

HOW FORMATIVE ASSESSMENTS IMPACT STUDENT OUTCOMES WITHIN A
SCIENCE CLASSROOM

by

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DEDICATION

I would like to dedicate this paper to my family and friends who were a guiding light through my master program. I would not have been able to finish this project without your love and unwavering support.

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ABSTRACT

Formative Assessments (FAs) help inform teachers of best practices, a student's level of understanding, and help provide predictions for a given standard throughout a unit. The use of Next Generation Science Standards (NGSS) aligned with FAs allows teachers to anticipate student outcomes concurrently while the unit is being taught. This study's purpose is to observe and test the use of incorporating NGSS aligned FAs to increase teacher clarity, responsiveness, and student outcomes within a genetics unit at Skyline High School. Students took a pre-assessment to identify their baseline understanding of genetics. Five FAs were provided to inform teacher strategies and practices to effect change in student understanding and defined outcomes over the course of delivery of the unit. Post-assessment results displayed an increase in student understanding and teacher self-reported responsiveness to address established concerns. A Teacher Journal posed five questions to allow reflection and track the teacher's classroom experience. The collected data was analyzed using a mixed methods approach to determine overall student and teacher growth. NGSS FAs were beneficial in addressing outcomes, responsiveness, and clarity by increasing awareness and adaptability. FAs promoted educator and student engagement, encouraged self-reflection through the educator's lens, and enhanced information accessibility, application, and retention of subject matter. Pedagogically FAs are useful and can help provide predictions of student understanding for all content curriculums.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Growing up, one of my goals was to become a scientist or a teacher. My mother and grandmother were teachers, which fostered my love for the profession. As a child, I was innately curious about life and the world around me. Being a teacher has not been easy; however, it has been one of the most satisfying experiences I have ever had. In January 2013, I was hired by Granite School District and taught 7th grade science and biology at Wasatch Junior High. In 2017, the ninth graders were moved up to Skyline High School (SHS) and I had an opportunity to transition with them. I have been at Skyline now for the past six years where I teach Biology and Medical Terminology.

SHS is in Holladay, Utah and serves the higher socioeconomic townships of Millcreek and Holladay, both suburbs of Salt Lake City. Classes at Granite School District rotate through an alternating schedule of A days (Monday and Wednesday) and B days (Tuesdays and Thursdays); and Fridays are an alternative between the two. SHS is ranked as the top public high school in Utah preparing students for college readiness (Nesbitt, 2023). SHS offers the International Baccalaureate (IB) program and a wide range of advanced placement (AP) courses. If students are along the pre-IB track, it is recommended they take a co-occurring honors class. The science department at Skyline consists of 10 IB qualified teachers. The science department offers Earth Science, Physics, Biology, Chemistry, Environmental Science, and Zoology. Among these courses are core, honors, four AP, and three IB classes and three Concurrent Enrollment.

Within the 2022-2023 school year, SHS trained teachers on developing formative assessments (FAs) and highlighted the benefits of instructional use within the classroom. Formative assessments have been defined as the process teachers and students engage in throughout phases of learning that enhances the receptivity for students to learn and respond in discourse (Cowie & Bell, 1996, p. 3). To assist with this transition, my school has integrated professional developments that outline student success and help teachers expand their curriculum to align with FAs. As SHS started the creation of FAs within our professional development, I wanted to focus my action research (AR) project on how formative assessments can directly impact student outcomes.

Focus Statement/Question

My focus question was, How does the use of Formative Assessments (FAs) aligned with Next Generation Science Standards (NGSS) impact teacher clarity and responsiveness when implemented within a genetics unit?

My sub-question includes the following:

1. How does the implementation of NGSS aligned with FAs impact student outcomes within a genetics unit?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

Assessments are prevalent within the classroom. From a pedagogical standpoint, Formative Assessments (FAs) inform teachers of best practices and the student's level of understanding. FAs are a way that a teacher can assess students without relying on summative assessments. The use of classroom assessments allows teachers to predict student outcomes for a given standard. These types of assessments allow for the teachers to understand when and where modified teaching needs to be addressed.

How Formative Assessments are Developed

FAs can be developed and administered in a variety of ways within the classroom. Lyon and Wylie (2016) created three questions to help teachers determine if educator assessments are beneficial, which are “where am I headed, where am I now, and how do I close the gap” (p. 3). They expanded the questions to highlight clear learning goals, the direction of student outcomes, student learning, identified spaces, and gaps between intended and actual learning. Cowie and Bell (1999) administered a two-year study to investigate the influence of planned and interactive types of FAs and the impact on elementary through secondary students. Findings reported that planned and interactive types of FAs within a classroom are vital and depend on the teacher's pedagogical practice (Cowie & Bell, 1999).

Abell and Sevian (2021) conducted a year-long investigation with 19 chemistry teachers, revealing that feedback and formative assessments within portfolios are crucial for identifying

student needs and transforming teaching practices. They determined that this type of feedback can be indispensable in helping a teacher to identify a student's needs present and future; portfolios showed how FAs can change a teacher's practice in "the areas of task design, purpose, and focus when evaluating student work" (Abell & Sevian, 2021, p. 1). The various means of implementing content exposed "additional time and effort is likely to be required to transform teachers' beliefs about the goals of chemistry FA in the classroom" (Abell & Sevian, 2021, p. 9). The findings were specific to chemistry teachers and students; however, it is plausible that across disciplines, students would benefit from ongoing classroom assessment use. Therefore, the integration of formative assessments and feedback into teaching practices holds promise for enhancing educational outcomes across various subjects.

Researchers found that responsive teaching was seen within each of the teachers who administered and changed FA design within their classroom (Abell & Sevian, 2021, p. 9). When feedback is implemented daily, teachers can see a student's learning take place. According to Fletcher-Wood (2018),

Constantly seeking to improve by identifying what students have learned and responding according should be central to our identity as teachers. Tracking student learning shifts our perspective away from the effort we put into our teaching and towards how well it is working (p. 14).

Although FA administration varies, the results depend on the teacher and the type of desired impact in the classroom. The full purpose of a FA is to identify where students' learning is taking place and not how teachers are teaching.

Formative Assessments Variations

Assessment types vary based on the situation and are vital to promoting the learning process. As stated in Lyon and Wylie's (2016) study, when teachers have FAs with established

dimensions, they can modify teaching styles and evaluate learning needs during the learning process. They stated that “the dimensions represent a set of integrated formative assessment practices; focusing on just a single dimension would not result in a robust implementation of formative assessment” (Lyon & Wylie, 2016, p. 3). Dimensions for implementing FAs in a classroom have been explored and categorized into ten areas. Along with the three different guiding questions, the dimensions help improve teachers' implementation (Lyon & Wylie, 2016, p. 38). An example of a dimension is learning goals. Each portion of the dimension is to help the teacher and student successfully identify the teacher and student involvement. Kohnke et al. (2022) stated “teachers can also benefit from its assessment of student learning to inform and adapt their teaching” (as cited in Popham (2008) & Yan et al. (2021), p. 2). Researchers collaborated in devising purposes and implementation strategies i.e., dimensions of FAs to inform educational practices. Taking the time to evaluate a teacher’s work is a vital step in carrying out FAs, because it helps a teacher attune to students needs to best support learning.

FAs, when implemented daily, can affect teacher/student relationships, and can impact how each student learns. Dini et al. (2020) break apart how assessments for learning can be integrated within the classroom. They are: (1) noticing/interpreting, (2) eliciting, and (3) advancing. A study done by Dini et al. created a way for teachers to see the impact of their interactions before and after the administration of FAs within the classroom. Within this study, Dini et al. looked at how FAs were executed from elementary to high school. They aimed to create a tool for teachers to analyze the usage of FA enactment and how it affected student and teacher outcomes. For example, Dini et al. (2020) stated,

Teachers' use of formative assessment (FA) has been shown to improve student outcomes; however, teachers enact FA in many ways Teachers' in-the-moment

purposes and larger learning goals were synthesized as they made choices about teaching acts. The model is framed in terms of utility to teachers to examine their own FA practices, with the aim of becoming better equipped to strategically enact FA in intentional ways to achieve their purposes (p. 1).

A variety of classroom assessment techniques can impact how a student understands concepts and help students succeed. When teachers can be successful in the establishment and implementation of FAs, students can see the impacts in their own learning.

Teacher Impacts Through the Usage of Formative Assessments

Teacher responsiveness and clarity can be increased through FAs. When given daily, it can directly change a teacher's responsiveness and clarity within the classroom. Fletcher-Wood (2020) defined "responsive teaching as a technique in which a formative assessment is used to identify what students have learned and helps teachers avoid distraction and distortion assessments, like summative assessments" (p. 4). FAs can be impactful on both students and teachers. When implemented within a classroom, FAs can help a teacher adjust instruction to meet individual students.

A study done in a Bangladeshi school demonstrated three diverse types of formative assessment to see if they would change the success rate of the teachers. Rahman et al. (2021) researched how FAs, specifically the School-Based Assessment (SBA), were implemented within schools and how it affected teachers and students.

Rahman et al. (2021) stated,

The key findings reveal that the absence of reflection of the marks of SBA in public examinations, teachers' insufficient orientation towards SBA, their negative attitude, lack of validity and reliability of SBA as an assessment tool, teachers' lack of honesty and fairness, their poor socio-economic conditions of teachers, their heavy workloads, large student population, large contents of syllabus, and absence of monitoring and supervision by concerned authorities were the barriers which impeded the successful implementation of this formative assessment approach (p. 15).

Within this study, when FAs were introduced through the SBA system it was found that teachers and students had a negative connotation. When teachers and students have an unpleasant experience, it affects the student success rate, in turn impacting the student performance and investment in learning. Rahman et al. found that when the FAs were introduced and teachers were trained, it changed the way responsive teaching was found within the classroom. Through the study, Rahman et al. listed the barriers that can directly impact how FAs can affect responsive teaching. Barriers are directly impacted by the type of feedback, teacher commitment to use FAs, how teachers enact the classroom assessment, and the overall practice of the implementation. Through proper training and implementation protocol, FAs can impact a teacher's reach within the classroom and to their students.

