

THE IMPACT OF PROBLEM-BASED LEARNING ON ACADEMIC  
ACHIEVEMENT IN THE HIGH SCHOOL SCIENCE CLASSROOM

by

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A professional paper submitted in partial fulfillment  
of the requirements for the degree

of

Master of Science

in

Science Education

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## DEDICATION

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This paper is dedicated to my students, who push me to learn and improve my practice every single day. And to my husband and son; without their support I could not have completed this work.

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## ABSTRACT

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In science classes, students will sometimes complain that a topic seems arbitrary, and have a difficult time connecting it to their lives. I believe this difficulty of recognizing science as directly connected to the real world contributes to a lack of student engagement and, as a result, low academic scores. In this study, I sought to use an instructional approach called problem-based learning, in which students learn content through solving a real-world problem.

The study was conducted at a suburban high school with a majority low-income, majority minority population. This set of learners has some unique challenges, including a high percentage of English-language learners and chronic absenteeism. Although my problem-based learning group did not perform better than a group of their peers who learned through a more traditional, lecture based format, there were promising results for the performance of English-language learner students and high levels of student engagement.

## INTRODUCTION AND BACKGROUND

Problem-based learning (PBL) has been shown to be effective in improving student academic performance, self-efficacy beliefs, and overall satisfaction with the learning experience. First developed by medical schools, PBL has gained traction in classrooms from kindergarten through college. The Buck Institute for Learning, an organization dedicated to supporting educators in implementing PBL, has defined seven essential project design elements that make PBL work: a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product (Buck Institute, 2015).

Westminster, CO is a town with a population of about 115,000 just northwest of the capital city of Denver. It is an urban area, with a young working-class populace (Informatics, 2016). Westminster High School is one of two high schools in the district, and one of the largest in the state. Enrollment is approximately 2,500 students. Seventy-six percent of students are Hispanic; many of these are English-language learners. The neighborhoods served by the school are lower middle class, and 77% of students are eligible for free-or-reduced lunch. Another factor that impacts teaching at this school is the high rate of chronic absenteeism; 22% of students miss 15 or more school days per year. I believe PBL will help address some of the unique academic issues that these students face.

In my classroom research study, I measured the impact of a PBL environment in comparison to a traditional learning environment. Specifically, I was interested in the following research questions:



1. Are students who have been instructed through a PBL model of learning, versus a traditional model of learning, able to achieve higher scores on post-assessment measures of student learning?
2. Does PBL have a greater impact on ELL students than on native English speakers?
3. Does learner engagement improve in a PBL model of learning?

The research was conducted in an eleventh grade biology classroom. This course is a required class for all students attending the high school. I instructed three classes (the treatment group) using a PBL model of learning, and my remaining two classes (the comparison group) using a more traditional model of learning.

### CONCEPTUAL FRAMEWORK

Problem-based learning (PBL) is “an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” (Savery, 2006). In various classroom environments, PBL has been shown to be effective in improving everything from self-efficacy beliefs (Mataka, 2015) to student attendance rates (Creghan, 2015), not to mention gains in academic achievement (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014).

Medical schools were the first to develop and implement the PBL strategy, and much of the research on the effectiveness of PBL comes from the medical field (Wilder, 2015). However, PBL has become a popular strategy for instruction in both secondary and primary schools in recent years.

PBL has been shown to have a positive impact on both performance on immediate post-assessments and on long-term retention of content. Two groups of 9<sup>th</sup> grade chemistry students were compared in a 2008 study in order to determine if PBL increased academic achievement. “Post-test mean scores...were found to be 81.8 in the experimental [PBL] and 62.4 in the control [traditional] group” (Tarhan, Aya-Kayali, Ozturk Urek, & Acar, 2008, p. 293). A 2014 study of active learning (including PBL) found “increases in examination performance that would raise average grades by half a letter, and that failure rates under traditional lecturing increase by 55% over the rates observed under active learning” (Freeman et al., 2014, p. 8410).

