit design in order to work in groups to create exhibits that teach elementary students about the Physics of New York City. The exhibits that they create will be housed in a Pop Up Museum in the Park Slope neighborhood. Children from neighboring elementary schools (including our own) will be invited and 8th graders will be docents for the visitors.	
Driving Question	How can we, as museum designers, plan an exhibit that demonstrates Newton's Laws in urban design?	
Entry Event	Students watch the PBL Documentary: "American Experience: The World that Moses Built". Robert Moses built bridges, highways, Jones Beach, Lincoln Center and the United Nations in New York. His were some of the most ambitious -- and controversial -- public works projects ever conceived and changed the face of the city. Students watch the movie and pick out aspects of the work that is being done and relate it to science and society.	
Products	Individual: • CBB (app) book on all major science vocabulary that includes video, images, and text • Test on material • Collection of data and analysis of experimental results	Specific content and competencies to be assessed: • See Significant Content noted above • Ability to understand how to use data to arrive at a conclusion
	Team: • ElectriCity Museum Review • Mock up for an exhibit on the physics of subways • Mock up for an exhibit on the physics of elevators • Mock up for an exhibit on the physics of skyscrapers • Final interactive exhibit piece for the Physics of New York Pop UP Museum	Specific content and competencies to be assessed: • Application of content to structures in cities • Ability to plan and execute a successful museum exhibit

Public Audience (Experts, audiences, or product users students will engage with during/at end of project)	During: • Skyscraper expert who accompanies on Empire State Building trip. • Elementary school students visiting the Pop Up Museum • A museum exhibit designer who works with groups and then "review" the final exhibits created by groups			
Resources Needed	On-site people, facilities: • Communications Director to help with publicity for pop up event • Location for the Pop Up Museum • Lego robotics training			
	Equipment: • A variety of science materials for various experiments • Lego supplies • Atwood pulleys			
	Materials: • Supplies for the construction of the exhibitions			
	Community Resources:			
Reflection Methods (Individual, Team, and/or Whole Class)	Physics of New York CBB Book of Terms	X	Focus Group	
	Whole-Class Discussion	X	Fishbowl Discussion	
	Lab Notebook	X	Other:	

APPENDIX B

IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Immunology & Infectious Diseases
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-5721
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu

MEMORANDUM

TO: Brooke Laundon and Walt Woolbaugh

FROM: Mark Quinn, Chair Mark Quinn cj

DATE: December 12, 2014

RE: *"Creating Authentic and Relevant Science Curriculum through Project-Based"* [BL121214-EX]

The above research, described in your submission of December 12, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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

APPENDIX C

MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE

Directions: Please take the time think thoroughly about each question. Then select the position on the scale that best reflects your feelings. Please do NOT make your selection based on what you think I want to hear. There are NO right or wrong answers to this survey, just answer as accurately as possible.

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

MSLQ Item List

The following is a list of items were adapted from the MSLQ (from Pintrich et al., 1991).

Part A. Motivation

The following questions ask about your motivation for and attitudes about this class. Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1. I prefer course material that really challenges me so I can learn new things.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

2. If I study in appropriate ways, then I will be able to learn the material in this course.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

Why did you answer the way that you did in the above problem?

3. I think I will be able to use what I learn in this course in other courses.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

4. Getting a good grade in this class is the most important thing for me right now.

1	2	3	4	5	6	7

Not at all true of me *Very true of me*

5. It is my own fault if I don't learn the material that is taught in this course.
   1 2 3 4 5 6 7
   Not at all true of me *Very true of me*

6. It is important for me to learn the course material in this class.
   1 2 3 4 5 6 7
   Not at all true of me *Very true of me*

7. The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.
   1 2 3 4 5 6 7
   Not at all true of me *Very true of me*

8. If I can, I want to get better grades in this class than most of the other students.
   1 2 3 4 5 6 7
   Not at all true of me *Very true of me*

9. I prefer course material that arouses my curiosity, even if it is difficult to learn.
   1 2 3 4 5 6 7
   Not at all true of me *Very true of me*

   Why did you answer the way that you did in the above problem?

