The Development and Integration of Nearpod Materials into a High School Biology Curriculum

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The Development and Integration of Nearpod Materials into a High School Biology Curriculum

By

Matthew Halloran
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Why Nearpod? Why Formative Assessment?

Teachers are always looking for ways to help their students increase their academic achievement as well as ways to increase their level of learning. Teachers in the 21st century are not lacking for technological tools that claim to increase student learning. Technological ways to share, display, and assess information are extremely common. Technological tools for formative assessment are still working their way into the classroom. In their review of formative assessment Black & William (1998) refer to formative assessment as “all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged” (pgs. 7-8). In their review, Black & William (1998) conclude that formative assessment improves student learning to levels that were among the largest reported at the time of the study (p. 37). They make the argument that formative assessment should be adopted at a large scale and could benefit the achievement of students to a great degree (Black & William, 1998). While most educators agree that formative assessment practices are beneficial, the implementation of formative assessment practice into classrooms has been varied and inconsistent (Dunn & Mulvenon, 2009). Due to the fact that formative assessment practices are difficult to incorporate into daily classroom practices, technology should be used to assist in that process (Bhagat & Spector, 2017). Colleges and universities were the first to incorporate technology based formative assessment practices into education (Lundeberg et al., 2011). Technology based formative assessment in a college lecture setting has typically been in the form of clickers. Clickers are small remotes that students bring with them to a lecture type class. They are valuable in the college and university setting because it is difficult for a professor to inform their teaching during the middle of a lecture. Clickers made it so data could be collected during a
lecture in a relatively quick and efficient manner. Clicker software was then brought in to the high school setting so that formative assessment data could be collected easier. There are negatives to clickers however. Clickers are relatively expensive, somewhat faulty, and at this point in time are very low tech. There are many programs and applications in the current market that take the premise of clicker software and make it more interesting, adaptable, and accessible to high school students. Nearpod is a web based application that takes the premise of clicker formative assessment and expands on it greatly. It allows teachers to monitor student responses to a variety of questions (Robinson, 2018). Students can answer open ended questions, take polls, draw pictures, experiment with 3D images, and use simulation software within Nearpod. Any data from student use is instantly saved and can be easily retrieved by the teacher during the lesson or at another time. Nearpod is compatible with both mobile devices and computers and allows for the relatively easy integration of increased formative assessment into a high school classroom. The integration of Nearpod into a high school biology curriculum will allow for lessons to be more engaging and will promote more participation within lessons.
The Role of Peer Climate and Best Friends

In this paper Nelson and DeBacker looked into connections between adolescent social patterns and what drives their achievement in school. Specifically, they sought to understand the relationship between achievement-related goals and peer influence (Nelson & DeBacker, 2008). To do this, the researchers developed a survey investigating student experiences for students to take during their science class. The study included 253 students from 6th, 7th, and 9th grade science classes. The students were from a suburban area and had above average parent income, parent education, and state test scores. The survey employed a five point Likert scale for all of its questions. Students were able to answer in a range of 1 for strongly disagree to five for strongly agree. The test asked questions referring to the student’s levels of self efficacy, mastery goal, performance approach goal, performance-avoidance goal, intimacy goal, approval goal, responsibility goal, classmates’ resistance to norms, classmates’ involvement, class belongingness, best friend’s resistance to norms, best friend’s academic valuing, and friendship quality. Statistical analysis was then used to determine if there was any correlation in the data between the points of interest.

Nelson and DeBacker’s contention that there are influences on motivation to learn flowing from the social environments of learners was supported by their findings (Nelson & DeBacker, 2008). Across a number of different variables it was shown that student’s motivation to learn and motivations for achievement are highly correlated to feelings of belongingness in a classroom. In addition, perceived classroom resistance to school norms correlated highly with
behaviors like avoiding school work and being highly concerned with how others viewed you. Although it was not the focus of the study, increasing grade level seemed to be linked to both decreasing achievement motivation and decreasing positive classroom interactions. Overall, many friend and classroom attributes were significant predictors for student’s motivation in the classroom.

Students that were in classrooms that placed little value on work and achievement generally placed little value on work and achievement themselves. The researchers admitted to a lower than expected correlation with the best friend variables, but tried to explain that away by saying that small effects may have a larger effect on the data over time. This research should be expanded into more of a wide ranging study that focuses on the same students over time. A more longitudinal approach would control for many of the grade level differences. In addition, if additional research into this topic continues to point toward positive classroom environments being predictors for achievement oriented mindsets, there should be research into methods for creating positive classroom environments. There are many ways to foster a positive classroom environment, but there must be some that are more effective than others.

How teaching science using project-based learning strategies affects the classroom learning environment

This study was focused on student feelings regarding project-based learning as opposed to traditional methods in the science classroom. 458 ninth grade students from Israel were taught using the two methodologies mentioned above. 230 of the students were taught using a project-based learning strategy while 228 of the students were taught using more teacher-centered
traditional approaches. Not much was said about the specifics for how each of the approaches were implemented in the classroom. In contrast, project-based learning was explained in great detail and it was very obviously hypothesized that project based learning would be more beneficial than more traditional approaches. After an unknown period of time the students were given a 38 question survey used to assess their opinions on five factors: satisfaction, enjoyment, and teacher supportiveness; tension and difficulty; student-student relationships; competitiveness; and teacher-student relationships. Each factor was assessed using multiple questions on the survey and the students answered using a Likert like response scale of not true (1), true to a certain degree (2), and true (3).

The findings showed that project-based learning showed significant improvement over teacher-centered traditional learning in multiple factors. Factor 1 (Satisfaction, Enjoyment, and Teacher Supportiveness) was higher in the project-based learning students to a statistically significant level. In addition, Factor 5 (Teacher-Student Relationships) was higher in the project-based learning students to a statistically significant degree. It can also be inferred that the project-based learning students perceived their tasks as less difficult and less stressful (Factor 2) (Hugerat, 2016). Factors 3 and 4 (Student-Student Relationships and Competitiveness) did not show any statistically significant difference between the two groups. These results speak to a more fulfilling classroom on the student and teacher level when utilizing project-based learning.

The results of the study are intriguing and this idea should be applied in a much more large scale study. A study that was focused much more on the methods of the study rather than spending so much time describing project-based learning would be beneficial. In addition, comparison studies like this should be done in multiple American settings. For instance, it would be interesting to see the results of urban, rural, and suburban students.
This study was focused on profiling student attitudes towards science education in Turkey. In addition, the data from the students was used to create distinct classroom learning profiles. Once data was collected from a number of students in Turkish biology classes, the student’s attitudes were compared to students across the world. To collect the data a specific survey was used. The survey utilized for this study was the What Is Happening In this Class? (WIHIC) questionnaire. This particular survey was used because it maps a comprehensive area of science learning environments. It was also utilized because it has had widespread use in many different countries and settings. Because the WIHIC has been used in many countries, the data collected from the survey could easily be compared with the data from other countries. The WIHIC assessed student perceptions on student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity. The participants in the study were 1474 students from 52 classes in four inner city schools in Turkey (Brok, Telli, Cakiroglu, Taconis, & Tekkaya, 2010). The students that participated were 57% female and 41% male while 2% did not indicate their gender.

There were not any major surprises in the data collected from this study. When comparing Turkish student data to students from other countries it was shown that Turkish students perceived their classroom environments less favorably on all scales than students in India, Indonesia, and Korea (Brok et al., 2010). In addition, scores for student cohesiveness, teacher support, cooperation, and equity were lower than all other countries compared except for Canada (Brok et al., 2010). In this aspect, the results aligned with what was expected for
Turkish students. A cluster analysis was also performed in order to identify specific classroom profiles for the Turkish science classrooms. There were six distinct classroom profiles identified from the data. The profiles were self-directed learning classroom, task-oriented cooperative learning classroom, mainstream classroom, task-oriented individualized classroom, low effective learning classroom, and high effective learning classroom. This data could possibly be used to help Turkish science teachers self-identify which classroom they most identify with. Strategies used by teachers with high effective learning classrooms should be duplicated while strategies used by teachers with low effective learning classrooms should be eliminated.

Implications from this study could be wide reaching. Teachers could try to predict which profile that their classroom would fit into. After predicting, they could be observed teaching while also having their students take the WIHIC. This will allow for a period of reflection on the data. It is very possible that teachers will incorrectly predict the learning profile of their classroom. This will provide an opportunity for learning and reflection on their methods. Even if a teacher correctly predicts the learning profile of their classroom they can benefit greatly from having an opportunity to reflect on their teaching practice. In addition, the classroom profiles should be examined to see if they were even partially affected or caused by the large number of inadequacies in the Turkish education system.
Introduction to the Literature Review

Formative assessments have a variety of definitions in the literature. A summary of those definitions would yield the statement that formative assessments are activities and assessments performed in the classroom for student learning. Formative assessments should include timely, accurate, and meaningful feedback to the students involved (Weurlander, Söderberg, Scheja, Hult, & Wernerson, 2012). Feedback that is timely and meaningful increases the engagement of the student while also giving them the opportunity to think about their own thinking (Scogin, 2016). Formative assessments can come in a variety of shapes and sizes. Some individuals have tailored opening questions as formative assessment, changed homework into project based formative assessment, or even have utilized local researchers to give feedback as a part of formative assessment (Zertuche, Gerard, & Linn, 2012) (Newby & Winterbottom, 2011) (Scogin, 2016). Studies showing the benefits of increased formative assessment use are numerous. Aydin and Urun (2016) show that a formative assessment oriented approach to teaching and learning is more beneficial to students when compared to a more traditional approach. In addition, formative assessments that integrate technology are also beneficial to students when compared against a control (Kapici, Akcay, & Yager, 2017). As students are able to practice their skills and get feedback on their performance they are more likely to improve their achievement. This is a phenomenon that has even held true for college mathematics courses (Hannah, James, & Williams, 2014) (López & Mazario, 2016).