In their study of secondary science students, Hang Wong and Day (2009) found that “the results from delayed post-testing suggest that PBL may have longer-term effects on students’ learning outcomes” (p. 635). Students in the PBL group worked in groups of five or six to determine a solution to a problem presented to the class by the teacher. The groups then presented their findings to their peers. The instructional design followed many of the essential design elements proposed by the Buck Institute, and incorporated many 21<sup>st</sup> century skills such as collaboration and communication, in addition to the science content.

Two additional studies were of particular interest, considering the demographics of the school at which the action research would be undertaken. In the first, the impact of a PBL curriculum on the attendance of economically disadvantaged students was analyzed. Creghan and Adair-Creghan (2015) looked at attendance rates of two schools in the same district over a three-year period. One of the schools utilized a traditional curriculum, while the other used a PBL curriculum. In the PBL school, there was a

statistically significant higher attendance rate for each of the years analyzed. In the second study, the researchers determined the verbal proficiency of students in both the control and study groups, and then analyzed the impact of PBL on students of different verbal proficiencies. While there was “no meaningful learning difference by instructional condition for the most verbally proficient students, students whose verbal ability was midrange and below learned more in PBL classes than they did in the lecture classes” (Mergendoller, Maxwell & Bellisimo, 2006, p. 62). This study indicates that PBL could be a very effective strategy for use with ELL students, whose reading, writing and speaking proficiencies are generally lower than their non-ELL peers.

While there are some promising implications of the use of PBL in the secondary science classroom, the current research on PBL is limited. Due to small sample sizes, Wilder (2015) states that “it is not possible to claim with a high degree of confidence that PBL is indeed more effective in increasing student content knowledge” (p. 432). Additionally, Vasconcelos (2012) found that “it is often observed that students who have little or no experience with PBL rely more heavily on their tutors” (p. 226), making PBL a labor-intensive strategy for teachers to implement.

Overall, current research shows overwhelmingly that PBL is an effective strategy to improve academic performance of students from diverse classroom settings. In a meta-synthesis of eight meta-analyses, Johannes and van Barneveld (2009) found that

PBL was effective when it came to long-term retention and performance improvement....therefore, preference should be given to instructional strategies that focus on students’ performance in authentic situations and their long-term

knowledge retention, and not on their performance on tests aimed at short-term retention of knowledge (p. 55).

PBL is not a silver bullet; it cannot address every single issue educators face today. In some educational settings, and for some types of learners, PBL is most certainly not the best approach. However, the research reviewed here has shown that PBL can not only improve academic achievement, but can also help students to learn essential skills such as teamwork, problem solving, and communication.

## METHODOLOGY

In this study, I sought to analyze the impact of problem-based learning on both academic achievement and learner engagement, as compared to a more traditional model of learning. Are students who have been instructed through a PBL model of learning, versus a traditional model of learning, able to better perform on post-assessment measures of student learning? And throughout the learning process, do students feel that they are more engaged in the learning process? My research questions were as follows:

1. Does performance on post-assessment measures of student learning increase in a PBL model of learning?
2. Does student engagement in the learning process increase during PBL?
3. Is PBL a more effective strategy for English language learners (ELLs) to acquire content knowledge and demonstrate proficiency?

### Participants

The study was conducted at Westminster High School, a large suburban high school with an enrollment of around 2500 students. Seventy-two percent of students are

Hispanic, and 31% of the student population is considered to have limited English proficiency.

The study was conducted in a biology classroom with a total of 112 students; 65 students were male and 47 were female. Students ranged in age from 14 to 19 years old. Five classes participated in the study: two were taught through a traditional lecture-based format (comparison), and three treatment classes underwent the PBL treatment.

Comparison class one consisted of 27 students (13 males, 14 females) and comparison class two contained 18 students (14 males, 4 females). Treatment class one consisted of 20 students (14 male, 6 female), class two had 20 students (9 male, 11 female) and class three contained 27 students (15 male, 12 female). For the purposes of data analysis, ELL students were identified in each group; however, these students received the same intervention as the non-ELL students. In the comparison group, there were five students classified as ELL. In the treatment group, 16 students were classified as ELL.