10. I am very interested in the content area of this course.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

11. If I try hard enough, then I will understand the course material.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

12. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.

1 2 3 4 5 6 7
Not at all true of me *Very true of me*

13. I think the course material in this class is useful for me to learn.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*
    Why did you answer the way that you did in the above problem?

14. When I have the opportunity, I choose course assignments that I can learn from even if they don't guarantee a good grade.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

15. If I don't understand the course material, it is because I didn't try hard enough.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

16. I like the subject matter of this course.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

17. Understanding the subject matter of this course is very important to me.
    1
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

18. I want to do well in this class because it is important to show my ability to my family, friends, or others.
    1 2 3 4 5 6 7
    Not at all true of me *Very true of me*

    Why did you answer the way that you did in the above problem?

Part B. Learning Strategies

Directions: Please take some time to thoroughly think about each question. Then select the position on the scale that best reflects your feelings. Please do NOT make your selection based on what you think I want to hear.

Remember:
• Participation is voluntary; you may choose to answer the survey questions or not.
• Your participation or non-participation will not affect your grade or class standing.
• There are NO right or wrong answers to this survey, just answer as accurately as possible.

Learning Strategies: The following questions ask about your learning strategies and study skills for this class. When the survey refers to the word *studying*, this mean completing any work for this class, not just studying for a test or quiz. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the same scale to answer the remaining questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

19. When studying, I often try to explain the material to a classmate or friend.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

20. I usually study in a place where I can concentrate on my course work.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

21. I often feel so lazy or bored when I study that I quit before I finish what I planned to do. (REVERSED)

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

22. I often find myself questioning things I hear or read in this course to decide if I find them convincing.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

23. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone. (REVERSED)

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

24. I make good use of my study time.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

Why did you answer the way that you did in the above problem?

25. I try to work with other students to complete course assignments.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

Why did you answer the way that you did in the above problem?

26. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

Why did you answer the way that you did in the above problem?

27. I work hard to do well in school even if I don’t like what I’m doing.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

28. When studying, I often set aside time to discuss course material with other students.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

29. I treat school material as a starting point for learning and try to develop my own ideas about it.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

30. I find it hard to stick to a study schedule.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

31. When I study for a class, I pull together information from different sources, such as lectures, readings, labs, and discussions.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

32. I ask teachers to clarify concepts I don't understand well.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

33. When schoolwork is difficult, I either give up or only study the easy parts. (REVERSED)

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

34. I try to relate ideas in this subject to those in other courses whenever possible.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

35. When reading for school, I try to relate the material to what I already know.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

36. I have a regular place set aside for studying.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

37. I try to play around with ideas of my own related to what I am learning in school.

1	2	3	4	5	6	7
Not at all true of me						*Very true of me*

38. When I study, I write brief summaries of the main ideas from the readings and my class notes.

1	2	3	4	5	6	7

Not at all true of me *Very true of me*

39. When I can't understand the material for a class, I ask another student for help.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

Why did you answer the way that you did in the above problem?

40. I try to understand the material in a class by making connections between the readings, concepts from class discussion, labs, and other activities.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

41. I make sure that I keep up with the weekly readings and assignments for schoolwork.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

42. Whenever I read or hear a claim or conclusion in class, I think about possible alternatives.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

43. Even when school materials are dull and uninteresting, I manage to keep working until I finish.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

Why did you answer the way that you did in the above problem?

44. I try to identify students in this class whom I can ask for help if necessary.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

45. I often find that I don't spend very much time on work in school because of other activities. (REVERSED)

1 2 3 4 5 6 7
Not at all true of me *Very true of me*

46. I rarely find time to review my notes or readings before a quiz or test.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

47. I try to apply ideas from one class to other classes.
1 2 3 4 5 6 7
Not at all true of me *Very true of me*

Why did you answer the way that you did in the above problem?