While regarded as beneficial, formative assessments face barriers to their implementation. Teachers struggle with a wide variety of issues day to day in their classroom and often struggle to implement strategies and interventions even when they know that those
strategies and interventions are beneficial to students. A lack of planning time, lack of common planning time, lack of experience with formative assessment, and lack of experience with technology are just a few of the barriers to implementing formative assessments (Grob, Holmeier, & Labudde, 2017). Modern classroom teachers often turn to technology to counteract many of the various barriers to formative assessment implementation. Training is often done in these instances so that teachers can become familiar with the technology while also improving their overall skills in formative assessment (Lee, Feldman, & Beatty, 2012). Even though many teachers have turned to technology to help incorporate formative assessments, there are still mindsets that need to change regarding the use of technology in the classroom, particularly mobile phones. While current mobile phones are powerful computing devices that make clicker systems obsolete, not all teachers are ok with the use of mobile phones in their classrooms (Thomas & O’Bannon, 2013). These thoughts and stances lie on contrast to meaningful work being done around the world showing that mobile devices can provide meaningful learning experiences for students (Sun, Looi, Wu, & Xie, 2016) (Shirley & Irving, 2015).

While increasing the ease of integration of formative assessment, technology does not provide instant success in a classroom. As stated before, formative assessments should be for learning and they should also be meaningful. Collaboration during the development of formative assessments is a practice that has shown to be very beneficial to teachers and students (Heredia, Furtak, Morrison, & Renga, 2016). As teachers collaborate, implement, and then reflect on the practice of integrating formative assessments their ability increases over time (Furtak et al., 2016). The questioning level in formative assessment is something that should be highly thought out and planned. Many teachers falsely assess the level of their own classroom questions (Eshach, Dor-Ziderman, & Yefroimsky, 2014). While research has shown that extremely high
levels questions do not always result in increased student achievement, the questioning level cannot be too low either (Feldman & Capobianco, 2008) (Terry et al., 2016) (Deboer et al., 2014).

The amount of formative assessment technology available to modern teachers is staggering. It was not long ago that clicker systems were the only meaningful way to pair technology and formative assessment in the classroom. The success of clickers in secondary classrooms has been mixed. The mixed success is often attributed to the skills, training, and experience of the teacher in implementing formative assessments (Lundenberg et al., 2011) (Fuller & Dawson, 2017). While teacher ability and experience plays the most pivotal role in the integration of formative assessments in the classroom the new technologies available to teachers are exciting and innovative. Students are currently able to draw concepts in virtual environments and notebooks and have their teachers give them feedback (Copeland Solas & Wilson, 2017). These drawings in virtual lab notebooks have even been shown to be better predictors of future summative assessment scores than written responses (Shelton et al., 2016). To help make formative assessments more meaningful and student tailored, there is also new technology that incorporates QR codes and GPS data. Students can answer questions that are specifically tailored to where they physically are at that particular moment (Conejo, García-Viñas, Gastón, & Barros, 2016). Nandungadi and Raman (2012) developed an intuitive web based platform for the formative assessment of students. The application tracks and logs student responses and uses the data to tailor content that is delivered to the student in the future. Ideally that is a task that would be performed by the classroom teacher, but barriers to implementation make technology like this much more appealing. There is even software available that is capable of rating free response answers from students (Liu, Rios, Heilman, Gerard, & Linn, 2016).
Due to the previously outlined benefits of formative assessment, and the increasing ability of technology of aid in its implementation there are very few barriers to experimenting with new technology in the classroom. While the technology available to classroom teachers does not need to be incredibly high tech, it should be compatible with what students and teachers already have at their fingertips. Applications like Socrative are beneficial because they allow for a classroom teacher to use technology already in the classroom (mobile phones and laptops) and utilize them in the collection of formative assessment data (Coca & Slisko, 2013). Students are typically highly engaged when using mobile devices in the classroom and while the “pay off” of student engagement does diminish over time with the increased use of an app, the decrease is not significant (Wang, 2015). Nearpod is an application like Socrative in that it allows for the classroom teacher to easily question their students and collect a large amount of data that can then be used to encourage student metacognition and learning. Nearpod has even more features that Socrative, including a drawing feature and a highly advanced data analysis report that can be downloaded after a lesson. Due to its beneficial capabilities that allow for many different types of formative assessment, Nearpod activities should be integrated into the curriculum of a high school biology classroom.

**Meaningful Feedback and Uses of Formative Assessment**

**Exploring formative assessment as a tool for learning: students’ experiences of different methods of formative assessment**
This study looked into the effectiveness of two different formative assessments utilized in an undergraduate pathology course. The two assessments were both meant to be formative but were designed rather differently. The first assessment was an individual assessment that involved the students answering a serious of multiple choice and short answer questions about content (Weurlander, Soderberg, Scheja, Hult, & Wernerson, 2012). Questions were factual, and did not require the students to use many problem solving or critical thinking skills. The other assessment was a group assessment that was more designed as a learning activity rather than a test or quiz. Students were placed into groups, asked to sort various cards, and were then asked to match them with various patient histories. The cards had a variety of information on them like lab tests, microscope images, and specimens from surgery (Weurlander et al., 2012). Students worked in groups to solve the problem presented to them and then presented their answer to their teacher. If the group matched enough patient histories to the cards, they passed and were allowed to be done with the task. If the group did not match enough cards to the patient histories, they failed the assessment and were required to complete the assignment again. The individual assessment was conducted early on in the course while the group assessment was conducted very close to the time of the final exam. A small sample of 17 students reflected on their experiences taking both of the assessments (Weurlander et al., 2012). Those reflections were analyzed and served as the main source of data for the experiment.

Data from the experiment showed that students showed very different sources of motivation for completing each of the assessments. The individual assessment resulted in a great deal of extrinsic motivation by the students. Students completed the assessment because it resulted in bonus points on their final exam as well as showed them types of questions that may be present on their final exam. The individual assessment also resulted in a pressure to study that
ended up being beneficial to the students (Weurlander et al., 2012). In addition, the individual assessment forced the students to write out answers and explain their thinking in a way that would make sense to an instructor. That task alone was extremely beneficial to the understanding of the students. The group assessment resulted in more intrinsic motivation as well as more engagement from the students. In addition, the group assessment resulted in more discussion between students and the instructor. Rather than just rely on whether their answers were correct or incorrect, students were able to get valuable conversational feedback in the group assessment. Students were engaged in the individual assessment but not to the level that they were engaged in the group assessment. Both assessments allowed the students to have a greater overall sense of their learning. Students were able to identify and focus in on areas of content that they struggled with the most.

Formative assessments are beneficial to students because they allow for meaningful and frequent feedback. Students can determine what they know and do not know along with their overall level of understanding. Not all formative assessments are created equally. Some formative assessments are merely stripped down versions of tests or quizzes. In these types of assessments, students are presented with practice questions and told if they are wrong or right. These type of formative assessments are not as encouraging to students and they do not result in the same level of understanding. Assessments like the group assessment described in this study make it so students describe and state their thinking in a complete manner. When students do this, they are more likely to get to their misconceptions and misunderstandings. Students may still be able to get a multiple-choice question correct while having a major misunderstanding or misconception. This would make it so they miss an opportunity for feedback. Assessments like
the group assessment avoid purely factual questions and help students get to the root of their thinking.

**Identifying the Factors Leading to Success: How an Innovative Science Curriculum Cultivates Student Motivation**

This study looked into the key features and characteristics of the PlantingScience program. The PlantingScience program involves groups of students performing scientific experiments in their classroom while being paired with a collaborative scientist. The scientist that is paired with the students acts as a mentor and is there to provide support, feedback, and guidance. In a way, the interactions between the students and scientists in this study are a form of formative assessment. Students design their experiment, monitor their experiment, and collect data, while semi regularly updating their collaborating scientist with their progress. Scientists then read the updates from the students and provide any feedback that they deem appropriate. All of the interactions between the students and the scientists are online. PlantingScience began in 2005 with 41 teams of students and had grown to 437 student teams in 2011 (Scogin, 2016). The program has been deemed extremely successful. To determine the causes of success four sources of data concerning the project were critically analyzed. Two of the sources of data were observations of teacher classrooms. The selected classrooms had been integrating the PlantingScience program into their classroom for quite some time. Another source of data was a focus group meeting that involved teachers, scientists, and students that had all been involved in the project at some point (Scogin, 2016). The final source of data was 17 recorded online
interactions between students and their mentor scientists. Data was limited to these four sources so that it could be properly analyzed and examined.

Analysis of the data determined that there were three major sources of student motivation in the PlantingScience program. One of the sources of motivation was student empowerment (Scogin, 2016). Students were highly engaged at the prospect of developing and conducting their own experiment. Engagement was shown to be very high, even in some students that were typically not very engaged. Another source of engagement were the interactions between the students and the scientists. Students were very responsive to the feedback of the scientists and their attitudes often mirrored the attitudes of the partner scientist. If the scientist was discouraging and judgmental, students were less likely to be excited about their experiment. In instances where the scientist was excited and supportive, the students also were more likely to be excited about the future of their experiment. Lastly, the fact that this was an authentic learning experience was motivating to the students. It was common for students to take ownership of their experiment and express concern about their experiment. In addition, strategies utilized by the teacher were found to have great impact on the overall success of the PlantingScience program. Positive feedback along with high expectations for students were high predictors of student success (Scogin, 2016). If students felt that their ideas and designs were valuable they were more likely to continue on with the project. In addition, holding the students accountable for their own ideas and not doing the work for them was a high predictor of success.