### Intervention

The intervention consisted of one unit of instruction (over a five week period) provided via problem-based learning to the treatment group. The time frame for instruction was consistent between the treatment and comparison groups. Instruction occurred during the second semester of the general biology course; the unit of study was genetic inheritance.

In the unit, students in the treatment group were asked to take on the role of a genetic counselor. Each small group was supplied with a family history for a client that was seeking genetic counseling. Their task was to produce a brochure for the client that

would outline the genetic condition in question, explaining how the trait was passed from one generation to the next and advising the client about their risks of passing the condition on to any potential offspring.

There were checkpoints built in throughout the project design to ensure that students were learning the background information that they needed to have in order to be successful in creating their final product (Appendix A). However, no direct instruction was given, and on any given day groups in the same class period could be working on a multitude of activities that were designed to support their learning of this background content. This student-paced learning is reflective of how work flow happens in the real world, and is meant to give students more control over what they learn and how they learn it.

#### Data Collection

I collected both qualitative and quantitative data in order to address all my research questions. The quantitative data consisted of a pre-unit and post-unit assessment (Appendix B). The qualitative data consisted of student interviews (Appendix C), student surveys (Appendix D) and teacher observations (Appendix E). 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 F).

Student surveys were offered to all students in both the comparison group and the treatment group. 97 students in total chose to complete the survey, 50 from the treatment group and 47 from the comparison group. Students indicated on these surveys whether or not they would be willing to participate in an interview about their experiences during the learning unit. From this list, four students were selected for interviews. Student

interviews were not incentivized, and so students simply self-selected based on their interest in sharing their perspective on their own engagement in the course.

Table 1  
*Data Triangulation Matrix*

Focus Question	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. Does PBL yield higher performance on post-assessments?	Pre-unit assessment data	Unit pre-assessment data	Unit post-assessment data
<i>Sub-Questions:</i> 2. Does PBL impact ELL students more than non-ELL students?	Unit pre-assessment data	Unit post-assessment data	Student survey (post-unit)
3. To what extent does PBL impact learner engagement?	Student interviews	Teacher observations	Student survey (post-unit)

## DATA ANALYSIS

My research questions focused on academic impact and student engagement, and both qualitative and quantitative data were collected in order to answer these questions. In order to determine that there were no pre-existing significant differences in academic performance between the treatment and comparison groups, a *t*-test was performed on the post-assessment scores for the learning unit prior to the classroom research unit ( $t(95) = 0.55, p = 0.5834$ ). The comparison group had a mean score of 19.7 (SD=6.39) while the treatment group had a mean score or 20.31 (SD=4.49), meaning there was no significant difference in the academic abilities of these two groups.

My primary research question was *does performance on post-assessment measures of student learning increase in a PBL model of learning?* My results indicated that not only

did student learning not increase in a PBL model of instruction, but that this intervention actually had a negative impact on student learning.

A *t*-test analysis was performed on both the pre- and post-unit assessments in order to determine whether there was a statistical significance between the performances of these two groups. There was no significant difference in performance between the comparison group (M=2.93%, SD=5.45) and the treatment group (M=4.17%, SD=10.67) on the unit pre-assessment ( $t(109) = 0.71$ ,  $p = 0.484$ ). However, there was a significant difference in performance between the comparison group (M=53.45%, SD=29.4) and treatment group (M=40.53%, SD=22.11) on post-assessment performance ( $t(87) = 2.44$ ,  $p = 0.0165$ ).

Normalized gains were also calculated for each group, and a *t*-test analysis performed.

Again, there was a significant difference in performance between the comparison (M=0.53, SD=0.30) and treatment (M=0.36, SD=0.25) groups.