Teacher clarity and responsive teaching can alter how these types of assessments are presented in the classroom. When FAs are analyzed, it helps change the one-size-fits-all approach and ensures instruction is clear. When an educator makes their learning intentions clear, student learning is significantly impacted. There are several components of teacher clarity and how it can be utilized within the classroom. The components of teacher clarity are one's ability to list planning goals, content, methods, and media within a unit. Reviewing and reflecting on classroom assessments can inform a teacher if their responsiveness and clarity were executed.

Through a teacher journal, a teacher can identify how FAs implementation was experienced. Based on FA application, teachers can identify if a student has been able to capture the concepts and is able to incorporate learnings in lived experience beyond the classroom.

Formative Assessment and Student Outcomes

FAs can impact student outcomes by informing students on areas of strengths and development. Ozan and Kincal (2018) investigated the impact of FAs on a student's academic achievement and attitude over 28 weeks.

Students were given a wide variety of formative assessments through performing tests, attitude inventories, learning skill scales, interviews, and observation forms. It was found that the student's attitude impacted their learning.

Through Ozan & Kincal's study, students were interviewed, and it was found that students' attitudes were positive towards their class, teacher, peer group, and formative assessments. Within this study, it was shown that formative assessments can impact how well a student does within a unit (Ozan & Kincal, 2018, p. 6). When students have clear directions and understand the application, accessibility of the material increases. FAs can help students succeed within the classroom by developing expectations, a shared overarching goal, and teacher supported strategies.

Student outcomes can change the way formative assessments are applied within a classroom. Formative assessments can help guide students throughout their learning, future career choices, and can give teachers and students the evidence that they need to look at student outcomes and the student's learning of a subject. Kohke et al. (2022) stated, "This study showed that learning analytics provided reliable evidence for understanding students' engagement and identifying at-risk students" (p. 1). By seeing an end goal and stopping points along the way,

students can directly anticipate what is expected of them and what type of learning will be taking place.

Conclusion

Throughout history, educators have been looking at ways to help students improve their learning potential within the classroom. Within the past 20 years, assessments for learning have shown a significant impact on how teachers can best help students. FAs are a way that a teacher can easily assess students without always giving a summative assessment. These types of assessments have various aspects and dimensions that can directly affect how teachers and students succeed. FAs vary amongst educators, how they are implemented within the classroom, and help students reach the student outcomes.

CHAPTER THREE

METHODOLOGY

Demographics

This action-based research study focused on implementing a variety of formative assessments (FAs) aligned with Next Generation Science Standards (NGSS) to determine how the FAs impacted teacher clarity and responsiveness. For this study, students were scored along the proficiency-based scale created by Granite School District, four years ago. By grading the students along such a scale, provided me with information about how my responsiveness and clarity aligned with the student outcomes. Formative assessments were implemented within three concurrent general biology classes serving 95 students total, over six weeks. Within each of these classes, respective students have 504 plans or Individualized Education Plans (IEP) and include Multilingual Learners (MLs). Out of these three classes: 7% of the students have IEPs, 8% of the students have 504s, and 11% of the students are Multilingual learners. Fifty-four percent of the students are female and 46% of my students are male. These three classes contained various stages of class grades which are: 35% of freshman, 4% juniors, and 61% are sophomores. Class instruction is adjusted based on students' needs and to help the identified students succeed.

Treatment

The genetics unit will be taught from January to February 2024. Before beginning the unit, students took the Genetics Pre-Assessment so that prior knowledge could be established (Appendix D). For the treatment, starter questions were used to help cover the previous day's

material. The starter question served as a review for students and as FAs. The following tools collected are: (1) Formative Assessment A, (2) Formative Assessment B, (3) Formative Assessment C, (4) Formative Assessment D, and (5) Formative Assessment E (Appendix C). At the end of the genetics unit, students took the Genetics Post-Assessment to measure growth and academic performance.

Table 1. Lists the various instruments used throughout the treatment and their order.

Type of Instrument	Intervention Taking Place
Genetic Pre-Assessment	Baseline for students' previous knowledge.
(1) Formative Assessment A	Mouse Question with a sticky bar graph.
(2) Formative Assessment B	Small white board activity with quiz check.
(3) Formative Assessment C	Quick check in over days with starter questions.
(4) Formative Assessment D	Complex Quiz Check.
(5) Formative Assessment E	Four corners of the room activity and then answering questions from a quiz.
Teacher Journal	The teacher will keep track of their own observations with how FAs affected the classroom.
Genetics Post-Assessment	Ending assessment to determine how or if formative assessments worked.

Data Collection and Analysis Strategies

To collect data that would help me address these questions, I documented student and teacher progress through the Genetics Pre-and Post-Assessment, Formative Assessments A-E, and my teacher journal (Table 2). The data collected via the instruments were analyzed using qualitative and quantitative data techniques to show how FAs increased teacher clarity and responsiveness.

Table 2. Data Triangulation Matrix.

Data Collection Instruments	How does the use of formative assessments aligned with NGSS impact teacher clarity and responsiveness when implemented within a genetics unit?	How does the implementation of NGSS aligned formative assessments impact student performance within a genetics unit?
Genetic Formative Assessments A-E	X	X
Genetics Pre-Assessment	X	X
Genetics Post-Assessment	X	X
Teacher Journal	X	X

Data Collection Methods

Each of the instruments was given to see how teacher clarity and responsiveness and students' performance were impacted. The Genetics Pre- and Post-Assessment will give an area of growth for what students know and understand before and after the unit. The teacher's journal helped identify whether my own growth was taking place within the classroom through the implementation of FAs.

Genetic Formative Assessments A-E

Genetic Formative Assessments A-E (Appendix C) allowed me to collect quantitative data about the students and use it to assess students' understanding of various genetic topics. To measure student outcomes, these check-ins were scored using a proficiency-based scale (1 to 4). Lylie and Wylie (2016) state, "Formative assessments are the ongoing process of collecting evidence of student learning during instruction to in the next steps in teaching and learning while there is still an opportunity to influence learning" (p. 9). Specifically tracking students' scores on

each of their FAs will be a guide for me to help monitor responsiveness and student engagement during unit material delivery. Additionally, the classroom assessments identified various areas where students were struggling and helped pinpoint areas for improvement. This data will be useful in tailoring science curriculum to meet student objectives. By creating a diverse set of checking for understanding questions, I was able to monitor adaptiveness in teacher engagement throughout the genetics unit and observe academic performance.

Genetics Pre-and Post- Assessment

A Genetics Pre-and Post-Assessment (Appendix D) was given to students at the start and end of the genetics unit. This process of implementation allowed me to capture students' baseline knowledge and how it compared to student understanding at the end of a unit. Additionally, the post-assessment allowed me to see if the use of FAs aligned with NGSS impacted clarity and responsiveness from a teacher's point of view. This method of data collection was appropriate because summative assessments are typically administered after the end of a unit, which allows teachers to make administrative decisions and quantify student achievement (Mertler, 2020, p. 153). As such, using FAs alongside summative assessments assisted in identifying whether implementation was effective in identifying teacher methods and responsiveness for overall adherence to unit goals.

Teacher Journal

My Teacher Journal is a form of qualitative data that I monitored throughout the unit (Appendix E). By keeping a Teacher Journal throughout the genetics unit, I was able to get a true sense of how I show up in the classroom as a teacher, particularly regarding whether there was any correlation between FAs and student performance at the end of the genetics unit. A resource

that I used within my Teacher Journal is called TeachFx. TeachFx is a teacher resource that helps identify the type of lesson being taught, the amount of teacher and student talk, and key words that are mentioned.

Mertler (2020) discussed the importance of educators keeping a teacher journal. He stated, "Teacher journals can similarly provide practitioner-researchers with the opportunity to maintain narrative accounts of their professional reflections on practice" (Mertler, 2020, p. 138). Within my Teacher Journal, I tracked subjective and objective impressions about myself and my students. From looking at my observations within this unit, I was able to identify how FAs can affect teacher responsiveness, preparedness for curriculum delivery, teacher clarity, student engagement, and student outcomes. The Teacher Journal can record different means of data collection and measurement to allow for further reflection.

Analysis Strategies

Various amounts and types of data were collected from the diverse instruments implemented. By analyzing the type of data through a mixed methods approach, I was able to make correlations between how FAs have impacted student outcomes and how teacher responsiveness was affected. Results can inform adaptations to teaching methods and reflect student participation within a genetics unit; however, teacher performance can be extended to support additional coursework or classes.

Quantitative Strategies

The data analysis approach for the genetics summative assessment was to administer a paired t-test and compare students' responses throughout the unit. The purpose of the paired t-test

was to allow me to gather data from the same group of students during the genetics assessment (Bartley & Bowen, 2014, p. 52). This perspective offers teachers the ability to compare two different forms of treatment and how they aligned to the desired student outcomes.

Hake (1998) defined normalized gains, “as a rough measure of the effectiveness of a course in promoting conceptual understanding” (p.1). Normalized gains were used to show the comparison of pre-assessment to post-assessment. Normalized gains will allow me to look at the gains that take place within the pre-and post-assessment scores. By providing different variations of data from FAs, I can identify how FAs impact teacher responsiveness and clarity.

Qualitative Strategies

Research design for qualitative data tends to be less structured and more open-ended than quantitative research designs (Mertler, 2020). The Teacher Journal captures unique perspectives from the teacher's point of view, which will allow them to track where they are, what they have accomplished and how they feel like their teaching has been executed. TeachFx will be extremely helpful in identifying the amount of student and teacher talk that will take place within my genetic lessons. TeachFx will allow me to pick up on the keywords that are mentioned with each lesson that I can record within my Teacher Journal. Organizing and collecting various points found within the Teacher's Journal allowed me to create an inductive analysis of all points included in the Journal. A Teacher Journal could be analyzed as mixed research, meaning both qualitative and quantitative. Inductive analysis is the process of “Systematically organizing and presenting the findings of action research in ways that facilitate the understanding of these data (Parsons & Brown, 2002, as cited in Mertler, 2020, p. 55). Inductive analysis will allow me to look for and organize the important themes and patterns present in the data (Johnson, 2008).

Inductive analysis fosters understanding by searching for common keywords, categories, or phrases within the data (Mertler, 2020, p. 174-175), which I will identify through color-coding. By including teacher reflections on FAs, I can identify whether the genetics unit improved student development (Christ & Kiss, 2018, p. 1). Through creating a bar graph, I can see the different components of how well each data point related to each other and if they were sufficient in terms of how they correlated to FAs.