This study and program are interesting in that they show an intimate connection between authentic inquiry, technology, teaching strategy, and the outside world. While not all students are able to have the amount of interaction with scientists that the students in this study had, there are generalizations that can be taken from this. Even with all of the technological advancements
present in modern day education, this study shows that there are few replacements for actual specimens and authentic inquiry. Watching a plant grow on a computer screen is not nearly equivalent to actually watching a seed sprout in person. This study is interesting in that it paired the use of authentic specimens with the use of technology. This pairing allowed for a great deal of feedback given to the students. While a scientist and not the teacher were giving the feedback, the students were still able to revise their thinking moving forward.

**How do Openers Contribute to Student Learning?**

In this study Zertuche, Gerard, and Linn looked into the effectiveness of openers as tools for increasing student understanding of complex topics (Zertuche, Gerard, & Linn, 2012). They wish to see a transformation from openers as purely things for students to do to keep busy to activities that are meaningful and effective tools at a teacher’s disposal. In order to research the effectiveness of openers the researchers used researcher-designed openers, teacher-designed openers, and a control of no openers. The teacher-designed openers were between 8-12 minutes long depending on the teacher. The researcher-developed opener was 20 minutes long and consisted of multiple components that were deemed important by the researchers. These components were eliciting, adding, distinguishing, and integrating ideas. The students involved in the study were broken up into groups and were exposed to either of the forms of opener (teacher and researcher designed) or no opener. Integrated into the unit being taught to the students, were many embedded assessments. The researchers used a pre and post test along with the embedded assessments to check for student understanding. Student understanding across all of the groups was compared in order to determine if openers were effective in increasing student
understanding. The students worked through a unit on hydrogen fuel cell cars during this study. During this unit, the students were exposed to topics like chemical bonding and energy. To work through this unit the students used a piece of online software called WISE. Wise software is an on-line platform that allows students to navigate through a topic while also having somewhat of a story that flows through the unit.

During this study, it was generally found that openers have a positive effect on student understanding. The improvements in student learning were shown to be statistically significant and were shown in a variety of ways. One of the ways that highlighted increased understanding was that students who were exposed to an opener (teacher designed or researcher designed) were more likely to go back and revise their work when compared to students who were not exposed to an opener. In addition, students exposed to the researcher-designed opener were significantly more likely to go back and revise their responses when compared to the students exposed to the teacher-designed openers. Another piece of data from the study was that a student who had at least partial understanding of the topic and was exposed to the opener made significant gains in terms of understanding. This is obviously in comparison to students with partial understanding who were not exposed to an opener. These gains in student understanding were assessed using the built in assessments in WISE. Not all of the data pointed to increased understanding however. This was shown when student’s pre and post test scores were analyzed. Pre and post test scores showed that there was no significant difference in scores between students who were exposed to an opener and students who were not exposed to an opener.

Implications for the research are straightforward. When students are exposed to activities where they are metacognitive and have the ability to practice their skills before they are assessed, their learning and scores will improve. The more times that these kinds of activities can be
integrated into a lesson, students will be better off. Because of this, formative assessments should not necessarily be distinguished from formative assessments. Openers are basically just formative assessments that are placed at the beginning of a lesson. Moving forward this study should be replicated with much more consistency across the board.

Can research homework provide a vehicle for assessment for learning in science lessons?

Newby and Winterbottom (2011) wanted to look into a way to incorporate more formative assessment practices into classrooms. An area that they identified to improve the amount of formative assessment was homework. The researchers identified that homework is often riddled with deadlines and is often assigned without much of a purpose. Students complete worksheets or assignments that have varying levels of connection to the material they are learning in class. In addition, the homework typically is not spread out over a period of time and is due the next time that the student is in class. To combat this, Newby and Winterbottom suggest research based homework. Research based homework basically involves assigning the students a long term assignment to complete outside of class. At various points during the assignment the students are asked to bring in their progress. Current work is either assessed by a peer or it is assessed by the teacher. The student is then able to take suggestions for improvement and apply them to their assignment moving forward. The assignments that were given to the students were intended to be of high interest, they needed to take multiple weeks to complete, while also allowing for varying methods of completion. The researchers looked into student feelings on research homework in three grades levels of students (9th, 10th, and 11th).
There were a few trends within the findings of this study. One trend that was rather obvious was that 9th grade students were much more accepting and positive towards the research homework than 11th grade students. While they were not given the same assignments, the researchers mentioned a number of possibilities for this difference. One of the reasons suggested was a simple deterioration of attitudes toward school with increasing age. Another suggestion was that 11th grade students had exams to contend with during the implementation of research homework while the other two grade bands did not. Across all of the grade bands student agreed that their assignments helped them to understand the topic in question, however the students in 9th and 10th grade reported much higher amounts of learning than the 11th grade students. A trend that was consistent across the board was that students enjoyed being able to determine when they were going to complete their homework and how much of that homework they were going to work on each night.

Implications for this study could be rather significant. By sacrificing out of class time to work on long term assignments, a teacher then needs to dedicate class time to discuss those assignments. If homework is meant to be used as a way for students to practice their concept knowledge and skills a teacher cannot just assign a long term assignment and never mention it again. In a way, research homework could be used as part of a flipped classroom. With a significant amount of buy in by students this could be a very effective form of formative assessment. Issues would arise if students do not buy into this method, and cannot find a topic that they are interested in. In addition, a teacher would have to spend a significant amount of time designing assignments that not only are interesting, but are also not too narrow in focus. These assignments should contribute to the overall learning of the student and address multiple learning standards within a unit.
The Effect of Formative Assessment Technique on Academic Success of the Students and Their Attitudes in the Unit “The Solar System and Beyond: The Space Puzzle” At 7th Grades.

In this study Aydin and Urun looked into the effectiveness of formative assessment driven instruction when compared to more traditional teacher centered instruction. In order to determine if there was any significant differences in learning between the two techniques, two groups of students were used. One group of students went through the “Solar System and Beyond” unit with their teacher heavily using formative assessment in their instructional practices. The other group of students went through the unit with traditional instructional practices. The Solar System was selected as the topic of study because students typically struggle with the large scope and scale of the unit, along with the fact that it is extremely difficult to incorporate hands on instruction into a unit on the solar system. After concluding the three week long unit, the students were assessed using two methods, an academic achievement test and an attitude test.

Initially, the researchers compared pre test data for the academic achievement test between the control group (traditional teaching method) to the experimental group (formative assessment). There was not a statistically significant difference in the performance of the two groups. This is important to show that the two groups were homogenous enough to compare against one another in the study. When the post data for the academic achievement test was compared there was a significant difference shown between the two groups, with the experimental group showing much better scores than the control group. In addition, data for the
attitude test for both groups was analyzed. When data from the pre and post attitude test was compared for the control group there was no statistically significant difference shown. Conversely, the post test scores for the experimental group were significantly higher than the pre test scores. To summarize, it was shown that teaching practices that rely heavily on formative assessment improve summative assessment scores as well as improve student attitudes towards science when compared to more traditional methods.

I do not see many implications for this study moving forward. In many studies, it has been shown that students show increased understanding of concepts when given opportunities to practice their skills and think about their thinking. Formative assessment provides students with that opportunity. The timing and administration method of formative assessment should be what we are researching moving forward.

Comparison of Science-Technology-Society Approach and Textbook Oriented Instruction on Students’ Abilities to Apply Science Concepts.

The study by Kapici, Akcay, and Yager (2017) focused on the difference between teaching with a Science-Technology-Society approach as opposed to a textbook approach. Science-Technology-Society approach is described as a teaching method where scientific concepts are presented and described to the students in the context of the society that the students live in. This teaching strategy is part of a constructivist approach to teaching that supposedly helps students increase the application domain of their learning. By applying their learning to novel situations and scenarios, students are able to exhibit higher level learning and move past rote memorization and surface level learning. This study was conducted on 609 students from
the Midwestern United States (Kapici et al., 2017). Approximately half of the students were assigned to be part of the experimental group that utilized the Science-Technology-Society approach. The other half of the students were assigned to be a part of the control group that utilized the textbook approach. Guidelines were given to the teachers of students in both groups in the study. The guidelines reminded the teachers in the Science-Technology-Society group to constantly connect their curriculum to social issues and the society that they live in. Teachers in the control group were reminded to stick to the content and not connect any of the information in the course to the society in which the students live.

It was shown in this study that there were statistically significant differences between student achievement in the experimental and control groups. Students who were taught using the Science-Technology-Society approach achieved significantly greater post test scores when compared to the control group. When the data was organized into small subsets, similar trends were shown. For instance, males in the experimental group showed significantly greater post test scores when compared to the control group. Females also showed significantly greater scores in the experimental group when compared to the control group. The researchers also chose to examine if students of different achievement levels showed any differences in post test scores for the two different groups. When high achieving students were compared between control group and experimental group, the experimental group showed significantly higher post test scores. In addition, when low achieving students were compared between control group and experimental group, they also showed significantly greater scores in the experimental group.

The implications of this study should not be very wide ranging. The concepts detailed in this study are dated and did not justify a study. Many of the studies referenced in this paper had been conducted at least 10 years prior to this study. The assumption that students achieve better
learning outcomes when they are able to apply what they have learned to novel scenarios is not a new idea to the literature. Science teachers should continue to involve real world scenarios in their teaching regardless of the outcomes of this study.

**Does computer-aided formative assessment improve learning outcomes?**

This study looked into the effectiveness of computer aided formative assessment on the learning of first year college math students. The students in the study were enrolled in two first year engineering math courses. The courses were sequential to one another, with one of the courses being a prerequisite to the other course. Because of this, one of the courses was named Math 1A and the other course was named Math 1B during the article. In both of the courses there were online quizzes available to the students that made up a very small percentage of the overall course grade. Because there was a grade attached to these quizzes they are technically summative, but due to the utilization and purpose behind these quizzes, they can mostly be seen as formative. These quizzes allowed unlimited attempts while also having an unlimited time to work on them. The rationale behind these quizzes was that with increased practice students would be able to master more basic math skills, which would allow them to perform better on summative assessments. Data was collected for four years from the Math 1A and Math 1B courses. The data collected was quiz scores, tutorial scores, time spent per quiz, quiz attempts, and improvement on quiz scores (Hannah, James, & Williams, 2014). Lastly, summative assessment scores were collected and analyzed for their possible connections to the quizzes.