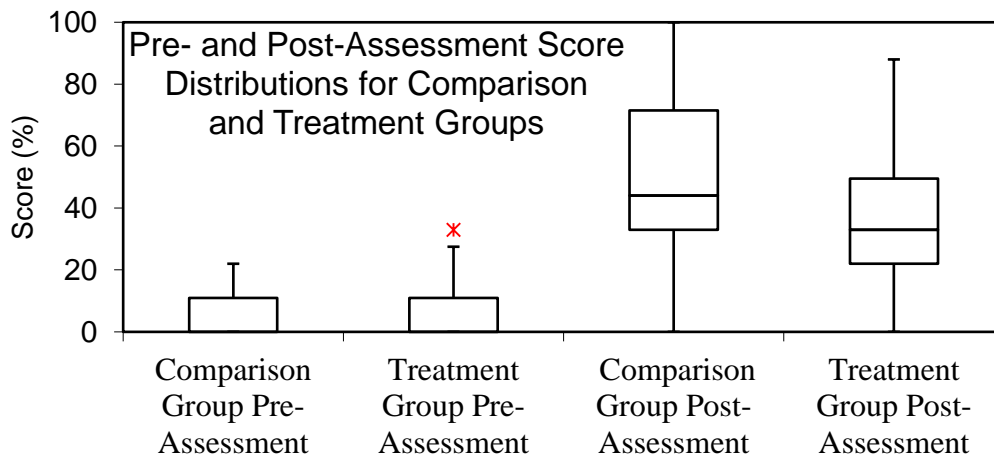


Figure 1. Pre- and Post-Assessment Score Distributions, ( $N=113$ ).

Students who completed the PBL unit performed statistically worse on post-unit measures of learning than their peers who completed the traditional unit. With a median score of 53.45%, versus 40.53% for the treatment group, the comparison group appears to



have gained slightly more content knowledge. However, both groups did make content knowledge gains during the unit.

My second sub-question was in regards to the academic achievement of ELL students (*is PBL a more effective strategy for English language learners (ELL) to acquire content knowledge and demonstrate proficiency?*). Median scores and standard distributions were determined for both the pre-and post assessment data for the identified ELL students within each group (Figure 2). Due to the small sample size (only 16 identified ELL students between the two groups), a *t*-test was not performed. On the pre-assessment, all members of the comparison group had a score of zero, while the treatment group had a median score of 2.75% with a standard distribution of 4.97 on the unit pre-assessment. On the post-assessment the comparison group had a median score of 19.25% (SD=25.99) while the treatment group had a median score of 34.83% (SD=21.41).

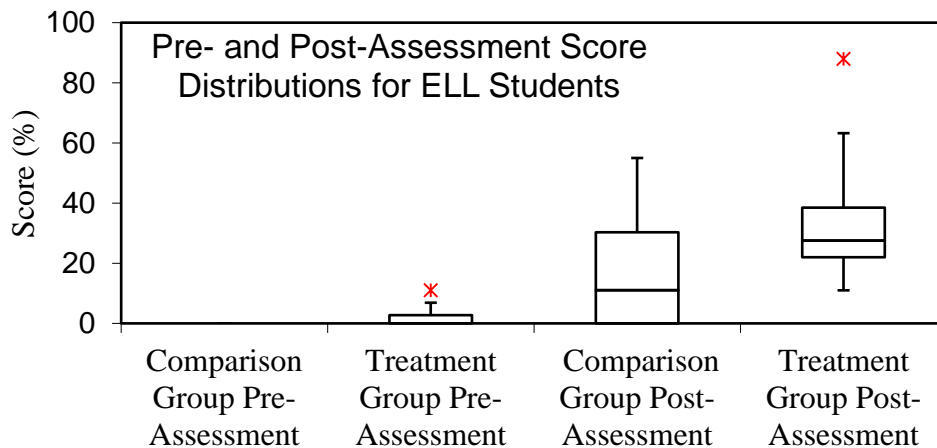


Figure 2. Pre- and Post-Assessment Score Distributions for ELL students, ( $N=16$ ).