Genetic FAs let me see where students are in the unit and how I can best help direct them from an academic standpoint. From implementing these types of assessments and how they correlate with student outcomes, observations would allow for me to see if there is an impact between the results obtained from completing the FA and cross-referencing the expected genetic student outcomes. Through the usage of FAs, a Genetic Pre-and Post-Assessment and a Teacher Journal, I can identify whether end goals were directly impacted by FAs.

CHAPTER FOUR

DATA ANALYSIS

Results

The purpose of this study was to research how NGSS-aligned FAs can increase teacher clarity and responsiveness. By looking at the questions and student's work, a teacher can measure how well their responsiveness takes place within a unit. Responsive teaching and clarity are when a teacher takes the time to understand exactly what should be taught and what learning should take place. A sub-question that was researched was how NGSS-aligned FAs impact student outcomes. During the genetics unit, students were given five various FAs, along with a pre- and post-assessment that targeted specific student outcomes. Over the course of this six-week study, it was found that FAs helped increase student outcomes by 53% and teacher responsiveness by 83%.

Inductive Analysis of Teacher Journal

Recording daily within my teacher journal allowed me to provide timely insights into student understanding and guiding targeted instructional adjustments. I tried to answer five questions each day which allowed me to identify the patterns and themes that took place. The five questions were: (1) How do I know that my students learned what we talked about today? (2) How many of the students showed a change? (3) Did I show clarity and teacher responsiveness? (4) What would I change? and (5) How will this inform my next section? I also recorded any student questions that were asked during the unit.

At the end of each day, I recorded what I noticed and what occurred during each lesson from the aspect of the five questions. Here is an example of how my Teacher Journal was kept:

I will know that my students will know what we talked about today by being able to apply Mendel's 3 laws and how it relates to the lab to which we are applying. I think that by first going through and over specific problems in class, it really helped solidify students' understanding of Punnett squares and how it works within a genetics problem. Students were able to understand how to set up a Punnett square and then fill out the problem (Appendix E).

From the example, you can see how I captured the productivity of teacher clarity and responsiveness through the usage of FAs.

Looking at each question helped me keep track of teacher clarity and responsiveness and for the learning impacts of the FA implementation. Specifically identifying scaffolding and clarity within each lesson helped me identify student outcomes and student changes. By color-coding the five different themes within my journal, I found the recurring patterns that occurred which are: (1) student learning, (2) student change, (3) teacher change/inform, and (4) responsiveness/clarity. Out of the twelve A days, student learning occurred each day (100%), teacher responsiveness occurred (83%), and students showing a change/what I changed occurred 60% of the time (Figure 1).

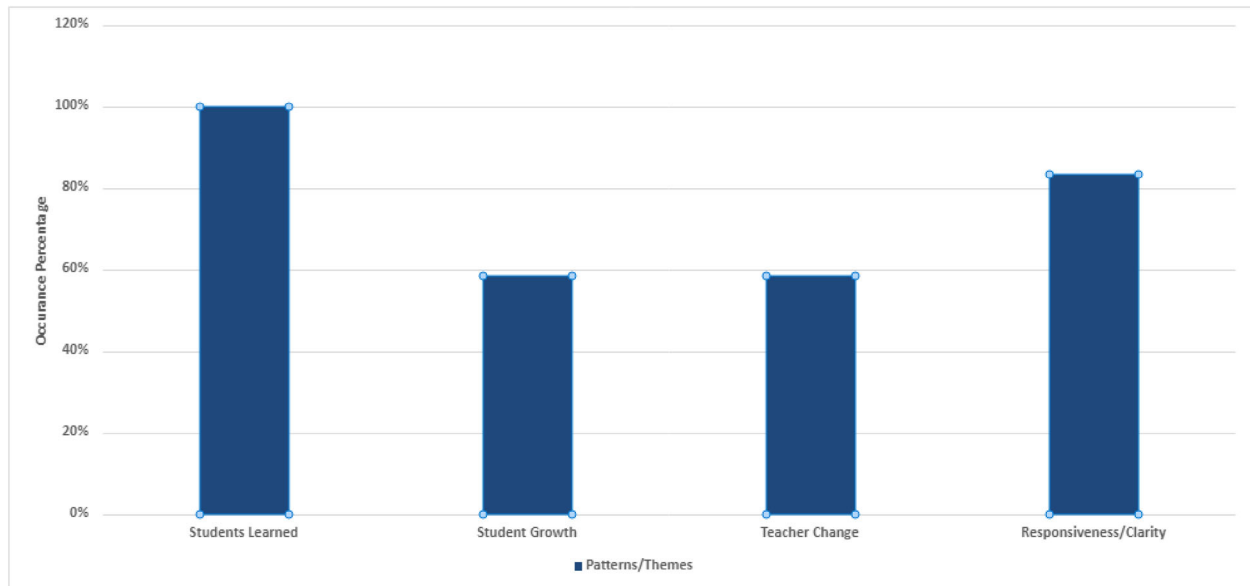


Figure 1. Patterns and themes found within my teacher journal.

By marking each of the four sections, one can compare how student learning and teacher clarity changed the way that genetics was addressed and how the essential question was identified. A program called TeachFX was used as a way for me to analyze teacher clarity and how well I responded to students as a teacher. From listening to the TeachFX recordings, I was able to identify the amount of teacher/student talk and the main topic that was being taught. (Figure 2).

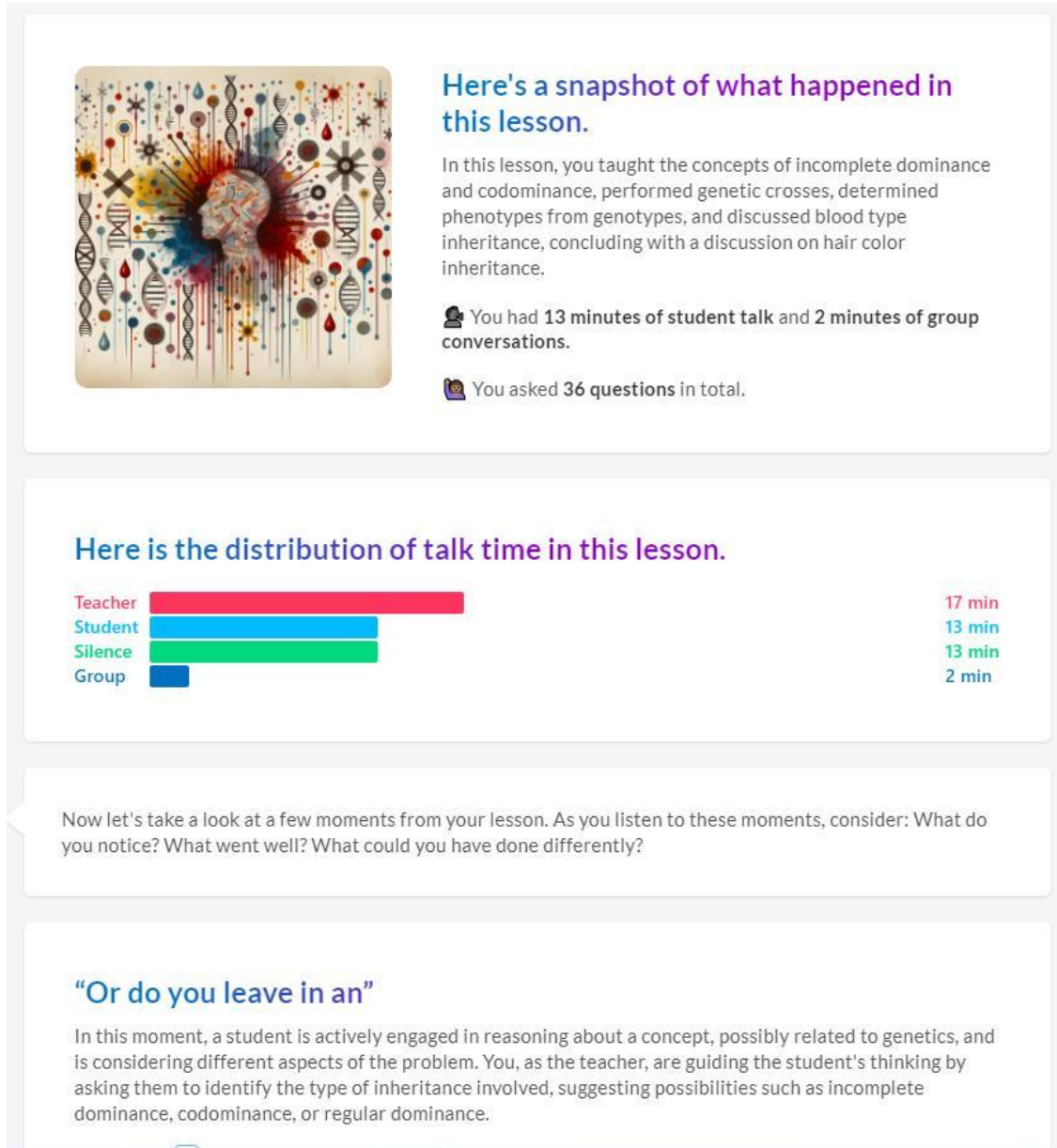


Figure 2. TeachFX layout of what was caught during the Genetic Formative Assessment E.

By providing this type of feedback, I examined how well teacher responsiveness and clarity were impacted from the type of FA being implemented for that day. TeachFX would record the student talking, teacher talk, and any group talking. Recording through TeachFx, would allow me to review any key words and questions that were being asked on a specific day.

Identifying what TeachFX recorded during the teacher talk and student talk provided me with insight into how the adjustments were made for my students' learning.

Pre-and Post-Assessment Data Results

Along with keeping a teacher journal, to help evaluate the scale of student and teacher growth, students were given a pre-assessment, five formative assessments, various practice assignments, and a post-assessment that were graded on a proficiency-based learning scale. At the very beginning of the genetics unit, students were given a pre-assessment where students scored an average of 0.68 and ranged between 0-1.66. At the end of the unit, students were given the same test where students scored an average of 2.35 and ranged between 0-3.9 (Table 3).