Analysis of the data showed a great deal of data that was not particularly shocking. Quiz scores were positively correlated with quiz attempts and time spent per quiz. As students spent
more time in the quiz environment, they gradually improved their quiz grades. One student gradually improved their quiz grade from a C+ to an A+ over repeated attempts (Hannah et al., 2014). Another finding from the study was that quiz scores in the second semester of the Math 1A course were significantly lower than the scores from the first semester (Hannah et al., 2014). This should be expected, because stronger students would have passed 1A in the fall and would no longer be in the Math 1A course in the spring. A course without the stronger section of students would naturally show a lower average quiz score. In addition, time spent in the quiz environment significantly dropped from the fall to the spring semester (Hannah et al., 2014). This coincides with the finding that exam scores (test scores) correlated positively with quiz time and quiz attempts but showed negative association with those two variables. In this instance, correlation does not imply causation.

The data from this study is surprising and should cause some pause to teachers that are very enthusiastic about including more formative assessment in their classroom. In this small sample, it was obvious that even though certain students were receiving timely, accurate, and quick feedback, it did not imply higher test scores. One would assume that with more practice and more feedback test scores would increase, which was not the case in this scenario. However, the formative assessment in this study was purely question based and was not rooted in strong pedagogy. Other research has noted that formative assessment should be part of a larger process that sparks student thinking and encourages discussion (Furtak et al., 2016). Students should be formatively assessed in a way that not only indicates if their learning is correct, but also sparks their thinking in a way that allows them to build knowledge. A piece of technology that simply makes it so the correct answer is provided is not necessarily providing much feedback in this context. Technology can make formative assessment easier to implement but it does not
necessarily make it more effective. The students in this example could have been continuously using the computer based formative assessment at the expense of other methods of learning.

The use of technology in a model of formative assessment.

This article summarizes the methods and results from an introductory university mathematics course that utilizes a great deal of technological formative assessment. One of the larger components of the student’s formative assessment are online Moodle quizzes. The students take eight Moodle quizzes throughout the semester, with each quiz corresponding to a particular topic identified in the course. Students are allowed two attempts for each quiz, with the highest grade being the one that counts. Feedback is given to the students for every answer, correct or incorrect (Lopez & Mazario, 2016). This is because the designers of the course noted that it is possible to get a question correct but have incorrect reasoning behind the answer. The Moodle quizzes make up 4% of the student grade and are mainly participation. Due to their small overall contribution to the overall course grade and their intention of providing feedback, these quizzes are formative in nature. Another component of the overall course grade for the student is a portfolio. The portfolio consists of a number of small assessments and assignments that have been given to the student throughout the semester. Each of the assignments is returned to the student with targeted feedback. The returned assignments are then compiled into a portfolio that makes up a considerable portion of the final grade for the student. A small group project is another component of the course grade. For the small group project students have the option of five different projects to complete in a group of two to three students. Projects are initially evaluated by the professor and given back to the groups with the opportunity to make
corrections and improve the overall grade (Lopez & Mazario, 2016). Students were also given the opportunity to have their small group projects evaluated by other members of the class community via an online learning environment. They could submit their SGP and wait for feedback from another student in the course. This is another instance of an assignment having both formative and summative components. Lastly, in order to take an exam in this course students are required to complete and hand in a set of practice problems.

This course, which is common among several degree programs, shows the highest pass rate among all the common courses offered in those programs during the examined semester (Lopez & Mazario, 2016). The course is generally regarded as a difficult course, and its pass rate is higher than would be expected. The pass rate could be due in some part to the Moodle quizzes. It was shown that 75% of students that scored 80% or higher on five or more Moodle quizzes were able to pass the course (Lopez & Mazario, 2016). These quizzes were a small portion of the overall course grade, so this points to the notion that increased practice with timely feedback helped to increase student performance. Participation in the Moodle quizzes dropped over the course of the semester along with the success rate on those same quizzes (Lopez & Mazario, 2016). This could be due to a number of factors, one of them being the increased difficulty of concepts over the course of the semester. Lastly, the participation in the open online environment was limited. Only 18 small group projects were uploaded into the environment. Almost all of the students involved in the online environment evaluated a small group project. In addition, the assessments completed by students on the small group projects agreed heavily with those of the professors.

Implications for this study are limited but meaningful. This course shows that increased expectations along with increased formative assessment can equal success. While in a secondary
education setting it is unlikely that all formative assessments will be required, there are obvious benefits to this. Students that do not put forth much work into formative assessments or try to cheat the system just to get them done would probably not have done the assessments anyway if they were not required. Students that appreciate the feedback and are looking for practice, would thrive in a setting like this one. Technology makes this possible, by allowing for certain tasks to be assessed through technology and more complicated tasks to be evaluated by the teacher. Peer feedback is another component of this course that could be valuable to tie into technology based formative assessment in a high school science classroom. Theoretically, students could submit answers to reasonably complex problems via an online platform like Nearpod. The teacher could then group students strategically so that students could build their knowledge from each other and then submit a revised answer to the problem.

Misconceptions and Barriers to Implementation

Formative Assessment to Support Students’ Competences in Inquiry-Based Science Education.

This study aimed to identify the challenges and difficulties with implementing formative assessment practices in an inquiry based science classroom. In addition, this study looked into methods suggested by teachers to improve the frequency and implementation of formative assessment practices in science classrooms. To accomplish this, the researchers recruited volunteer science teachers from Swiss secondary science classrooms. The teachers were asked to implement a form of formative assessment during every semester. The types of formative
assessment that they had to choose from were written teacher assessment, peer assessment, or self-assessment. At the end of every semester, the teachers filled out a self-assessment survey that focused on the challenges and difficulties of implementing formative assessments into their classroom routine. The results of the self-assessment survey were sorted and analyzed into two main groups. The first main group of responses were the challenges that teachers identified with implementing formative assessment practices into their classrooms. The second main group of responses were suggestions by the teachers that would help support them in implementing formative assessment in their practices.

The major findings of this study were basically a list of the responses that they received from teachers after implementing a form of formative assessment into their practices. When teachers listed the difficulties that they faced when implementing formative assessment strategies the researches grouped the responses into five main categories. The first category dealt with embedding formative assessment into daily practice. It was difficult for teachers to properly plan for incorporating formative assessment on a short term and a long-term basis. Another category explained that it was difficult for teachers to determine how much feedback to give and in what form it should be given. Teachers also struggled with students giving feedback to other students. They were not sure that the feedback would be accurate enough. They also were unsure if the student receiving the feedback would take it seriously enough. Lastly, students and teachers struggled with the importance of formative assessment in the learning process. Students and teachers were consistently unsure of how much importance to place on formative assessments especially when placed in context with summative assessments.

Teachers also mentioned a number of supports that would be helpful in aiding them to incorporate formative assessment into their practice. One of the things that teachers thought
would be helpful was examples of good formative assessment. This makes sense because exemplars are often used by teachers to help students know what is expected of them. To use exemplars to show what is expected of teachers is not much of a leap. Teachers also identified that more time would be helpful in incorporating formative assessments into their teaching. Another request was an opportunity for training on the use of formative assessment in the classroom. Other things that were identified by teachers could generally be classified as opportunities for collaboration and reflection with colleagues on the topic of formative assessment. While many of the challenges identified by teachers and requests by teachers were not surprising, the process of identifying them and chronicling them was a worthwhile practice.

Future research should somehow quantify the responses by teachers in this survey. A survey could be made from these teacher responses and a new set of teachers could identify which challenges and supports they most agree with. This could be purely a yes / no survey or it could be based on a number scale. Either way, this would allow this initial research to move more towards a point where the research could be applied back to classrooms and benefit students.

**Factors that Affect Science and Mathematics Teachers’ Initial Implementation of Technology-Enhanced Formative Assessment Using a Classroom Response System.**

The research presented in this article sought to understand the barriers that confront educators when they are initially implementing a Technology Enhanced Formative Assessment (TEFA) program. In order to understand some of the pitfalls and challenges associated with
implementing this kind of program the researchers deeply investigated the teaching practices of a small number of middle and high school math and science teachers. The teachers involved in the study had all volunteered and all taught at the two different schools that had been selected for the study. One school (School A) was a combination middle school and high school in a rural area, while the other school (School B) was a high school located in a college town. All the teachers in the study were provided with student response systems (SRS) and were directed through professional development led by the researchers throughout the study. The teachers were instructed on how to use the software and clickers in a manner that was consistent with strong pedagogy. Strong pedagogical use of the student response systems involved using the clickers in a manner that would facilitate meaningful group discussion. Data collection mostly consisted of monthly surveys that were comprised mostly of Likert-type questions along with some free response questions. Survey data was triangulated with additional forms of qualitative data such as class video recordings, interviews, student surveys, and teacher journals (Lee, Feldman, & Beatty, 2012).