It is interesting to note that the median score of the ELL students in the treatment group was 34.83%, compared with the 19.25% of the ELL students in the comparison group.

While both groups performed lower than the averages for their respective groups, it seems PBL might have been a more effective learning strategy for ELL students.

The third sub-question was *does learner engagement improve in a PBL model of learning?* A *t*-test was performed for the results of each of the nine Student Engagement Survey questions; the results are presented in Table 2. It was determined that there was a significant difference in the mean responses between groups for each of the nine questions on the survey.

Table 2  
*t*-Test Analysis of Student Survey Questions

	Comparison Group		Treatment Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Question 1: I can see how the material we learned in the genetics unit applies to real life.	3.60	0.97	4.06	0.74
Question 2: The material we learned in the genetics unit is important.	3.77	0.87	4.24	0.72
Question 3: I felt like I had control of what I was learning during this unit.	3.36	0.79	3.88	0.90
Question 4: The expectations in biology are fair.	3.72	0.74	4.14	0.76
Question 5: When I am in biology, I check to make sure I understand what I am doing.	3.53	0.76	3.96	0.83
Question 6: When I do well in biology, it's because I've worked hard.	3.99	0.91	4.16	0.87
Question 7: The test/project we had for this unit did a good job of measuring what I've learned.	3.55	0.83	3.96	0.81
Question 8: What I'm learning in biology will be important in my future.	3.32	1.04	3.82	0.92
Question 9: I feel like I have a say about the work I do in biology class.	3.21	0.98	3.82	0.85

*Note.* Responses were indicated on a Likert scale, 1 = strongly disagree, 5 = strongly agree. ( $N=97$ )

Mean scores for each question, along with standard deviations, are summarized in Figure 3 below.

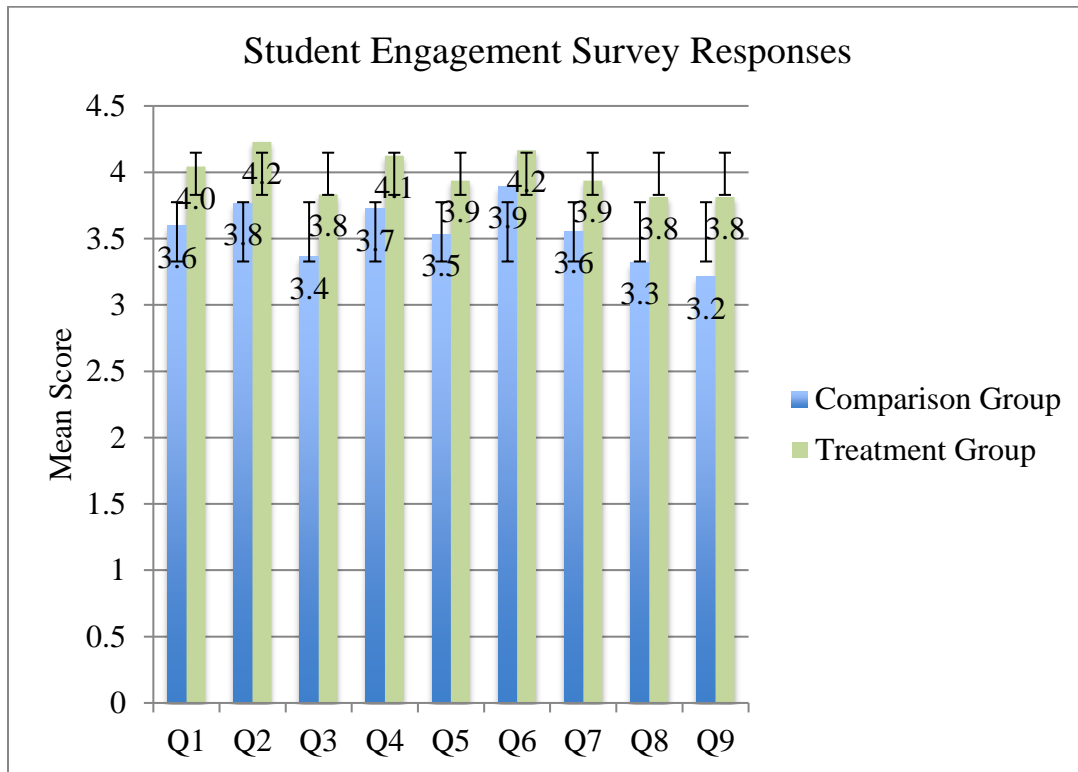


Figure 3: Student engagement survey responses, (N=97).