Table 3. Identifies the range of scores given with the pre- and post-assessment, ($N=70$).

	Pre-Assessment	Post-Assessment	Statistical Significance
Mean	0.68	2.35	$P=0.00147$, $P<0.05$
Range	1.66	3.90	

Within the student outcomes (Appendix B), on the pre-assessment, students averaged 0-1 and students averaged a 2-3 range, after taking the post-assessment. This shows that even before the usage of FAs within the unit, students were less proficient in their genetics knowledge, by scoring a mean of 0.68 on the pre-assessment. After implementing FAs, students were approaching proficiency within the genetics unit, by scoring a mean of 2.4 on the post-assessment. Having a variety of FAs was strongly positively correlated to student outcomes by having a $p>0.05$.

Overall, there was an increase in the average scores from the pre- to the post-assessment of a difference of 44%. The median score increased by a score of 1.72. Looking at the Canvas Quiz statistics, it is also fascinating to note that the standard deviation rose from 0.39 to 0.71. By looking at the graphs that Canvas Quiz Statistics created for these two assessments, one can see that the scores changed between the pre- and post-assessments (Figures 3 & 4).

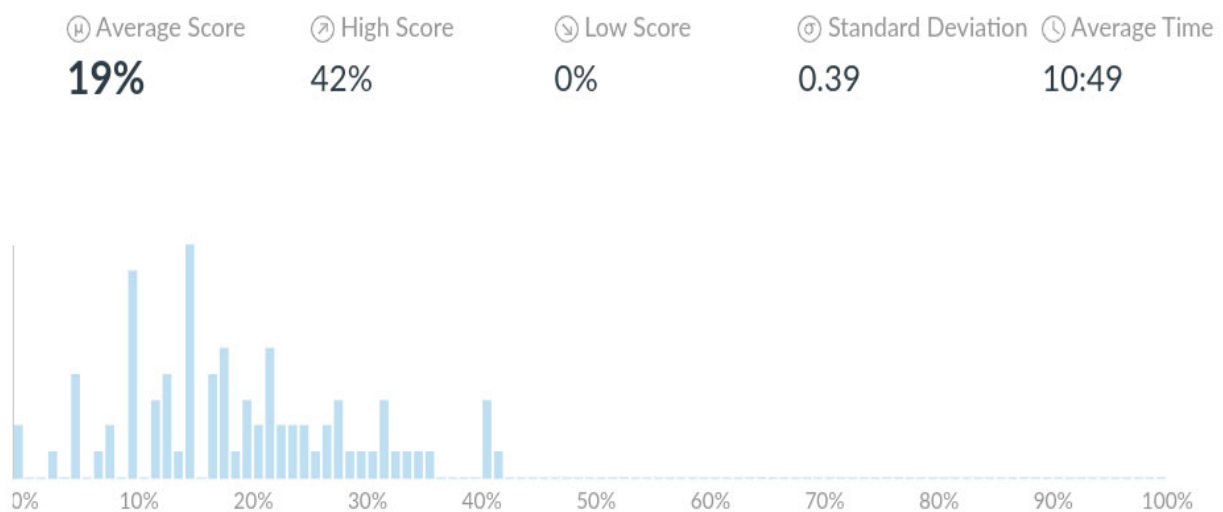


Figure 3. Pre-Assessment Canvas Quiz Statistic scores and graph.

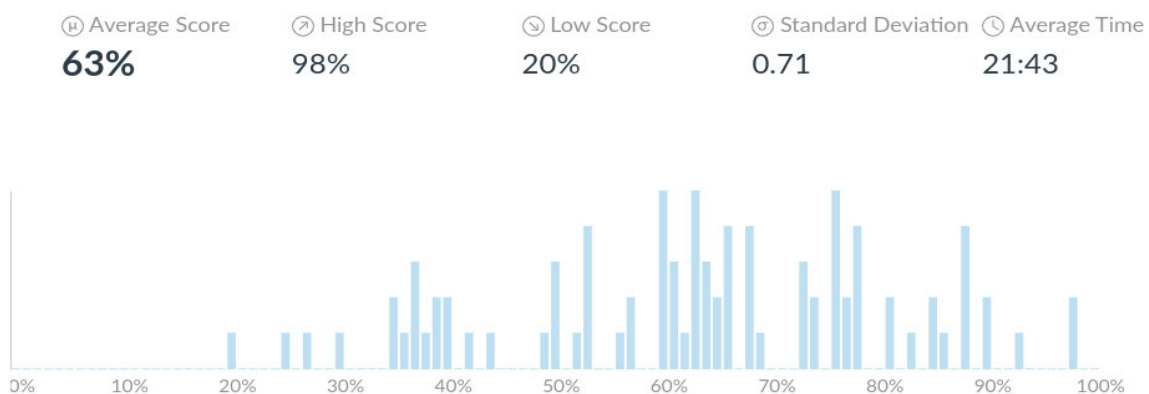


Figure 4. Post-Assessment Canvas Quiz Statistics scores and graph.

Evaluation of Formative Assessments Data

To help me analyze the variety of informal feedback, I decided to administer a normalized gains test to see how well formative assessments increased student outcomes. During the genetics unit, students scored an average of 0.68 on the pre-assessment and after the treatment students scored an average of 2.35 ($N=70$). The normalized gains were 50%, meaning that formative assessments caused the students to understand 50% of the genetic concepts than they had started off understanding. Thus, the variety of formative assessments that students participated in significantly improved from their pre-assessment scores, demonstrating medium learning gains according to Hake (1998).

Another analysis that was done to help show the increase in teacher responsiveness and clarity was a paired t-test. A paired t-test indicated a significant difference between pre- and post-assessment scores ($p<0.05$). By having a desired P value > 0.05 allows me to fail to reject my null hypothesis which would have been that formative assessments did not increase student outcomes. Failing to reject the hypothesis shows that FAs can increase and directly impact a unit within the classroom.

A comparison of formative assessment averages and post-assessment scores reveals the impact of FAs on student growth and achievement of specific standards. Looking at the comparison between the FAs averages and the post-assessment scores, one can see how the bar graphs compare to each other. By creating a graph and laying out the formative assessments average scores and how it compares to the post-assessment average score, you can identify how close the FA scores were to the post-assessment scores. Student growth was also even higher on various assessments, which then showed that outcomes were achieved for that specific standard (Figure 5).

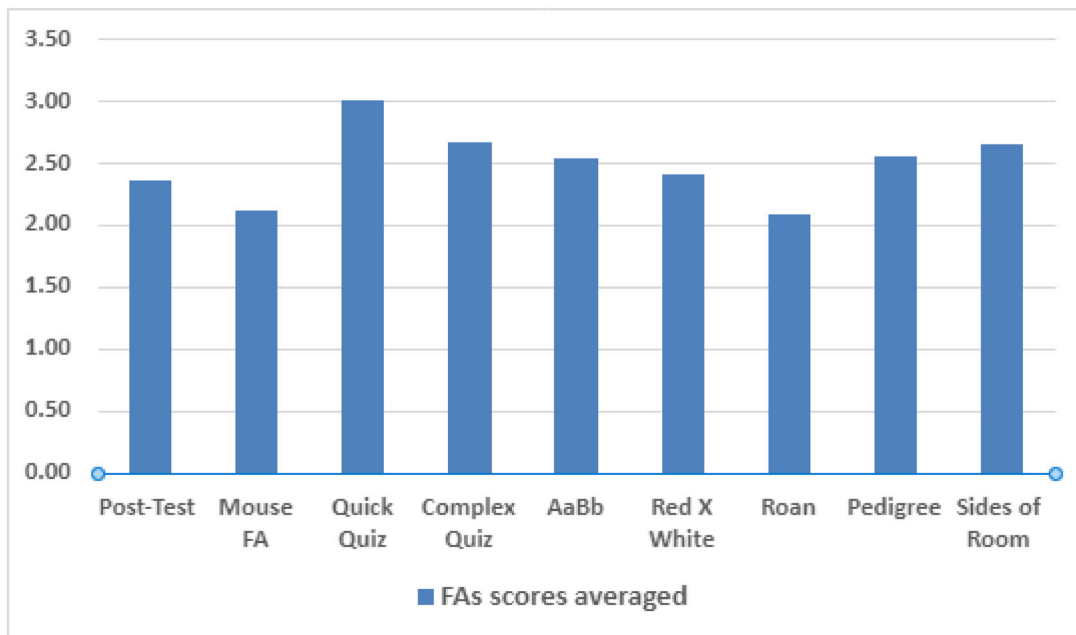


Figure 5. FA scores averaged and post-assessment comparison, ($N=70$).

Results indicated a positive correlation between FAs averages and student outcomes. Looking at the results, one can see how the student outcomes increased within the genetics unit through the implementation of classroom check-ins.

During the genetics unit, students were given a pre-and post-assessment, and five NGSS-aligned FAs over a course of six weeks. By looking at the impacts of formative assessments on teacher clarity, teacher responsiveness, and student outcomes, analyses of qualitative and quantitative data provided insight into how the FAs showed a positive correlation between all three. Inductive analysis was performed on the Teacher's Journal to look for patterns and themes in journal responses. By identifying the patterns and themes, one can observe the increase in student growth and teacher responsiveness. Other tests that were performed were a normalized

gain, correlation, bar graphs, and paired-to test. Looking at these types of statistical tests, there is a positive correlation between the impact of formative assessments and student outcomes.

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Understanding the efficacy of instructional strategies in enhancing student outcomes is a critical pursuit in education. In the context of biological education, the assessment of student learning outcomes holds particular significance due to the complexity of the subject matter and the diverse needs of learners. Over six weeks, this study investigated the impact formative assessments (FAs) had on student outcomes during the genetics unit. By employing FAs, which are strategically integrated into the instructional process, this research aims to discern the extent to which student comprehension and responsiveness within the genetics unit are influenced. Moreover, through the implementation of pre- and post-assessments alongside the utilization of five distinct FAs, this study sought to pinpoint the areas of student learning progression and ascertain the effectiveness of instructional interventions.

Claims From the Study

From this study, two claims were identified to answer the research questions. The first claim was the NGSS aligned formative assessments enhance teacher clarity and responsiveness. The second claim was that implementing FAs can facilitate more effective instruction and student understanding.