Analysis of the survey data yielded a large amount of data concerning the barriers that confront educators when they are initially implementing a TEFA program. The researchers identified ten major factors that contributed to difficulties in implementing a TEFA program (Lee et al., 2012). Some of the factors were intrinsic to the software and its use. Teachers struggled with the clicker software or with the use of technology in general. Other factors were associated with the amount of time that a teacher has throughout the day. Participants identified that the pressure to get through their entire curriculum in a specified amount of time was difficult, along with finding enough time to develop rich meaningful questions to use with the software. The ability to motivate students and lead them in meaningful discussion was another
noted trend in the data. Some teachers in the study noted that they were lacking in the ability to lead an effective group discussion that was not rooted in their urge to give away the right answer (Lee et al., 2012). Other teachers noted that some students struggle with the ability to be appropriate in a group discussion format. Struggle with TEFA was not homogenous across all the participants in the study. The participants fell into various spots along a spectrum of full implementation. To describe various spots along the spectrum the researchers utilized vignettes that described five of the participants in the study. Teachers that fit into a spot early in the continuum were described as “failing in initial technology integration” (Lee et al., 2012). Ending up at this end of the spectrum meant that the teacher could not overcome the initial hurdles that new software provides and did not enter into any kind of meaningful use with the SRS. Other participants overcame the initial technological hurdles but struggled with using the SRS for anything other than checking answers. Teachers that fell at this next spot on the continuum were described as “no pedagogical implementation” (Lee et al., 2012). A number of teachers were able to get to a point where group discussions were fostered; however, they were not consistent. Teachers at this next point on the continuum were not convinced of the value of consistent group discussion, and struggled with the need to cover curriculum in a timely manner. Passive pedagogical implementation was the label used by the researchers for this group of participants (Lee et al., 2012). Lastly, there were teachers that moved past all of the intrinsic and extrinsic barriers to implementation and found full use of a TEFA program. These teachers were able to use technology in a meaningful way and moved the focus of the lesson from themselves to the students. This was described as active pedagogical implementation (Lee et al., 2012).

This study shows a great deal of relevance and value to current schoolteachers. At this time in educational history there is a great deal of technology that is available for use. Some
teachers have an aversion to technology because they have become comfortable with their own traditional teaching style. Other teachers hold the false belief that just the use of technology will help increase student achievement. This study shows that the appropriate use of technology takes a great deal of time and effort. To be able to properly integrate new technology in a classroom requires a great deal of professional development and patience. It is not enough to just buy technology and hope that teachers will figure out a way to properly integrate it into their instructional practices. This study also shows that persevering through various extrinsic and intrinsic challenges with technology can be worthwhile and can sometimes result in changes in educational approach that benefit both the teacher and students.

**Cell Phones in the Classroom: Preservice Teachers’ Perceptions.**

The researchers in this study looked into the perceptions of preservice teachers on the use of cell phones in classrooms. To determine teacher perceptions, a survey was given to 92 preservice teachers from a small liberal arts college. The survey included items to address the multiple research questions present in the study. One of the major research questions was whether preservice teachers were supportive of the use of cell phones in the classroom. In addition, teachers were asked what features of a cell phone would be most useful for use in a classroom setting. A literature review was conducted in order to determine the aspects of cell phone use in the classroom that were possible benefits and aspects that would be possible barriers. The preservice teachers were asked to agree or disagree with the possible benefits and barriers that had been identified by the literature review. Lastly, the survey aimed to determine if there was a considerable difference between preservice teachers that grew up in this current age
of technology, and those that did not. The two groups of preservice teachers were identified as technology natives or technology immigrants. Technology natives were defined as preservice teachers that were born after 1980 while technology immigrants were defined as preservice teachers that were born prior to 1980 (Thomas & O’Bannon, 2013).

When the preservice teachers were asked about their support of cell phones in the classroom, the answers provided showed that there was not much support. Support was indicated by 25% of the teachers, while 22.8% of the teachers stated that they did not support the use of cell phones in the classroom (Thomas & O’Bannon, 2013). The rest of the teachers polled for this particular question stated that they were undecided. Preservice teachers also indicated the features of a cell phone that they felt would be most useful in a classroom. The choices that were selected most often by the teachers were the calculator, access to the internet, and audio recording capability (Thomas & O’Bannon, 2013). Access to social media and texting were indicated the least often (Thomas & O’Bannon, 2013). The notion that learning opportunities could be anytime, increased classroom engagement, and being able to differentiate instruction were all the most common selections among preservice teachers when they were asked about possible benefits of cell phone use in the classroom (Thomas & O’Bannon, 2013). Those possible benefits could be contrasted with the most common barriers selected. The most common barriers selected were increased classroom disruptions, increased ability to cheat on assessments, and the associated cost of the devices (Thomas & O’Bannon, 2013). Lastly, when the responses of the technology natives and technology immigrants were compared, there was no statistically significant difference between the perceptions of both groups.

The results of this study are interesting and definitely significant. It may be assumed that younger teachers, especially those who have not spent time in front of their own classroom,
would be inclined to support the use of a multitude of different technologies. The results of this survey, while limited, show that this may not be the case. There is a significant hurdle to get over if technology is going to be heavily integrated into the classroom, especially cell phones. Cell phones have traditionally been viewed as pieces of technology for pleasure, and not for purpose. As the capabilities of cell phones increase, the perceptions of teachers and the public may start to change. When this study was published (2013) the capabilities of cell phones were significantly less than they are currently (2018), only five years later. Exponential technological growth will make it so the cell phones in five more years have far greater capabilities than the present models. Further research into the perceptions of teachers on cell phone use would be warranted in order to determine if there are any noticeable shifts in future perceptions.

The Innovative Immersion of Mobile Learning into a Science Curriculum in Singapore: an Exploratory Study.

This study looked into the integration of a mobile technology focused curriculum called the Mobilized 5E Science Curriculum (M5ESC). The Mobilized 5E Science Curriculum is a curriculum that focuses on the integration of mobile technology into science class in a sound pedagogical manner. Rather than simply incorporating technology for the sake of incorporation, the M5ESC aims to use mobile technology as a tool that can be used to encourage collaboration, discussion, and inquiry in the science classroom. The curriculum utilizes Windows operating smart phones that are equipped with a number of different apps that the students can use during class. Some of the apps installed on the phones are KWL, Sketchbook (for student drawings), MapIT (for concept maps), Blurb, NotePad, and Recorder (Sun, Looi, Wu, & Xi, 2015). In order
to determine the effectiveness of the curriculum on student learning, a case study was performed on an experienced teacher in Singapore. The teacher in question was observed for an entire school year. A mixed methods design was employed in order to collect as much data as possible. Some of the data collection methods used were class observations (video and notes), teacher interviews, collections of student work, formative assessments, and summative assessments (Sun et al., 2015).

Over the course of the year, the teacher in the case study became much more skillful with the use of technology in her classroom. When she first started utilizing the M5ESC curriculum, her questioning practices were developing. She would often ask straightforward questions to the higher achieving and more engaged members of the class, while seeming to ignore other members of the class. In addition, while she was incorporating the mobile technology into her classroom, she did so in a manner that did not encourage the students to use higher level thinking skills. As she became more comfortable with the technology and with asking exploratory questions, her skills began to improve. By the end of the year it was common to observe her as a facilitator rather than as a lecturer. Students were encouraged to use their phones to aid in the process of exploring and experimenting with the world around them. Phones were used to take notes, take pictures, record data, and to interact with the other members of the class community (Sun et al., 2015). Mobile technology was also utilized as a way of collecting and evaluating formative assessments. Student work was able to be shared via the mobile devices between teacher and student. The teacher was able to seamlessly collect student work while also providing timely and valuable feedback through the new mobile technology. It was noticed that students were more likely to utilize their mobile technology when provided with challenging questions that required the students to provide evidence for their answers. Lastly, student
summative assessment scores increased as the teacher became more adept at the implementation of the new curriculum. When administered a unit test early on in the year the student average was 76.65 out of 100 (Sun et al., 2015). When given a unit test later on in the year the average was 82.39 out of 100 (Sun et al., 2015). While the content on the tests was not the same, this can still be used as supporting evidence of the effectiveness of mobile device integration with sound pedagogical practices.

The message from this study is one that should be followed by many current generation teachers. The urge to implement new technology into the classroom grows stronger as each year passes. There are many districts that focus on the implementation of technology, as well as many teachers that place implementing technology as a priority in their classroom. This study serves as evidence that without solid questioning, discussion, and inquiry based activities, technology can easily be rendered meaningless. Teachers should be finding ways to get the most out of technology, rather than just using it to accomplish the same tasks that could easily be accomplished without that technology.

**Connected Classroom Technology Facilitates Multiple Components of Formative Assessment Practice.**

This study was an in depth qualitative analysis of the technology based formative assessment practices of four high school science teachers. The teachers selected for this study had been involved in a previous study that looked into the effect of connected classroom technologies in math and science classrooms. They all had used the software utilized for the study for a year, and voluntarily decided that they would like to continue with the study. These
teachers were not only selected because they volunteered, but also because they had shown themselves to be particularly skilled at utilizing TI-Navigator in their classrooms. TI-Navigator is the connected classroom technology that had been utilized in the previous study and this study. Researchers conducted classroom observations, facilitated student focus groups, and conducted multiple interviews with the teachers in order to gain a higher understanding of how connected classroom technologies were specifically utilized in these teacher’s rooms. By investigating the practices of these four model teachers the researchers hoped to determine what tasks were made easier by connected classroom technologies and how connected classroom technologies specifically help to implement formative assessment in a classroom.

After coding and categorizing the collected data the researchers were able to make three main assertions based on how connected classroom technologies affect formative assessment. The first assertion that was made was that connected classroom technologies assist a teacher in implementing various classroom tasks (Shirley & Irving, 2015). For instance, one of the teachers in the study described how he used the software as a way to display classroom data during a laboratory activity. Students were able to observe all of their classmate’s data in real time and use it to construct graphs, tables, and make statistical analyses. It was also noted that connected classroom technologies made it easier for the teachers in the study to administer tests and quizzes. While the tests and quizzes were assigned a grade and therefore not true formative assessments, the teacher was able to evaluate them quickly, often before the students had even left class for the day. This kind of timely feedback is valuable to student learning, even if it involves a grade. Another assertion made by the researchers was that connected classroom technologies allow for the teacher to know more about the status of student learning in their classroom (Shirley & Irving, 2015). Some of the teachers in the study noted that before their use
of connected classroom technology they thought they were able to accurately gauge the level of understanding in their classroom. Because connected classroom technologies are able to collect and display data so quickly and accurately those teachers were able to see within a lesson that their past assumptions about student learning may not have been true. Concepts that they felt were universally understood by students were shown to be confusing, and skills were still developing. Lastly, the researchers asserted that connected classroom technologies make it so teacher’s planning and decision-making can be constantly supported by data (Shirley & Irving, 2015). This assertion is similar to the second assertion but is different in that it pertains to how teachers use the data moving forward. If teachers formatively assess their students using traditional pencil and paper methods, they may not be able to evaluate student work in time to make any meaningful changes to instruction. With connected classroom technologies a teacher can quickly obtain a large amount of data, and use that data to determine their instructional practices for the next day, week, or month.