The level of student engagement and overall satisfaction with their experience in the biology class was significantly higher among students who participated in the PBL unit. Students in the treatment group, as a whole, felt that the content we had covered was more important, and more relevant to their lives, than did the students in the comparison group. They also reported feeling more ownership and control over their own learning; for example, the median score in response to question 9 (“I feel like I have a say about the work I do in biology class”) was 3.82 for the treatment group, but only 3.21 for the comparison group.

The student interviews seem to agree with this data. When asked “did you like learning in this way?” students from the treatment group all stated that they did. “I like it because it

was more engaging, and helps me interact more with my classmates,” stated one student. “It was more fun, and a lot easier” said another.

### INTERPRETATION AND CONCLUSION

Problem-based learning has been shown in several studies to be an effective strategy for content knowledge acquisition in the sciences. Unfortunately, I was not able to demonstrate this during my classroom study. In his 2015 work, Wilder stated that “it is not possible to claim with a high degree of confidence that PBL is indeed more effective in increasing student content knowledge” (p. 432). My results agree with this statement, as not only did my treatment group not demonstrate increased content knowledge, they actually performed somewhat worse than their peers in the comparison group.

In a 2006 study, Mergendoller, Maxwell & Bellisimo found “no meaningful learning difference by instructional condition for the most verbally proficient students, students whose verbal ability was midrange and below learned more in PBL classes than they did in the lecture classes” (p. 62). While my ELL student sample size was low, it is interesting to note that the ELL students in the treatment group did perform somewhat better on the post-assessment measure of learning than did the students in the comparison group. The genetics unit of learning is a vocabulary-intensive unit, and so perhaps for these students especially, learning the content and vocabulary through real-world application was easier than learning through a more traditional lecture-based format. On measures of student engagement, my treatment group agreed with the studies that have shown that PBL is a helpful strategy for improving student self-efficacy beliefs and engagement. The treatment group, as a whole, found the content more important and more relevant to real life. These students were also more likely to attribute their success

in the course to their own hard work, and to report the expectations of the course as being fair. When asked what part(s) of the PBL process they liked the most, one student reported that he “liked all of it...especially the unit tracker, so that I could work at my own pace.” Students recognized that this was reflective of how work proceeds in the real world: a deadline will be set for a project, and they have to work through a certain number of steps in order to complete the project on time. Although many students in the treatment group struggled with time management, and many did not actually complete their project on time, I believe that it was a valuable learning experience in goal setting and budgeting their time.

As an educator, my classroom research has been enormously helpful as I work to incorporate more PBL units into my instruction. In the future, I realize that I will need to scaffold much more for my students, especially during the first few PBL units.

Vasconcelos (2012) found that “it is often observed that students who have little or no experience with PBL rely more heavily on their tutors” (p. 226). While I can attest to this, I believe that over time, and with significant scaffolding and support, PBL instruction can become intuitive and valuable for both instructors and students alike.

I believe the use of strict deadlines for all phases of a project should be enforced, not just a deadline for the final product. This is borne out by the reflections of one of the students whom I interviewed. “I wish I would have had more due dates...I know there was one big due date, but I just wanted a due date for each thing that we were supposed to turn in.” Accountability should be a built-in part of the process.