FAs Enhance Teacher Clarity and Responsiveness

After the treatment, teacher clarity and responsiveness were positively impacted. The Teacher Journal was helpful in identifying the connections between what was already taught and

where I was headed with my instruction. It also helped me identify how FAs have impacted my responsiveness or clarity throughout this unit. Mertler (2020) discussed the importance of educators keeping a teacher journal. He stated, "Teacher journals can similarly provide practitioner-researchers with the opportunity to maintain narrative accounts of their professional reflections on practice" (p. 138). Additionally, using TeachFX to record my instruction and capture the changes I made throughout the unit based on FAs helped me identify learning needs and improve instructional clarity. Comparing my Teacher Journal and the scores that were identified helped me see how FAs can impact student outcomes.

Effective Instruction and Enhance Student Understanding

The usage of NGSS aligned FAs can facilitate more effective instruction and enhance student understanding within a genetics unit. Using a variety of FAs allowed me to make "instructional decisions to improve student learning" (Christ & Kiss, 2018, p. 1). By analyzing student progress through the unit via formative assessments and observing changes in their scores between pre- and post-assessments, I could see how students aligned with the expected outcomes each time a formative assessment was administered. From administering FAs within the genetics unit, my students scored an average of 2.4 on their post-assessment and a 2-3 average score range on each of the eight assessments. Through formative assessments and pre- and post-assessment scores, student outcomes showed growth, demonstrating the impacts of increased teacher clarity and responsiveness throughout the unit. Specifically focusing on responsive teaching and clarity has allowed me to see exactly what was being taught and how FAs have impacted that within my genetics unit.

Value of the Study and Consideration for Future Research

The implementation of formative assessments can significantly transform teaching practices and lesson planning. My teaching practices and lesson planning has been transformed from the use of FAs. I learned how to really be intentional with what I wanted my students to know and how to get my students to the end goal. The usage of FAs has changed the way that I address feedback and how I answer questions. FAs helped guide the type of feedback that I gave and informed me of any gaps within the lesson.

FAs can change a teacher's practice in "the areas of task design, purpose, and focus when evaluating student work" (Abell & Sevian, 2021, p. 1). I plan on looking at student outcomes more in depth within each of my lessons and what I can do to plan formative assessments within those lessons to help drive home the end goal. Specifically, I am planning how I can change the way I approach each concept and also my classroom culture. I aim to emphasize responding to my students and maintaining the flexibility to adapt within a lesson.

Consistently reflecting on what I want the students to know and how to help them achieve that understanding will be at the forefront of my future lesson planning. I started out this project by creating a lesson map of each of the formative assessments that will be used, the questions that I will ask and what the main idea or outcome is of each lesson. I feel like this type of planning was vital for me to fully understand exactly what teacher clarity and responsiveness were. I plan on exploring this within my other units and what specific end goal will be explained. Furthermore, I will continue to explore innovative ways to implement FAs, considering both their immediate impact on student learning and their long-term benefits for overall educational growth.

Impact of Action Research on the Author

This action-based research was one of the hardest yet most rewarding processes I have undertaken. Much like a caterpillar transforming into a butterfly, I have evolved into a better teacher by implementing formative assessments (FAs) in my classroom. Lyon and Wylie (2016) developed three guiding questions for classroom assessments: “Where am I headed? Where am I now? How do I close the gap?” (p.3) (Figure 6.) These questions profoundly impacted my teaching and continue to shape my approach. I plan to keep mapping my units around these questions and the various dimensions of formative assessments.

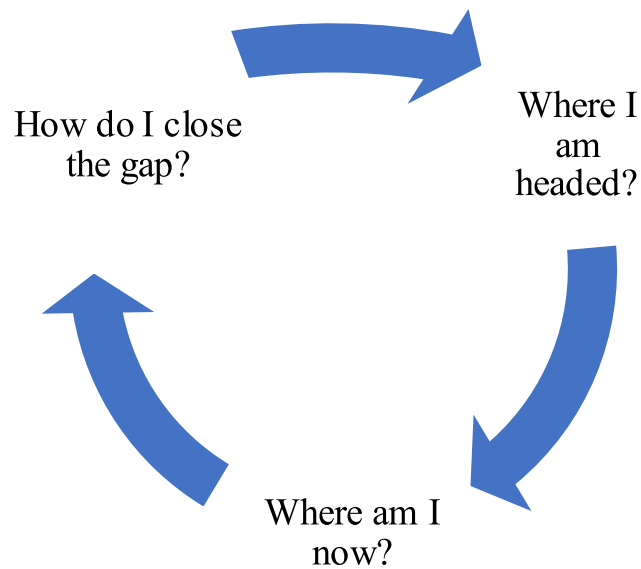


Figure 6. Three guiding questions for formative assessments usage.

I enjoyed focusing on the end goal for my students and devising strategies to help them achieve it. By meticulously mapping out my lesson plans, I can pinpoint the outcomes that need to be taught and the types of formative assessments required. Specifically, identifying my objectives and bridging the gap has transformed my perspective on lesson planning, formative assessments, and student outcomes. Throughout this project, I made mistakes and often found myself misaligned with my goals. However, I learned that making mistakes is a valuable part of the process. Revisiting Lyon and Wylie's questions helped me realign my focus and future aspirations.

I have gained significant insights into how formative assessments can enhance teacher responsiveness. This is an area I plan to continue exploring next year, in collaboration with my instructional coach. Together, we are planning a lesson focused specifically on teacher responsiveness through formative assessments. I will continue using formative assessments across all my units, as evidenced by the positive impact observed during the genetics unit. I resonated deeply with how these assessments transformed my teaching clarity and responsiveness. Exploring and developing various types of formative assessments allowed me to see how and where my students were progressing. This project not only improved my approach to the genetics unit but also altered my teaching methods for Biology and Medical Terminology classes. I am excited about the future and the ongoing improvements I can make.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY'S INSTITUTION REVIEW BOARD COMPLIANCE

Hello Groesbeck, Malia,

Your protocol was reviewed by the IRB and has been approved.

PI: Groesbeck, Malia

Approval Date: 1/11/2024

Title: HOW FORMATIVE ASSESSMENT IMPACTS STUDENT OUTCOMES WITHIN A SCIENCE CLASSROOM

Protocol #: 2024-1173-EXEMPT

Review Type: Exemption

Expiration Date: 1/11/2029

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

- > Review Category designation determined by the IRB can be found in the final section of your protocol.
- > IRB-stamped active Consent Forms are attached within your protocol where applicable.
- > Any changes must be submitted via Amendment prior to implementation.
- > Per the Common Rule, research only requires Interim (annual) Review by the IRB if 1) it was reviewed via Full Committee or 2) is regulated by the FDA.
- > All research is subject to post approval monitoring.
- > All protocol types must be renewed 5 years after approval.
- > Inform the IRB once your research is complete so that the protocol may be inactivated.

Please contact your IRB Program Manager with any questions or if you are in need of assistance. Thank you for your diligence in the care of human subjects research participants.

Institutional Review Board for the Protection of Human Subjects | Office of Research Compliance | Montana State University

Access your protocol anytime at <https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Fmontanaprod.topazti.net%2F%2FElements%3FemailLink%3D11%252c102%252c10993&data=05%7C02%7Cmalia.groesbeck%40student.montana.edu%7C521b4c4b5e744f63d49808dc12e47cfb%7C324aa97a03a644fc91e43846fbced113%7C0%7C0%7C638406019759051153%7CUnknown%7CTWFPbGZsb3d8eyJWljoIMC4wLjAwMDAilCJQljoIV2luMztlLCJBTil6lk1haWwILCJXVCi6Mn0%3D%7C3000%7C%7C%7C&sdata=17CerlgJOC79CvDFbAUCU8JgUONlqRcVdTpoak4makY%3D&reserved=0>

APPENDIX B

STUDENT OUTCOMES

NGSS Students who demonstrate understanding can:

HS-LS3-1.	Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. <i>[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</i>
HS-LS3-3.	Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. <i>[Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]</i>

State Standards:

 **BIO.3.2 Use computational thinking and patterns** to make predictions about the expression of specific traits that are passed in genes on chromosomes from parents to offspring. Emphasize that various inheritance patterns can be predicted by observing the way genes are expressed. Examples of tools to make predictions could include Punnett squares, pedigrees, or karyotypes. Examples of allele crosses could include dominant/recessive, incomplete dominant, codominant, or sex-linked alleles. (LS3.A

1	2	3	4
I can fill out a Punnett square(monohybrid).	I can describe how individuals are affected by having or not having the trait.	I can explain how variations and patterns are distributed of the traits.	I can complete and explain complex genetic problems and how they can be applied to basic genetic patterns.
I can explain where individuals get their traits.	I can explain that all traits are not expressed and why.	I can define and apply all genetic vocabulary (see notes) to how individuals and populations can receive Nonmendelian traits.	I can describe how traits are passed from generation to generation through Mendelian and Nonmendelian traits.
I can read a pedigree chart.	I can read a pedigree chart to determine how genes are passed through a family.	I can make predictions on how a trait will be passed down from parent to offspring.	I can apply a Punnett square to a pedigree chart and a karyotype.
I can describe who Gregor Mendel was and why he was important.	I can list Mendel's laws of genetics.	I can apply Mendel's Laws to complex genetic problems.	I can use real world problems to describe the benefits and limitations of Mendelian genetics to explain real life situations.
I can describe where genes come from.	I can describe various functions of genes.	I can create a prediction to show how genes can vary, that cells have different variants of genes, and how proteins code for various genes.	I can create a model to explain how protein synthesis relates to genetics.
The vocabulary that I need to know is: Homozygous Heterozygous Dominant Recessive	The vocabulary that I need to know is: Dihybrid Hybrid Ratio Plus, Level 1 Vocabulary	I can use a Punnett square (monohybrid, dihybrid, and other non-Mendelian) to determine ratios of genetic problems.	I can apply all vocabulary and types of Punnett squares to real life situations.

Genotype Phenotype Monohybrid			
I know some of the genetic vocabulary and how it applies to Punnett square.	I can share some of the genetic vocabulary and how it applies to genetic problems.	I can apply all vocabulary to genetic problems that we have learned in class.	I can apply all vocabulary to real life situations and complex genetic problems.
I can describe a karyotype.	I can apply a karyotype to a pedigree chart.	I can apply a Punnett square to a Pedigree chart.	I can apply a Punnett square to a pedigree chart and a karyotype.