The implications for this study are straightforward. When used correctly, technology can make various teaching tasks much easier. One of the tasks that can become much easier is formative assessment. Tools that allow for the rapid and accurate collection of data will help teachers better plan their instructional activities and respond to the needs of their students. Technology is not a magic wand, but rather a way to make practices that have been shown to be beneficial for student learning easier to conduct. As teachers become more comfortable with new pieces of technology, they will find more novel and beneficial uses for them in their classroom. When technology for formative assessment is used to its maximum potential, it is effectively helping the teacher facilitate metacognition in the students along with being an effective data collection and lab administration tool.
Sound Formative Assessment Design and Implementation

Science Teachers’ Representations of Classroom Practice in the Process of Formative Assessment Design.

This article looked into the collaborative development of formative assessment tools. Specifically, this research analyzed how specific discourse and interactions among members of a high school biology faculty led to the development and revision of formative assessment tools. The study was conducted over the course of two years and involved seven teachers, two student teachers, and multiple university facilitators and investigators. Over the course of the two years of the study, the individuals involved met 18 times. Each of the meetings lasted approximately 90 minutes. Six formative assessment tools were developed over the span of the two years but only one was chosen to be focused on for this study. The formative assessment tool chosen for analysis for this study involved natural selection. In the formative assessment tool, students were asked to analyze a number of scenarios involving natural selection. After looking into the various scenarios, the students were then tasked with developing hypotheses for what they observed in the various scenarios (Heredia, Furtak, Morrison, & Renga, 2016). The teachers were videotaped when implementing this formative assessment tool, and then used the videotape to help lead their conversations around the tool during the next cycle of meetings with their colleagues (Heredia et al., 2016). To look into how conversations among colleagues helped revise the formative assessment tool, their conversations were recorded, coded, and categorized.

Coding of the conversations between the teachers revealed a number of different themes. Early meetings between the teachers resulted in mostly “new idea” codes along with some
“representations of practice” (Heredia et al., 2016). As the teachers began to enact the formative assessment tool in their classroom, they started to include more “formative assessment criteria” codes in their discussion. After the formative assessment tool had been used in a number of different classrooms, the conversations started to include “formative assessment revision” codes (Heredia et al., 2016). Most of the second year of meetings continued to revolve around revision of the formative assessment tool, as well as new ideas for future enactment. The researchers described much of the language between individuals in the study as opaque in the early going. Opaque language meant that the conversation was superficial and did not dig into actual reasons behind the success or failure of the formative assessment tool. As language began to transition from opaque to transparent there started to be more progress in revising the formative assessment tool. Transparent language led to dialogue, which led to the teachers involved trying to incorporate as many ideas as they possibly could (Heredia et al., 2016).

This study demonstrates that effective dialogue between faculty members can improve the development of formative assessment tools. In addition, this study demonstrates that while all conversation among members of a group is beneficial, transparent conversation is more beneficial. Formative assessment, just like other teaching practices and tools, benefits heavily from practice and experience. The more opportunities that there are to reflect on student responses and incorporate those reflections into the development of formative assessments, the better the formative assessments will be. Good formative assessment practice relies as much if not more on proper feedback given to the students but good design can help focus that feedback. In addition, this practice of group formative assessment design, implementation, and revision could be easily replicated in other schools. Teachers naturally improve their practice by going through periods of reflection, but group reflection allows for that many more ideas to be brought
to the table. Formative assessments, when designed with care and thought, should work for a number of teachers. This is because they are designed to bring student thoughts to the forefront. What a particular teacher does with those ideas determines if the formative assessment practice is merely satisfactory or exemplary.

**Teachers’ formative assessment abilities and their relationship to student learning: findings from a four-year intervention study.**

This research looks into the development of formative assessment skills in a group of teachers after they were involved in a directed three-year intervention led by researchers. The intervention that the teachers were involved in was called the Formative Assessment Design Cycle. The Formative Assessment Design Cycle (FADC) involves teachers going through various steps in the hope that they learn to design higher-level formative assessment tasks. The FADC begins with a teacher being guided in a process of investigating and exploring the ideas of their students. After looking into the ideas of their students, a teacher then designs formative assessment tasks in collaboration with other teachers. Designed formative assessment tasks are then practiced by the teacher, so that they can be prepared for possible student reactions and responses. Practice and preparation leads to the teacher actually performing the tasks in their classroom and videotaping the lesson. Reflection on the lesson is the last step in the FADC. Reflection can be performed individually or with colleagues. In this particular study, nine teachers immersed themselves in FADC for three years. Before and after the study, the teachers involved were assessed in their ability to perform and apply various skills related to formative assessment. Teachers were assessed in designing effective formative assessment tasks, asking
questions that instigated student thinking, effectively interpreting the ideas and learning progressions of students, and giving appropriate and effective feedback to students (Furtak et al., 2016). The researchers in the study developed a quantitative method to assess all of these skills and did not utilize qualitative methodology for any of the data analysis.

The data collected in this study pointed to the improvement of teacher’s formative assessment skills over time. For the four skills assessed, all of their means increased over the course of the study. There were individual teachers that decreased in some of the skills involved, but not enough to make it so the mean for all of the teachers decreased over the course of the study. Questioning, interpreting student ideas, and feedback all showed growth at a statistically significant level when the data from the final year of the study was compared against the baseline data (Furtak et al., 2016). Even though the mean increased for the design of formative assessments, it did not increase at a level that was statistically significant. Students also showed statistically significant achievement increases when their testing data from the final year of the study was compared against the baseline data. When the baseline testing data was compared against the teacher skill assessments the only skill that showed high association to scores was teacher feedback (Furtak et al., 2016). However, when the final year testing data was compared against teacher skill assessments two skills showed high association. These skills that showed high association were formative assessment design and interpreting student thoughts (Furtak et al., 2016).

Findings from this study go to show that effective formative assessment is not something that is necessarily natural or easy to implement. Formative assessment takes practice and involves a variety of components that work to together in order to affect student learning. For instance, the fact that questioning skills did not show a high association to increased student
achievement is interesting. As a teacher moves through their preservice coursework and initially enters a classroom they are taught the benefits of pure inquiry, and that open-ended questioning is valuable to student learning. This data points to the notion that while open-ended questioning is valuable in unveiling student thinking, it may not be effective in isolation. When paired with skillful identification of student ideas and misconceptions along with timely feedback, that questioning can then be beneficial. These skills take time to master and incorporate into teaching. Technological tools that make the implementation of formative assessments easier are becoming more and more numerous. These tools, while valuable, need to be used in conjunction with and grounded in solid pedagogical practice. This research points to the value of formative assessment training and practice. This training and practice when paired with technology could be incredibly effective in increasing student achievement and understanding of concepts.

**Question Asking in the Science Classroom: Teacher Attitudes and Practices.**

This study looks into the nature of questioning within typical science classrooms. The researchers state that while it is widely agreed within the scientific and educational community that higher level questioning is valuable to student learning, effective questioning is not utilized as much as it should be. To assess the extent and quality of questioning, the researchers observed nine separate science classrooms across a variety of grade levels. Three Primary, Three Middle, and Three High School science teachers from Israel were observed across a span of five lessons each. To help answer the research question both qualitative and quantitative data was collected. Quantitative data was collected in the form of direct classroom observations. The questions used by teachers and students within the classroom were observed by a third party, classified into groups, and then the number of questions of each type was totaled. Qualitative
data was collected in the form of interviews conducted with the teachers in the study after their five lessons had been taught. The teachers were asked a series of open-ended questions about the questioning process within the classroom. They were also asked to state the role of teacher and student questioning within the classroom according to pre-generated statements. Teachers either agreed or did not disagree with the statements presented to them.

In the study it was determined that questioning is not properly utilized in science classrooms. The determination that science was not effectively utilized in classrooms was contradictory to what the teachers stated during their interviews. When the teachers were asked what was the role of questioning in the classroom all of the teachers involved agreed with the statement that questioning by the teacher should be used to increase student stimulation, interest, and curiosity (Eshach, Dor-Ziderman, & Yefroimsky, 2014). Most of the teachers also agreed with the statements that questioning by the teacher should be used to interact with the students and to evaluate student knowledge (Eshach, Dor-Ziderman, & Yefroimsky, 2014). When asked about the role of student questioning within the science classroom there was not a consensus among the teachers. Five of the nine teachers said that student questions could be used to increase student interest, clarify material, and develop thought (Eshach, Dor-Ziderman, & Yefroimsky, 2014). The quantitative data from this study showed that higher order questions made up an extremely low percentage of the teacher questions across all of the classrooms and grade levels tested. In addition, the amount of student questions that were higher order was also extremely low when compared to middle order and low order questions. It was informally observed that in many instances the teachers were asking questions for a very specific response and then very quickly shifted to the rest of their lesson. A trend throughout all of the classroom
observations was that it was extremely rare to see a question shifted back towards the students so that they could experience the process of discovery.

There are a number of different takeaways and implications from this study. The obvious disconnect between teacher’s opinions and their actual questioning practices is striking. It could be hypothesized moving forward that this disconnect between thought and practice could hold true for other classrooms. If this is something that holds true there definitely needs to be more effort put forth towards improving teacher-questioning skills. This could be in the form of professional development, opportunities for teachers to observe their own classrooms, or district initiatives. Another striking takeaway was the lack of student questioning in the observed lessons. Many of the teachers seemed to use questions to have students recite factual knowledge. When students asked questions of their teacher that required extra thought or an in-depth answer teachers seemed to do whatever they could to move past that question. If this is not an isolated occurrence, the educational community should be extremely concerned. Students that feel as though their questions are not taken seriously will continue to become more isolated in the classroom. This could even cause a student that is extremely excited about school to become more and more cynical.