APPENDIX D

ITEMS COMPRISING THE 10 MSLQ CATEGORIES

Items Comprising the 10 MSLQ Categories (Pintrich et al., 1991)

Scale	Items Comprising the Scale	Number of Items
Motivation Scales		
1. Intrinsic Goal Orientation	1, 9, 12, 14	4
2. Extrinsic Goal Orientation	4, 7, 8, 18	4
3. Task Value	3, 6, 10, 13, 16, 17	6
4. Control of Learning Beliefs	2, 5, 11, 15	4
Learning Strategies Scales		Total = 18
1. Elaboration	31, 34, 35, 38, 40, 47	6
2. Critical Thinking	22, 26, 29, 37, 42	5
3. Time/Study Environmental Management	20, 24, 30, 36, 41, 45r, 46	7
4. Effort Regulation	21r, 27, 33r, 43	4
5. Peer Learning	19, 25, 28	4
6. Help Seeking	23r, 32, 39, 44	4
		Total = 66

* r = reverse question

APPENDIX E

PHYSICS TEST

Newton's 3 Laws of Motion Unit Test

(40 points)

I. Multiple Choice (2 points each)

Write the correct letter on the blank line.

_____ 1. You are standing in a moving subway car on roller skates. You forget to hold onto the pole as the train rapidly slows down and comes to a stop. You:

a. Roll to the front of the car because you have inertia.
b. Stay where you are because you are not in motion.
c. Roll to the back of the car because you have inertia.
d. Fall to the side on top of the person reading the newspaper.

_____ 2. According to Newton's 2nd Law of Motion, if the force on an object remains constant, and the object's mass increases, then the object's acceleration must:

a. stay the same
b. decrease
c. increase
d. none of the above

_____ 3. Pick the best example of Newton's Third Law in action.

a. A rocket taking off from earth, which pushes gasses in one direction and the rocket in the other direction.
b. The force of a fly hitting a windshield is equal and opposite to the force of the windshield hitting the fly.
c. The reason a cannon/tank needs to be so massive is to slow its acceleration backwards when the equal and opposite force is created using gunpowder in order to accelerate the cannonball/bullet forwards.
d. All of the above.

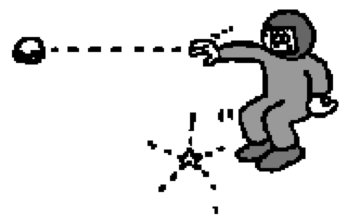
_____ 4. A ball is thrown straight up in the air. According to Newton's first law of motion, what is the reason for the ball falling back to Earth?

a. The ball has inertia and wants to keep doing what it is doing.
b. The forces acting on the ball are balanced forces.
c. Unbalanced forces are acting on the ball.
d. The ball exerts a force on the air surrounding it.

_____ 5. A vehicle goes from 5m/s to 45m/s in 8s. What is its acceleration?

a. 6.25 m/s^2
b. 5m/s^2
c. 225 m/s^2
d. -5 m/s^2

_____ 6. The diagram at the right shows an astronaut in outer space, throwing a donut to the left. Which of the following statements is **TRUE** according to Newton's Laws of Motion?

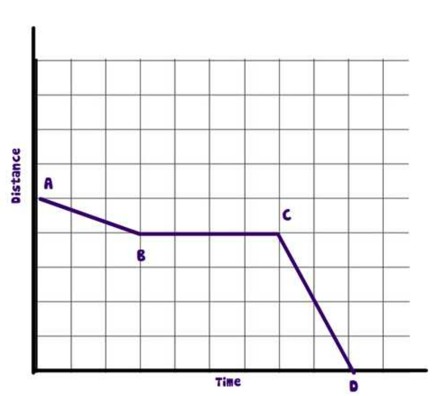


a. The donut will slow down and eventually stop.
b. The equal and opposite force is from the donut acting on the astronaut.
c. The astronaut will accelerate to the right.
d. b and c

____ 7. A stalled car is experiencing 150 N of frictional force to the left. The driver pushes with 60N of force to the right. What force must a good citizen apply to help the car move with a Net Force of 20 N to the right?

a. 80 N
b. 110 N
c. 90 N
d. none of the above

<u>II. Graphing</u>



8. Create a scenario that describes the motion depicted in the graph above. Make sure to include a description for: **(4 points)**

- each point (A, B, C, and D), and
- each segment (A-B, B-C, C-D).
- Make sure your story is told in chronological order. That means don't discuss the points and then the segments but rather discuss them together.