APPENDIX C

GENETIC FORMATIVE ASSESSMENTS A-E

Genetic Formative Assessment A: Baby Mice



Seif's pet mouse had babies. Five of the babies were black, and two were white. The father mouse was black. The mother mouse was white. Seif and his friends wondered why the mice were unusual colors. These were their ideas:

Jerome: Baby mice inherit more traits from their fathers than their mothers.

Alexa: The baby mice got half their inherited information from their father and half from their mother.

June: Male traits are stronger than female traits.

Seif: Black mice have more traits than white mice. **Fiona:** The black baby mice are male, and the white baby mice are female.

Lydia: Parents' traits like fur color do not matter—nature decides what something will look like.

Billy: Blood type determines what traits babies will have.

1. Whom do you most agree with?
2. Explain your thinking?

Students will be creating a sticky bar graph based off what they thought at the end of completing this quick quiz. I will be able to get a sense of what their understanding is and will be able to give them quick feedback through the following rubric.

Mouse FA (Formative Assessment) Rubric

4	3	2	1
Students have justified their answer with the vocabulary we have learned so far.	Students have justified their answer with most of the vocabulary.	Students have justified their answer with at least three vocabulary words.	Students have used 1 or 2 vocabulary words to justify their answer.
All answers are justified with the following descriptors.	Some of the answers are justified with three of the descriptors.	The answer has two descriptors to add to their justification.	Students has included one descriptor within their justification,
Justify your answer with the following vocabulary		Justify your answer with the following descriptors.	
☐ DNA ☐ Protein ☐ Gene ☐ Mitosis ☐ Meiosis ☐ Genotype ☐ Phenotype ☐ Genetics ☐ Heredity ☐ Trait		☐ I can explain where individuals get their traits. ☐ I can create a prediction to show how genes can vary, that cells have different variants of genes, and how proteins code for various genes. ☐ I can describe how individuals are affected by having or not having the trait. ☐ I can explain that all traits are not expressed and why. ☐ I can create a prediction to show how genes can vary, that cells have different variants of genes, and how proteins code for various genes.	

Genetic Formative Assessment B: Punnett Square Problems

Lesson: As we start learning about Punnett squares, students will be practicing various monohybrid and dihybrid Punnett square problems. During this time, I will be passing out small whiteboards to practice as a check and this would allow me to quickly identify if students understood how to set up a monohybrid and dihybrid problem/read a Punnett square problem. To give extra feedback, I plan to implement the following quick quiz based off what we discussed during the day.

Height in pea plants is determined by two alleles. T = tall and t = short. Consider the following cross: **Tt** x **tt**.

1. What percentage of the offspring will be tall?
 - a. 75%
 - b. 50%
 - c. 100%
 - d. 25%
2. What percent of the offspring will be short?
 - a. 25%
 - b. 50%
 - c. 75%
 - d. 100%
3. What is the phenotype of the tt parent?
 - a. Tall
 - b. Short
 - c. Neither
4. An allele is:
 - a. different forms of gene.
 - b. the physical characteristics of a gene
 - c. An actual gene
 - d. None of the above

Genetic Formative Assessment C: Quick Check

Periodically throughout this unit, I ask my students questions from the previous day about what we have learned and then we discuss them. I have used these as quick checks of understanding, and it allows me to help my students/give feedback to them.

Quick Check Questions:

1. Complete the following cross $AaBb \times AABb$.
2. Complete the following problem: Red Flower color is dominant to white. Cross a heterozygous red flower with a homozygous white flower. Show the genotype and phenotype ratios.
3. Complete the following problem: Cross a roan cow with a white bull. Be sure to include ratios and describe what type of problem this is.
4. Draw out a pedigree for one trait and do at least 3 generations.

Genetic Formative Assessment D: Complex Genetics Quiz

1. In certain species of chicken, color is determined by two alleles: C^WC^W (White) and C^BC^B (Black) When a black chicken is crossed with a white chicken, the offspring are speckled (they have both white and black coloring). What type of inheritance is shown?
 - a. Codominance
 - b. Incomplete dominance
 - c. Sex-Linkage
 - d. Dominant/Recessive

2. In a species of Groot tall is dominant to short (T =Tall, t =short). If I cross a heterozygous Tall female Groot with a homozygous short Groot male what would be the genotype of the parents be?
 - a. $Tt \times tt$
 - b. $TT \times Tt$
 - c. $Tt \times Tt$
 - d. $TT \times TT$

3. A father with straight hair and a mother with curly hair have a child with wavy hair. What type of inheritance is shown?
 - a. Dominant/Recessive
 - b. Incomplete dominance
 - c. Sex-linkage
 - d. Codominance

4. A form of high blood pressure is an X linked recessive trait. A woman who is a carrier for high blood pressure marries a man who does not have high blood pressure. What are the parents' genotypes?
 - a. $X^BX^b \times X^bY$
 - b. $X^BX^B \times X^BY$
 - c. $X^BX^b \times XXY$
 - d. $X^BX^b \times X^BY$

Genetic Formative Assessment E: Agree/Disagree Sides of the Room Exit Ticket

Students will be learning incomplete and codominance through various scenarios that are presented to them, whether they stay on the agree or disagree side or move to another side of the room. Students will be moving across the room, about whether they agree or disagree with the different scenarios. On the sides of the room, students will be discussing with a partner to provide evidence of their thinking of why they chose the reason they did. Students will then grab another partner (matching stick partner) and discuss what evidence they discussed and found.

Students will then make a final decision of what they think based off their discussion with a partner.

From this activity, students will then fill out an exit ticket and write out things they were confused about, learned from it, what they want to do further, and if there was anything they had questions about.

1. Give students whiteboards to work out the problems.
2. Always start in the middle and then have student work out problem before they go to the different sides.
3. Assign some specific problems and have those specific sides of the room as Incomplete, Codominant.
 1. Give some lower-level questions: Vocabulary/Easy guiding questions.
 - i. Expand the question to a higher level.
 - ii. Take the mice problem and break it apart into a higher level and lower level.
 - iii. Can give pictures as questions, what type of inheritance and do a cross.
4. Choose the specific side of the room based off what they are thinking.
5. Students will then grab another partner (matching stick partner) and discuss what evidence they discussed and found.
6. One final scenario with limitations of genetics and to explain their definitive answer.
7. From this activity, students will then fill out an exit ticket and write out things they were confused about, learned from it, what they want to do further, and if there was anything they had questions about.
8. Have them choose two more problems of mouse paper to turn in as their practice/activity.

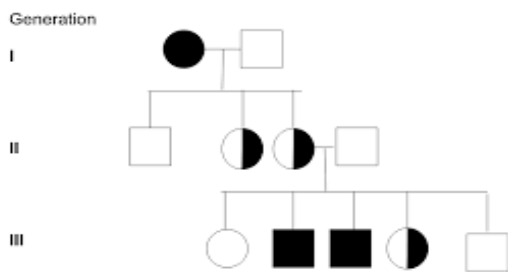
APPENDIX D

GENETIC PRE-AND POST-ASSESSMENT

Genetic Pre-Assessment and Post-Assessment

1. Write correct vocabulary term next to the following definitions.
 - a. Different forms of a gene
 - b. Inheritance where a trait is controlled by several genes.
 - c. An allele that can be hidden by a stronger allele.
 - d. Condition of having two of the same alleles for a trait.
 - e. A characteristic resulting from genes.
2. What phenotypic ratio did Mendel find organisms in the F₂ generation tended to follow?
 - a. 3:1
 - b. 100%
 - c. 1:2:1
 - d. 2:2
3. The set of alleles, Dd, would be best classified as _____.
 - a. homozygous dominant
 - b. homozygous recessive
 - c. Purebred
 - d. Heterozygous
4. A gene pair with one dominant and 1 recessive allele is known as:
 - a. Homozygous
 - b. Homozygous Dominant
 - c. Homozygous Recessive
 - d. Heterozygous
5. The set of alleles, TT, would be best classified as _____.
 - a. homozygous dominant
 - b. hybrid
 - c. homozygous recessive
 - d. Heterozygous
6. A gene pair that has two identical alleles would be considered _____.
 - a. Heterozygous
 - b. Homozygous
 - c. Hybrid
 - d. None of these
7. The physical appearance of a trait is_____

8. If pointed heads are dominant to round heads, which of the following genotypes could express a round phenotype?
- PP
 - Pp
 - pp
 - none of these
9. Human Blood exhibits codominance. If a woman with AB blood marries a man with O blood, what would the genotypes of the children be?
- 25% AA 50% AB 25% BB
 - 25% AA 50% O 25% BB
 - 50% AA 50% BB
 - 50% Ai 50% Bi



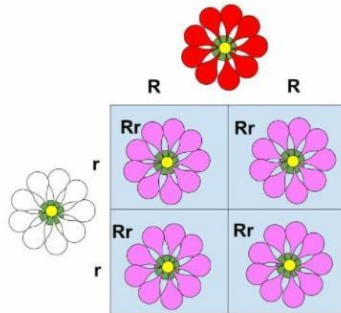
10. The following pedigree is a _____ trait.
- sex-linked dominant
 - sex-linked recessive
 - Autosomal recessive
 - autosomal dominant
11. Create a Punnett square for the following information: A tall (TT) plant is crossed with a short (tt) plant. What allele pair would be in box 1?
- TT
 - Tt
 - tt
 - None of the above

1	2
3	4

1	2
3	4

12. Create a Punnett square for the following information: A **heterozygous** brown rabbit is crossed with a **homozygous** white rabbit. What percentage of the offspring would be **white**?
- 75%
 - 50%
 - 25%
 - 100%
13. A tall (Tt) plant is crossed with a tall (Tt) plant. (Note: Your answer does not depend on where you put the parents on the Punnett square) What allele pair would be in box 2?
- Tt
 - Tt
 - TT
 - None of the above.
14. In mink, brown fur color is dominant to silver-blue fur color. If a homozygous brown mink is mated with a silver-blue mink and 8 offspring are produced, how many would be expected to be silver, blue?
- 3
 - 6
 - 8
 - 0

15. What type of inheritance is shown in the Punnett square below? How do you know?
- Multiple Alleles: There are more than 2 alleles for the gene.
 - Codominance: The phenotype is between the dominant and recessive
 - Incomplete Dominance: Two different traits are expressed.
 - Incomplete Dominance: The phenotype is between the dominant and recessive



16. Are Human Blood Types an example of which type of inheritance?
- Codominance
 - Sex linked traits.
 - Simple Dominance
 - Incomplete Dominance
17. In Unicorns, plain white horns are dominant over sparkly pink horns. Lilly Potter really wants a sparkly horned unicorn as a pet. However, her parents were only able to find a plain white horned unicorn. How can Lilly find out if it is possible to breed her plain white horn unicorn to get a sparkly-horned unicorn? If it is possible to get a sparkly horned unicorn, what is the probability (using ratios) of getting a sparkly horned unicorn?
18. Two parents with brown eyes have two children with blue eyes. Assume that only one gene for eye type is involved.
- How is this possible? Defend your answer by presenting genotypes for individuals in this scenario.
 - Are brown eyes dominant or recessive?
 - What does Protein synthesis have to do with the traits that are apparent?