**Teacher Learning of Technology Enhanced Formative Assessment.**

This study looked into how formative assessment technology is integrated into a high school classroom. The teachers that served as participants in this study were all high school physics teachers of different experience levels. Two of the teachers in the study were novice teachers in their first two years of teaching while the other six teachers had a considerable
amount of experience. The physics curriculum being taught in this study ranged from
introductory physics typically taught to high school freshman, to advanced placement physics
being taught to high school seniors. All of the teachers involved in the study participated in
professional development that focused on the use of the clicker software along with its practical
implementation in the classroom. Professional development was conducted during the summer
and was conducted in a workshop format. Teachers were explicitly taught how to use the
software, were given time to develop their own assessment questions, and were involved
immersing themselves in the technology so that they could get more of a student perspective.
Throughout the course of the school year, the teachers in the study participated in an ongoing
action research cycle. The researchers in this study facilitated the action research cycle. They
encouraged the teachers to share their experiences, ideas, and materials. In order to collect data
the researchers conducted a number of different qualitative research methodologies. Some of the
methodologies used were interviews, surveys, direct classroom observations, and focus groups
(Feldman & Capobianco, 2008).

This research illuminated a great deal of ideas concerning the implementation of
formative assessment technology in the classroom. One of the concepts illuminated by this
research was that the perceptions of formative assessment changed over time. When teachers
were initially asked about formative assessment before their involvement in the study, their
answers were short, non-descriptive, and did not have many practical examples. After being
involved in the implementation of formative assessment technology for a year, the teachers were
much more descriptive in their answers. They were able to draw on experience of how formative
assessment is used to enhance learning by providing feedback to the teacher and the students.
Teachers were also able to grow as educators through their involvement in the study. The
researchers documented how one of the novice teachers struggled with facilitating discussions while using the personal response systems early on in the study. He was often inclined to fall back into question and answer techniques that were very teacher driven. After being immersed in the study for a considerable amount of time the teacher in question was much more inclined to use the data obtained from the personal response systems to facilitate discussions and illicit student feedback. Lastly, through triangulation of the qualitative data that was collected, the researchers were able to identify four “technologies” that they deemed essential to successfully implement formative assessment technology into a classroom (Feldman & Capobianco, 2008). Teachers needed to become skillful with the technology and hardware associated with the personal response systems. Through this, they needed to overcome any logistical challenges associated with the implementation of the clickers. Teachers also needed to become proficient at developing questions that were both challenging but not too daunting in that they would discourage participation. Facilitation of discussion was another “technology” that the researchers deemed essential (Feldman & Capobianco, 2008). Without the ability to facilitate discussion, the clickers and associated questions were rendered useless. If these three technologies could be developed at a high level, it was then the responsibility of the teacher to incorporate the new technology into their curriculum. This was something that was easier said than done. Later in the year when the technology was no longer novel, the teachers described their increased difficulties with effectively utilizing the technology to facilitate classroom discussion (Feldman & Capobianco, 2008).

This study should be considered by any teacher looking to incorporate new educational technology into their classroom. Through detailed interview responses and observations, a very clear picture is painted. The picture that is painted is one that describes how there are many
factors at play when trying to weave new technology into a classroom. It is not enough to just be adept at technology without accompanying knowledge of appropriate pedagogical techniques. While the technology used in this research is somewhere dated, the concepts are not. The ways that a teacher can collect formative assessment data are numerous in present day education. The technology is so numerous that it is tempting to fall into the trap of constantly trying out something new. This study shows that in order to be effective a teacher should identify a singular piece of technology they would like to incorporate and then spend a great deal of time finding ways to mesh it with best teaching practices.

Eight Is Not Enough: The Level of Questioning and Its Impact on Learning in Clicker Cases.

This study aimed to understand the extent to which the level of questioning can effect learning outcomes. The students in this study were college students that were enrolled in an introductory biology course. Case studies were used as the primary method of instruction in this study. Case studies have been utilized as an instruction tool because they provide a real world connection to material that may otherwise be difficult for a student to grapple with. The researchers in this study implemented case studies in large college lecture courses with the utilization of a clicker system. Clickers are personal responders that students can use to answer questions posed by the teacher throughout a lesson. There were six classes involved in this study taught by three different instructors at two different colleges. Two of the instructors taught at the same college, which is significantly larger than the college of the third professor. These two professors each taught two sections of biology with each section being over 300 students. The third professor also taught two sections of biology but his student enrollment was closer to 100
for each section. All of the professors taught the same units using case studies but the types of clicker questions between their two sections was different. Each professor used low order clicker questions within the case studies for one of their class sections and used higher order clicker questions within the case studies for their other class section. Quantitative data was collected in the form of a comprehensive pre and post test given to all the students within the study. In addition, students were asked to rate how engaged and interested they were during class by completing a post course Likert scale survey.

The data collected in this study was not consistent with what was hypothesized by the researchers. It should not be surprising that across all the courses in the study the post test scores were higher than the pre test scores at a statistically significant level. However, when the low order clicker question courses were compared against the high order clicker question courses there was no significant difference. Learning obviously occurred throughout the semester, but the amount of learning that could be measured by this particular pre and post test method was not different between sections that utilized high order and low order questions. In addition, the data from student surveys on emotion and engagement showed no trends. Case studies that were high in student engagement were not necessarily the ones that show greater learning when compared to lecture methods. In addition, case studies that were ranked near the bottom in terms of student engagement were likely to show high amounts of student learning.

While the hypothesis of this study was not supported, there are significant implications from this study. High school teachers with access to case studies should highly consider implementing this approach in their classroom. Students showed that they were highly engaged and they learned content at a statistically significant level regardless of questioning type. In addition, teachers looking for ways to incorporate more formative assessment within their
teaching practices could definitely present case studies along with a form of technology, like clickers. This would allow teachers to collect more data while also using a method that engages students. The data from this study that supports the notion that low order and higher order questions produce similar learning outcomes should be taken with a grain of salt. Far too much research supports the use of higher level questioning to take this one study as fact.

**Comparing three online testing modalities: Using static, active, and interactive online testing modalities to assess middle school students’ understanding of fundamental ideas and use of inquiry skills related to ecosystems.**

DeBoer et al. (2014) looked into the effect of online testing on a large subset of American middle school students. Specifically, the researchers looked into the extent to which different online testing modalities would have an effect on the student’s performance on an online assessment. The three different modalities that were tested were static, active, and interactive. Ecology, specifically predator-prey relationships and population dynamics, was the subject matter of choice utilized for this study. This subject matter was chosen for its historically high levels of student performance, as well as for the well-documented student misconceptions within the topic. A topic with a high level of documented student misconceptions was important due to the need for answer choices that would help to document misconceptions that still held true after testing. Students that were involved in the study were exposed to all three of the testing modalities after being taught about the content in class during the weeks leading up to testing. The three testing modalities were administered on three consecutive days and consisted of 25 questions or tasks each. To control for any order bias not all of the students took the tests in the
same exact order. Static modality consisted of static pictures, figures, and tables on the screen along with written explanations for any tables or diagrams presented to the students. Active modality consisted of animations or organisms as well as animations of figures and tables that the students could play and rewind. The animations were used in place of the static pictures and diagrams that were present in the static modality. Lastly, the interactive modality was similar to the active modality in that it consisted of animations of organisms in their environment as well as animations of figures and tables. The difference between active and interactive modality was that interactive modality allowed the students to manipulate variables in order to create figures as tables. It also required the students to construct an energy flow diagram rather than just interpret one.

The results of the study showed that on average the students scored better when using the static modality test when compared to active and interactive modality. DeBoer et al. (2014) attributed the difference to students possibly being unfamiliar with manipulates that are utilized on a computer (p. 548). While students did score better using the static modality, the results of all three modalities were generally similar. Another similarity among all three modalities was that they all showed score increases when administered later on in the process. For instance, the marginal mean for the interactive modality was 65.7 percent when it was given as the first test compared to 73.6 percent when given as the last test. In addition, misconceptions seemed to be consistent for students across modalities. If a student was not able to identify a particular organism as a producer within one modality, they were also highly likely to not be able to identify another organism as a producer in another modality. In addition, students generally scored higher on items that asked for identification of trends rather than having to manipulate
variables or tables themselves. Test items that asked for identification of trends were more common in the static modality than the other modalities.

This study should emphasize the notion that increased technology does not always allow for higher learning outcomes. Even with a high degree of sophistication and in depth animations, students did not perform better on assessments that utilized the additional amounts of technology. According to this data, students were more likely to perform better on online assessments that more closely mimicked paper and pencil assessments. This does not necessarily mean that paper and pencil is definitely better. The differences in outcomes could have been due to a lack of familiarity with online simulations by the students, the teachers, or a combination of both. In addition, it should be noted that some of the test items on the interactive modality required more output and conceptual knowledge from the student. This is something that should naturally be expected to cause lower assessment scores. However, lower assessment scores do not have to mean lower amounts of student learning. As students are exposed to more scenarios that require higher level thinking and questioning, their learning should increase.

Innovative Formative Assessment Technologies

Context matters: increasing understanding with interactive Clicker Case studies.