III. Calculations

Read the questions carefully and write out the correct formula based on the variables mentioned in the problem. Show all math work (meaning identify the variables, substitute, and solve) and BOX your final answer including units for full credit. Round to the nearest tenths place if necessary.

9. What is the speed of a plane that travels 5585 km from NYC to London in 7 hours? **(3 points)**

10. You drive a car for 450,000 m from Los Angeles to Phoenix at a velocity of 25 m/s. How long will the drive take you? **(3 points)**

IV. Short Answer **-**

Read each question carefully and answer every part in detail on a separate sheet of paper. Use your best writing.

11. Give an example of balanced forces in one of your exhibits. Then, give an example of unbalanced forces in one of your exhibits. Make sure that you explain what balanced and unbalanced forces are.
(4 points)

12. Think about ANY of the exhibits you created or that one of your classmates created. In one sentence describe the exhibit. Explain how this exhibit connects to **2** of Newton's Laws of Motion. State each law and then explain the connection.
(6 points)

13. The following is an article that appeared in the magazine Wired on May 12, 2012 by Keith Barry. Read the article and explain in terms of one of Newton's Laws of Motion why repaving roads would reduce energy consumption. **(6 points)**

"A NEW STUDY predicts that repaving US roadways with firmer surfaces could save up to 273 million barrels of crude oil each year. Researchers at MIT used mathematical models to examine the forces at work when a rubber tire travels over a road surface and found that cars and trucks must use slightly more energy on less-stiff streets. Just as beach sand underfoot tends to sink, the weight of a vehicle tends to tamp down softer pavement – a phenomenon known as deflection. The end result is that tires rolling on malleable road surfaces are constantly climbing up a very small incline, which wastes fuel. Together with rough road surfaces, pavement deflection costs American drivers in total about $15.6 billion in added fuel costs and is responsible for 46.5 million metric tons of CO2 emissions."

APPENDIX F

STUDENT PROJECT SELF-REFLECTION

Think about what you did in this project, and how well the project went. Write your comments below

Student Name:

Driving Question:

List the major steps of the project:

About Yourself:

What is the most important thing you learned in this project?

What do you wish you had spent more time on or done differently?

What part of the project did you do your best work on?

About the Project:

What was the most enjoyable part of this project?

What was the least enjoyable part of this project?

How could your teacher(s) change this project to make it better next time?

APPENDIX G

COLLABORATIVE GROUPS CHECKLIST

Behaviors/Activities	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
All members actively participate.							
Group members are respectful of one another.							
Group members attempt to complete work on their own before asking me questions.							
Group stays on task.							

APPENDIX H

STUDENT INTERVIEW QUESTIONS

Before the interview begins, students were reminded that participation in this research is voluntary and participation or non-participation will not affect a their grade or class standing in any way.

1. What did you think about the physics unit that we just completed?
2. Thinking back on the entire unit how often do you think you were asked to work with at least one other person?
3. Do you think working with others is an important skill and can help you learn?
4. How closely do you think what you learned about relates to the real world?
5. Do you think connecting science to your life outside of school is important?
6. How would you characterize my role as the teacher throughout the unit?

APPENDIX I

TEACHER JOURNAL REFLECTION PROMPTS

Journal entries were completed once a week during the PBL unit.

1. What went well in today's class?
2. What did not go well with today's class?
3. Were students learning about a topic that is relevant and authentic?
4. What was my role in the classroom today?