APPENDIX E

TEACHER JOURNAL

Teacher Journal:

Questions that I would reflect upon throughout my genetics unit.

7. How do I know that my students learned what we talked about today?
8. How many of the students showed a change?
7. My own thoughts and feelings on the teaching and how the formative assessment went.
 - a. Did I show clarity?
 - b. Teacher responsiveness?
8. What would I change?
9. How will this inform my next section?
10. What types of questions did I notice being asked?

Table 3: Ways to Record Formative Assessments

Objective for the Day	Type of Formative Assessment	How did I know that my students understood it?	Did I change anything?

Week 1: Days 1-3

Day 1:

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

I know that my students learned what we talked about today, but reviewing the content that we did within the notes and by answering the questions that were found within my outcomes. I had students create a worksheet with four boxes and they each had to do their own thing to answer the questions. Then they taught each other about what they learned.

2. How many of the students showed a change?

Not sure if this specifically applies to this lesson/

3. My own thoughts and feelings on the teaching and how the formative assessment went.

- a. Did I show clarity?

- b. Teacher responsiveness? I showed this by walking around and making sure my students understood what was expected of them and by checking in with what they were doing. I had some students wanting confirmation that they were correct in answering the questions, but I didn't tell them yes or no because I really wanted them to think it through. I could have responded differently and directed them to their own thinking.

4. What would I change?

I would change how I set this up and the amount of time given for each section. Each student's choice varied by the amount of time and effort that they needed to complete and talk things out.

5. How will this inform my next section?

This will inform my next section because it will allow me to see and understand if my students got what they needed to learn and how they needed to learn it. Also, we are talking about Monohybrid crosses and what vocabulary is applied to the problems.

6. What types of questions did I notice being asked?

1. Ms. Groesbeck, am I right in that he discovered alleles?
 2. Traits change over time, so it led to the dominant always changing...

Day 2:

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

It was interesting to look at what the students thought about traits; they struggled to understand and use the vocabulary, but they did understand that traits are passed on and by how.

2. How many of the students showed a change?

A lot of students who I did not think would understand or had a tough time applying the vocabulary could at least describe it in their own words.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity?

I did. It was informative for me to see how well my students did and they that could apply their own thinking.

b. Teacher responsiveness?

Yes. I checked in throughout the room and they could understand what was required of them.

4. What would I change?

I really liked the lesson that I had first planned. I would break apart the vocabulary and its order. I should have implemented the KWL and showed them the problem first off and then as we go through the vocabulary, then have them answer their response.

5. How will this inform my next section?

I am going to have them create Punnett square about their reasoning and how it can apply to their overall response.

6. What types of questions did I notice being asked?

How to use the vocabulary and how it is applied to the work we are doing in class.

Table 3: Ways to Record Formative Assessments

Objective for the Day	Type of Formative Assessment	How did I know that my students understood it?	Did I change anything?
I know some of the vocabulary and how it applies to Punnett square. I can describe how traits are passed on and why that is important. I can describe where Genes come from.	Mouse FA	By looking at the graphs they created and their responses with the vocabulary.	No, but I want to follow up with some students about their vocabulary usage and how it can be used within this problem.

Day 3

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

Today I changed my plan to review over Punnett squares. I decided to go over my Mouse FA again and review the terms. I also decided to have my students create Punnett square first. I really liked doing this because it was an excellent way for me to check in with my students about if they understood Punnett squares or not. I then had them talk out their answers and explanations with each other. This was helpful because they could hear their peer reviews reasoning. Then I had to them add anything to their explanation.

2. How many of the students showed a change?

Vocabulary usage is a struggle with my students, but after day four it was interesting to see how they can interconnect terms with how a problem should be solved. I did not see this until today (Day 4), but it was nice to help see how my students understood.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

- a. Did I show clarity? I believe so. I really liked watching my students grow and talk out their reasoning with other students. I also liked the students asking me if their Punnett square was correct. I turned around and pointed out some questions that I had, which helped them realize if there were any problems along their way.

- b. Teacher responsiveness? Yes.

4. What would I change? I think I would have students look up vocabulary words first and then go back and apply it to the mouse activity.

5. How will this inform my next section? This will inform my next lesson because it will help me see how students apply genetics through Punnett squares and how vocabulary usage is still a struggle.

6. What types of questions did I notice being asked?

- ∄ If their Punnett square was correct?
- ∄ Did they have the right answer?
- ∄ What are specific vocabulary words?

Day 4 Quick Genetic Quiz

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today? I will know that my students will know what we talked about today by being able to apply Mendel's 3 laws and how it relates to the lab to which we are applying.

2. How many of the students showed a change?

I think that by first going through and over specific problems in class, it helped solidify students' understanding of Punnett squares and how it works within a genetics problem. Students were able to understand how to set up a Punnett square and then fill out the problem.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity? Yes, I was able to give my students time and even went back through the problem. Students were willing to try and work through specific problems and then complete them on their own.

b. Teacher responsiveness? Yes. I went through and answered where students struggled and even went back to setting up specific problems.

4. What would I change? First, remember what I am doing and how this works in my lesson plan. But giving them the quiz right after we did the problems and not at the end of class.

5. How will this inform my next section? By understanding if students can apply and work on a dihybrid problem.

6. What types of questions did I notice being asked?

≠ What is a regulatory gene?

≠ Is this Punnett square, correct? Does it work with the problem at hand?

≠ What is a genotype and phenotype?

Table 3: Ways to Record Formative Assessments

Objective for the Day	Type of Formative Assessment	How did I know that my students understood it?	Did I change anything?

Applying Punnett Squares and Mendel's 3 laws	White board activity and quick genetic quiz	By showing me the answers on whiteboards and even talking it out within the classroom. There was an incidence where a student did not understand and the other turned around and was able to directly explain to them what was going on. They then understood how to apply the problem.	Just the order of how I did things for the rest of the day.

Day 5

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

I know my students learned what we talked about today because I could see students trying to understand what we did, and they followed along with what we were learning about. Also, students were asking questions about how to set up Punnett Square and if they were correct.

2. How many of the students showed a change?

Students showed a change in how to set up a Punnett square and put traits back together. They were able to make a change by looking at what they were doing and then aligning the alleles back together.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

- a. Did I show clarity?

I think so. I was able to identify the students struggling and those I could help quickly. I also could see where students were struggling and then could help students make quick adjustments where they were needed.

- b. Teacher responsiveness?

Yes. I really liked watching students grow and develop their understanding of the concepts. I also like watching students where something is hard to understand, but they still try.

4. What would I change?

I would show a video on crossing over and helping students visually see that. I also probably would have the students practice more with setting up the Punnett square.

5. How will this inform my next section?

This will inform my next section because I will pull the students that were struggling and where I could see the struggle occur.

6. What types of questions did I notice being asked?

∅ I am lost.

- ∄ Am I right?
- ∄ I do not know where to begin.
I made a mistake and am confused about where the traits are going.
- ∄ Which letter comes first and why does it?

Table 3: Ways to Record Formative Assessments

Objective for the Day	Type of Formative Assessment	How did I know that my students understood it?	Did I change anything?
Students will be able to understand and apply a dihybrid square.	Starter Quick check: AaBb x AaBB	By being able to set up and understand what Punnett square was telling them.	I changed the order of when I did this FA and let them discuss it out.

Day 6:

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

I know that my students learned what we talked about today was that my students were able to set up the Punnett square at the end of the class period. We started out by reviewing how to read and set up a basic Punnett square. Students then learned about incomplete and codominance. Throughout the lesson, students practiced different problems together. Students were then given a problem of codominance. I did not tell them how to set up the problem nor what type of dominance is, because I wanted to see how my students were at setting up the problem and if they understood the concepts being taught.

2. How many of the students showed a change?

About half of the students understood how to set up the Punnett square, but about a $\frac{1}{3}$ of my students could successfully identify what type of problem it was.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

- a. Did I show clarity?

I think so. My students could answer the essential questions that I had asked for the lesson. My students could set up and understand how to read an incomplete and codominance problem.

- b. Teacher responsiveness?

Yes. My students seemed interested in the material and how to apply it towards the concepts that we learned today.

4. What would I change?

I do not think I would change anything. The problem was check-in for me.

5. How will this inform my next section?

This will help inform my next section because I am implementing the sides of the room FA. Students will learn how to read and apply a Punnett square towards incomplete codominance.

6. What types of questions did I notice being asked?

- ≠ Is this codominance?
- ≠ How do I read a problem/identify whether it is incomplete/codominance?
Does each time pink/pink flowers (incomplete dominance) get lighter or darker as you cross them?

Table 3: Ways to Record Formative Assessments

Objective for the Day	Type of Formative Assessment	How did I know that my students understood it?	Did I change anything?
Applying incomplete/codominance concepts	Quick Starter check #three	I know that my students learned what we talked about today was that my students were able to set up the Punnett square at the end of the class period. We started out by reviewing how to read and set up a basic Punnett square. Students then learned about incomplete and codominance. Throughout the lesson, students practiced different problems together. Students were then given a problem of codominance. I did not tell them how to set up the problem nor what type of dominance is, because I wanted to see how my students were at setting up the problem and if they understood the concepts being taught.	