## VALUE

PBL has the potential to be a powerful learning opportunity for all students, but I think most especially for students who may have been disenfranchised from a more traditional classroom setting. Though the academic results of this study were disappointing, it was still a valuable learning experience for all of my students. Not only did they gain some content knowledge in the area of genetics (though slightly less than their peers in the comparison group), they also developed important 21<sup>st</sup>-century skills such as time management, collaboration, critique and revision, and metacognition. Additionally, students self-reported that they felt more engaged and had an overall better attitude towards biology both during and after the unit. The outlook for ELL students, especially, learning through PBL is promising.

The use of student data to inform instruction is imperative for teachers to improve their practice. It is important to have a grasp of the latest educational research and techniques, but it is equally important to be able to assess and analyze the impact of techniques within your own classroom. Although my data from this particular study did not show increased content knowledge acquisition through a PBL mode of learning, I do plan to continue developing PBL units because I see the value in this type of learning beyond academic performance.

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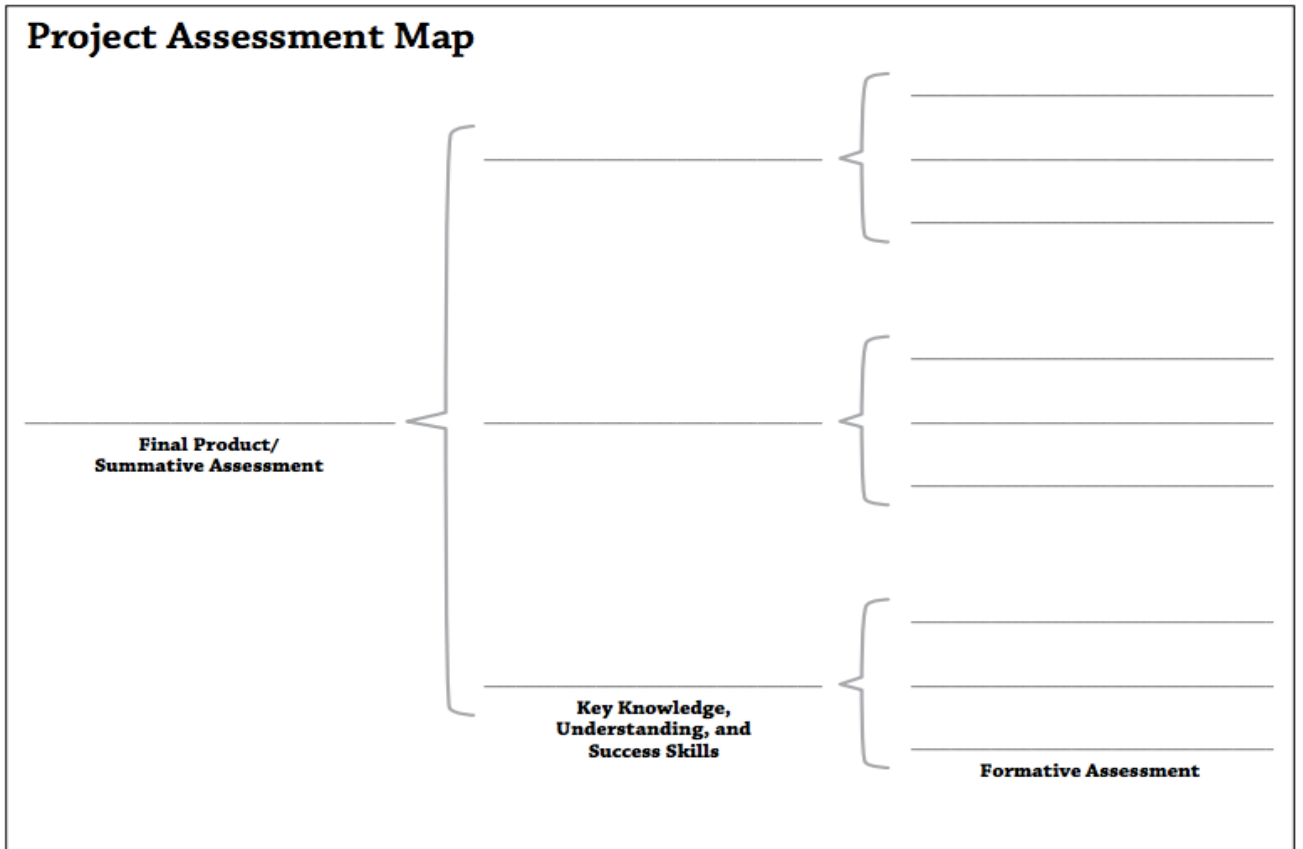
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APPENDICES