Day 7

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

I will know what my students learned about today by asking them questions and listening to what they are telling their classmates. I really enjoyed watching my students turn and discuss what we were learning about and how it applies to real life problems.

2. How many of the students showed a change?

I would say 90% of my students showed a change in how to set up Punnett Square and how it applies to the problems that I have given them. I also asked students questions about how they knew or understood the problem and described back to me what they understood.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

- a. Did I show clarity? Yes,

- b. Teacher responsiveness? Yes, other than I made a mistake and told my students a problem was codominance when it was incomplete dominance. I noticed the change and fixed it quite quickly.

4. What would I change? I changed and rearranged how I started out my review with my students. I also had them getting up and moving a lot sooner than I thought, which I really liked.

5. How will this inform my next section? This will inform my next section because students will be able to apply what they have learned to setting up a sex-linkage Punnett square.

6. What types of questions did I notice being asked?

- ∄ How do I set up a blood type problem?

- ∄ How do you arrange the letters?

- ∄ How do you read a Punnett square again and apply what it means to what the question is asking

Day 8:

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

I know that students learned what we talked about today was because they could answer the questions that I posed to them and, they could fill out a Punnett square correctly (Sex-Linkage).

2. How many of the students showed a change? Not sure where students are exactly on completing a Punnett square with sex-linkage problems. Many of my students understood and applied the concepts taught today.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity? I believe so. This question is a hard one for me to answer because students often show a lack of interest....and it is hard for me to gauge where their understanding are. I do like pulling them in with real life questions and seeing if they can apply what we are talking about and how it works with genetics.

b. Teacher responsiveness? Yes. Students understood and were able to follow along with what I was teaching today.

4. What would I change? The number of notes that we took. I wish that I had broken up the number of things or applied my incomplete/codominant problem with this activity...and then did the review.

5. How will this inform my next section? By allowing me to see if students can complete the sex-linkage problems.

6. What types of questions did I notice being asked?

∅ How to read a sex-linkage problem.

∅ Did I do the Punnett square correctly?

∅ Is my understanding of this Punnett square, correct?

∅ How does the genotype change now with sex-linkage?

Day 9

Changed things around:

Something that I noticed is that I unintentionally changed things around with what I had already planned. I had planned an upcoming flex day for my students to use, and I had already used that. I also combined teaching two lessons together because things went so well. It was nice to do a check-in with my students and how they handled that much information. According to my Genetic Map that I created, I am off and on by each day, which is quite okay. I am not off my original plan, just the number of things changed.

Honestly, I combined these three days:

Day 1-3: Is where I used part of my flex day:

Day 8:

Agenda:	What is the Takeaway	What am I going to do?	Students do:	Questions I am going to ask
1. Starter 2. Guided Notes on Sex-Linkage 3. Sex-Linkage Video 4. Activity	I can read and apply genetic vocabulary to various real-world problems. I can read and apply a pedigree chart.	Guided notes on Sex-Linkage and steps Complete Sex-Linkage problems as a class Help student on sex-linkage activity	Take guided notes on Sex-linkage and epigenetics, lethal genes. Complete some sex-linkage problems as a class. Work on individual or as partners sex-linkage activity	1. What is a nonmendelian trait? 2. How does that apply to what we know? 3. Why is that important? 4. What can sex-linkage help with? 5. How can the environment impact genetics?

Day 9:

Agenda:	What is the Takeaway	What am I going to do?	Students do:	Questions I am going to ask
1. Starter: 2. Complex FA 3. Finish sex-linkage notes, recap, and practice. 4. Pedigree/Autosomal Genes 5. Finish sex-linkage Worksheet	I can show how a trait can be affected by environmental factors. I can predict how genes can vary.	Guide students on Complex FA: Reteach any concepts needed. Guide students on notes/recap on sex-linkage, nondisjunction, etc. Help provide answers to questions about sex-linkage activity.	Complete FA Ask questions to help clarify any areas of concern. Review notes and work on practice problems. Finish sex-linkage activity	1. How does the environment impact genes? 2. What can be done to help those genes who are susceptible? 3. How can a pedigree impact our family lines?

Day 10 and 11 will be combined into one entire day. I will be giving the last starter check as an exit ticket instead of a starter:

Day 10

Agenda:	What is the Takeaway	What am I going to do?	Students do:	Questions I am going to ask
1. Starter : Quick Check 2. Recap/ Reteach Quick Check 3. Notes 4. Review and recap. 5. Summarize everything together	I can use patterns in the data to predict changes in a population trait through environmental changes. I can do everything listed in the other levels. I can read a pedigree chart. I can apply a karyotype to a pedigree chart	Help with Quick Check and provide areas of clarification. Guide students through notes of pedigree, lethal genes and other nonmendelian traits. a. Reading a pedigree b. Applying a pedigree c. Environmental factors? Real life situations	Finish with Quick Check and ask for help on areas. Take guided notes of pedigree, lethal genes and other nonmendelian traits. d. Reading a pedigree e. Applying a pedigree f. Environmental factors? Real life situations Practice Problems Pedigree and Karyotype Activity?	1. What is a pedigree? 2. Why is it important? 3. What can know other diseases help with reading a pedigree? 4. Can Punnett squares be applied to a pedigree?

Day 11

Agenda:	What is the Takeaway	What am I going to do?	Students do:	Questions I am going to ask
1. Starter: Quick Check #4 2. Finish pedigree s. 3. Review for Test	I can do everything in level 4 and all other levels.	Reteach with Quick Check Guide and finish notes. Review and refresh on any concepts that are needed	Take Quick Check 4 Finish any portions of notes. Ask questions on any areas of concern	1. How does a pedigree apply to a Punnett square? 2. Are there areas of concern? 3. What outcomes do you struggle with and need a refresher on?

Day 9 Questions:

Questions that I would reflect upon throughout my genetics unit.

Questions I asked: Do I do too much for my core students?

Students were confused about the drawing of turning off and on genes example. Not sure how to show or demonstrate epigenetics. Probably should have explained more.

1. How do I know that my students learned what we talked about today?

I know my students understood what we talked about today by applying the complex genetics quiz and the drawing we completed on epigenetics. Most students could complete the complex genetics quiz and the overall score was half 1-2s and half 3-4s. I could see how students understood the concepts being taught and what we applied to class.

2. How many of the students showed a change?

After discussing the example, students understood the idea that genes could change. Also, some students discussed the quiz with me and the ideas behind it. We are going to address the problems further and go more into depth on what was confusing.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity? I believe so. It is hard to tell with this day because students seemed all at varying degrees with what we were learning and applying.

b. Teacher responsiveness? This I did because students needed me to check in and respond to them with the drawing. I was going to go around and talk with students about their problems but ran out of time.

4. What would I change? I would break up the amount of work and concepts I am instructing my students.

5. How will this inform my next section? This will inform my next section because I am planning to review the problems that were being asked and how students can apply it to their upcoming test.

6. What types of questions did I notice being asked?

Day 10

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today? I knew that my students understood what we talked about today, them being able to read and apply a pedigree chart. We went through notes and then practiced on how to read a pedigree. I even gave them numerous examples and tips/tricks on how to apply a pedigree. Students then created their own pedigree of 3 generations. Students used a list of various simple inheritance traits to apply or choose one of their own. Students also had a chance to retake the quiz we took on Day 9, and many students showed a change. The majority is now 3-4s. We also reviewed their test today and went over vocabulary/how to approach genetic problems.

2. How many of the students showed a change?

Students also had a chance to retake the quiz we took on Day 9, and many students showed a change. The majority is now 3-4s.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity? I believe so. I really tried to walk my students through what we were learning and how they had a chance to apply what we learned.

b. Teacher responsiveness? Yes. I answered questions and took the time to walk around the classroom to show my students what we talked about.

4. What would I change? Breaking about the amount of time per activity and what was talked about last time. I wished I had taken out less information for them to understand.

5. How will this inform my next section? My students are taking their posttest next time, so this would inform my next section if they understood all the concepts we learned.

6. What types of questions did I notice being asked?

∄ Did I set this up correctly?

∄ What traits can I show?

∄ Can I show intermarriages taking place?

∄ How do I map out the traits being shown?

How do I read individuals on a pedigree?

Day 11: Find time to review over outcomes.

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today?

My students understood what we talked about today because they were given their post-assessment. We reviewed before the post-assessment and my students were given an opportunity to also study on their own. We went through vocabulary one more time and then they were given the same exact test as before. I was excited to see if my students caused a change over this unit. I was also excited to see the end goal and how big a difference was made with my students from the pre to the post-assessment.

2. How many of the students showed a change?

1A: 25 students made a meaningful change. One student did not show any change.

3A: 28 students made a meaningful change; five students still have not taken the test.

4A: 24 students made a meaningful change, one student did not show a change, and 9 students still need to take the test.

3. My own thoughts and feelings on the teaching and how the formative assessment went.

a. Did I show clarity? Yes.

b. Teacher responsiveness? yes

4. What would I change?

5. How will this inform my next section? We will go through the test and the outcomes to help me with any portion that my students did not understand. Also, it is quite interesting doing the same thing with my honors students and watching them improve just as high or higher than my core students. The difference makes me wonder if I should do this for all my units.

Review over outcomes: Day 12

Questions that I would reflect upon throughout my genetics unit.

1. How do I know that my students learned what we talked about today? This was surprising to see how my students compared what they understood on the test to the student outcomes. I should have asked them where they think they are graded compared to what they got. I do think that was a good check-in for them and me because it helped me see where my students think they are and where they sit. I also learned quite a bit about how my students could complete formative assessment and then what was lined up with the post-assessment. I think my students could do their formative assessments but still needed support.
2. How many of the students showed a change? All my students showed growth, except two. I have been doing retakes now and it is interesting to see how well my students understand the concept compared to what they got the first time around.
3. My own thoughts and feelings on the teaching and how the formative assessment went.
 - a. Did I show clarity?
 - b. Teacher responsiveness?
4. What would I change? Time and giving them a variety of formative assessments. I want to continue looking at outcomes and how they align back to the test and how they are set up.
5. How will this inform my next section?
6. What types of questions did I notice being asked?