APPENDIX A  
PROJECT ASSESSMENT MAP



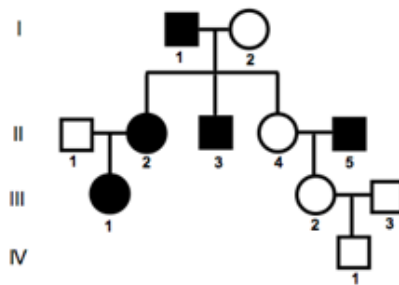
APPENDIX B  
PRE- AND POST-ASSESSMENT

Name:

Date:

### Genetics Assessment

1. Cross a pea plant homozygous dominant for purple flowers (P) with a white pea plant. Provide potential genotypic *and* phenotypic ratios of offspring. Use a Punnett Square to determine your answers.
  
2. Use the pedigree below to answer the following questions:
  - a. Suppose the disorder in question is an autosomal dominant disorder. Provide genotypes for following individuals: I-1, II-1, III-1.
  
  - b. Suppose individual III-1 has a child with an unaffected male. What is the percent chance that the child will *not* have the disorder?



APPENDIX C  
STUDENT INTERVIEW QUESTIONS

**Student Interview Questions**

1. How well did you understand how a trait is passed down from one generation to the next, prior to this unit?
2. How do you feel you understand human genetics now?
3. Describe how this learning unit was different for you than other learning units we have had in this class.
4. Did you like learning this way? Why or why not?
5. What challenges did you have during this unit?
6. Which parts of the process were most helpful?
7. Which parts of the process were least helpful?
8. Is there anything else you would like to tell me about your learning during this unit?



APPENDIX D  
STUDENT ENGAGEMENT INSTRUMENT

# Student Engagement

Please rank the following items on a scale from 1 (strongly disagree) to 5 (strongly agree). Your responses will be kept confidential and will have no impact on your grade in the class.

I can see how the material we learned in the genetics unit applies to real life.

Strongly disagree      1      2      3      4      5      Strongly agree

The material we learned about in the genetics unit is important.

Strongly disagree      1      2      3      4      5      Strongly agree

I felt like I had control of what I was learning during this unit.

Strongly disagree      1      2      3      4      5      Strongly agree

The expectations in biology are fair.

Strongly disagree      1      2      3      4      5      Strongly agree

When I am in biology, I check to make sure I understand what I am doing.

Strongly disagree      1      2      3      4      5      Strongly agree

When I do well in biology, it's because I've worked hard.

Strongly disagree      1      2      3      4      5      Strongly agree

The test we had for this unit did a good job of measuring what I've learned.

Strongly disagree      1      2      3      4      5      Strongly agree

What I'm learning in biology will be important in my future.

Strongly disagree      1      2      3      4      5      Strongly agree

I feel like I have a say about the work I do in biology class.

Strongly disagree      1      2      3      4      5      Strongly agree

Would you be willing to participate in an interview about your experiences during the genetics unit?

Yes

No

APPENDIX E  
TEACHER OBSERVATION INSTRUMENT



APPENDIX F

IRB Approval



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

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**MEMORANDUM**  
 .....

**TO:** Kayla Robinson and Eric Brunsell  
**FROM:** Mark Quinn  
**DATE:** November 30, 2016  
**SUBJECT:** "The Impact of Problem-Based Learning on Academic Achievement in the High School Science Classroom" [KR113016-EX]

The above research, described in your submission of November 30, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (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.