This study looked into the effectiveness of the clicker case study method in teaching introductory biology. The researchers in this study describe case studies as realistic examples of the content being presented in the course. They are designed to be both engaging while also addressing common student misconceptions within a topic. To make case studies more
accessible to a large class group, clickers were utilized. Clickers are handheld devices that allow students to answer questions presented throughout a lecture. The instructor of the course is able to collect the student responses in real time and possibly use the responses to alter their instruction moving forward. In order to get a large amount of data, the researchers recruited 15 professors from a variety of colleges and universities. All of the professors in the study taught at least two sections of introductory college biology to a class that consisted of at least 100 students. The professors collectively designed case study presentations for a variety of topics that were common to their entire curriculum. Professors then alternated teaching topics with either a case study approach or a PowerPoint presentation approach. To determine if the case study approach was significantly better than a standard PowerPoint presentation pre and post tests were used. The pre and post tests were designed collectively among all of the professors involved in the study.

The data collected from this study was largely without a significant trend and did not necessarily support the hypothesis that the clicker case study method would produce significantly higher student learning outcomes. Some of the topics such as Cancer and Genetics produced significantly higher post test scores in the experimental group (Lundeberg et al., 2011). However, there also were a number of topics that did not produce significantly higher post test scores in the experimental group. Some examples of topics that did not produce significantly higher post test scores in the experimental group were the Characteristics of Life and the Scientific Method (Lundeberg et al., 2011). Overall, the student learning shown in the case study lessons was higher than the PowerPoint lessons but not by much. The differences between the two methods also seemed to be minimized when compared to other possible effects like instructor style or the nature of the topic. After instruction of all of the topics, the instructors
were polled using a Likert scale on what would produce an effective case study. Some of the case studies, like the Cell Division case study, were rated as excellent by the professors. Professors generally rated a case study excellent if it was engaging to the students, included a real life example as a way to lure students in, and was sufficiently challenging to the students. Case studies like the Characteristics of Life were not rated well because they did not include much discussion, were not engaging to the students, and did not have effective questions on the pre or post test.

The professors came up with a number of possible implications from this study during their meeting together after all of the case studies were taught. The professor’s expertise and newfound experience utilizing the technique should be applied to future rounds of research. If case studies were consistently improved so that they include all of the identified key components, they would likely be extremely beneficial in improving student-learning outcomes. Future research should also include groups that utilize clickers along with the PowerPoint method of presentation rather than just with the case study method. If future revisions to the case studies can be made, this method could be an extremely effective way to increase the amount of formative assessment in a classroom while also not sacrificing student engagement.

**Student Response Systems for Formative Assessment: Literature-based Strategies and Findings from a Middle School Implementation.**

This study looked into the integration of student response systems within a small number (12) of middle school teachers in a school district. The teachers involved in the study had limited amounts of experience with student response systems, and were wary of using a piece of
technology that they had little experience with. To counteract the lack of experience of these teachers, a professional development program was developed by the technology specialist of the same district. In the professional development program, teachers were instructed on literature-supported applications of student response systems. The technology specialist in the district determined that there would be three strategies taught to the teachers in the study. The strategies introduced by the technology specialist to be used with student response systems were contingent teaching, warm-ups, and peer instruction (Fuller & Dawson, 2017). To determine whether the integration of student response systems was effective, each teacher in the study was involved in an observation cycle. Observation cycles included a pre-conference, an in depth observation of a lesson, and a post conference. The observation cycles were used to determine the level to which the teachers in the study were using student response systems as well as to determine how much student response systems were affecting student learning.

When analyzing the data from observation cycles of all the teachers involved in the study, it is apparent that student response systems were used effectively by almost all of the teachers involved. Eleven of the twelve teachers involved in the study earned a score of Proficient or Exemplary when assessed on their ability to effectively integrate student response systems into their lesson. A rating of Proficient involved the teacher not just using student response systems but also using them in a manner that allowed efficient data collection to inform their teaching moving forward. To receive a rating of Exemplary the teacher had to use the data collected to inform their teaching while also incorporating students in the reflection process. It was not uncommon to observe teachers in the study collecting data using the student response systems and then using that data within their lessons to determine the pace and structure of the lesson moving forward. Teachers in this study also were able to demonstrate that the inclusion
of student response systems increased the amount of genuine student participation within the lessons. Students were observed answering questions using their devices, getting involved in whole class discussions and working with other students in their class. Observations of student engagement agreed with what the teachers stated during their post conferences.

The amount of data in this study is small but the implications of this research can be wide ranging. The research into technology assisted formative assessment is limited but this study increases the amount of research. Teaching methods that increase the amount of available data to reflect on are universally regarded as positive. According to this study, web based student response systems can increase the amount of data collected during a lesson while also increasing the amount of student engagement. By weaving in professional development with the integration of student response systems this school district addressed one of the concerns with web based student response systems. A concern has been that teachers may not be comfortable with the use of web-based technology in their classroom. Teachers not comfortable with web based technology could easily be responsible for observations that make it appear as though web based student response systems are not effective at increasing data collection and student engagement. Professional development that increases the effective use of web based student response systems seems to be something that is worthwhile. The more comfortable that teachers become with this use of technology the more they can design and develop research backed uses of the technology.

**Instructor’s Use of Student-Generated Annotated Concept Sketches in Formative Assessment in General Science.**
The researchers in this study mention the role of formative assessment in education and acknowledge its benefits (Copeland Solas & Wilson, 2017). Copeland Solas and Wilson also mention however that formative assessments have many difficulties during their implementation and sometimes struggle with accomplishing their main goal, which is to drive student learning and understanding. As a possible solution to the shortcomings of traditional formative assessment, the researchers looked into the effectiveness of drawings used as formative assessment tools. Drawings were selected at the topic of study because the researchers hypothesized that drawings would stimulate thinking, display student comprehension, and facilitate cooperation between students during class. This study was conducted with 150 female university students in Turkey who were all Arabic English Language Learners. Two different Environmental Science concepts were being taught to the students during this study. The topics being taught were Photochemical Smog and Ozone Layer Depletion. Students were asked to make annotated sketches for each of the concepts in order to display their understanding of the concept. Some of the drawings were completed independently while others were completed in groups of students. All of the students were encouraged to work in groups while they completed their drawing. Results of the study were compiled by having faculty members evaluate the student drawings using a rubric. The rubric was designed by the researchers and adapted from a prior study by other researchers. Drawings were evaluated in terms of their content, detail, and presentation.

The data from this study was analyzed almost completely qualitatively. Copeland Solas and Wilson (2017) made a number of observations after looking through the student’s drawing examples as well as after observing them while making their drawings. It was noted that the students seemed to be much more engaged using this technique more than more traditional
methods. Students seemed to put forth a great deal of time and effort into their drawings, with some students even losing track of the amount of time that they were spending on their drawing. It can be assumed that drawing is an enjoyable activity for many students, even if their understanding of the science is limited or developing. This technique also allowed for the students that were participating to get timely feedback on their understandings and misconceptions, which is extremely important for a method of formative assessment. Another observation by the researchers was that students who had a more limited understanding of the concepts typically showed that when their drawings were assessed using the rubric. The same logic was also true of the students with higher level understanding. Their drawings typically scored better on the rubric and those students also performed better on future assessments.

While the data in this study is hard to grapple with and understand, there are definitely implications for this study moving forward. Copeland Solas and Wilson (2017) mentioned in their background that formative assessment was notoriously difficult to implement (p. 145). Using drawings as a formative assessment tool seems to be an easier way to engage students with the technique while also not demanding as much in terms of time from the teacher. Instead of having to write a number of questions for students to answer, a teacher could develop a sound rubric that includes all of the standards that the teacher wishes for the students to meet. The only real difficulty after that would be selecting appropriate concepts to utilize with this drawing style of formative assessment. Disciplines like Chemistry, Physics and Earth Science would seem to lend themselves more to this technique than a discipline like Biology. However, Biology is not completely unable to have this technique integrated into it. Punnett Squares, diagrams of the cell, and organisms at various spots along a cladogram are just some examples of uses for drawing formative assessments within a Biology course.
Shelton et al. analyzed drawings and writing samples as sources of formative assessment data (2016). The researchers looked into drawings and writing samples because they felt as though there was already a large resource that included drawing and writing sample samples. This resource is the science lab notebook. The lab notebook is a tool used by many practicing scientists and it is also integrated into a number of science classrooms. Something that has not been as widely integrated into science classrooms is a virtual science notebook. A virtual notebook could allow for it to be more accessible to students because of the increasingly technological world that they live in. In addition, digital notebooks along with other digital tools in the science classroom assist in collecting and analyzing student data. In this study the researchers utilized a research project called the Leonardo project. The Leonardo project is a piece of software that is designed to assist elementary students in their acquisition and retention of scientific concepts. The Leonardo project has a virtual science notebook within it called CyberPad. To gather data there were a large number of teachers and classroom that were recruited to use this software as a method to teach a unit on magnetism. All of the teachers were trained to use the software so that inconsistencies with application would be limited. When students used the software they were exposed to information and images that correlated with whatever magnetism topic they were studying at the time. Students were asked probing questions throughout the topic. Some of the probing questions asked the students to draw a diagram using the software while others required the students to complete a written response.
After all of the data was collected, the researchers chose to focus on a smaller sample of 20 classrooms that were taught by 14 teachers. This was a relatively small collection compared to the initial amount of students involved in the study. This was due to a number of reasons but mostly because of inconsistencies with the length of time the students were exposed to the problem along with technical difficulties in some of the classrooms along the way. The student’s written and drawing responses were analyzed using a rubric in order to determine the student’s level of understanding of the concept being assessed. One of the trends that was evident in the data was that the rubric scores for the drawings were much larger than the scores for the writing samples. This was consistent along different concepts and prompts. In addition, it was shown that the student’s drawing samples were more predictive of future performance on a summative assessment than writing samples. The researchers suggested a number of reasons for this, one of them being that the level of written expression that the subjects of the study were capable up is probably not near the visual expression. It would take some time for student’s to develop their written expression in order for it to accurately represent what they are thinking and feeling.

This study is one that should definitely be replicated with older students. Replicating this study with grade bands would allow for a more definitive answer to the question of whether or not students are always more comfortable with expressing complex concepts through visual means when compared to written ones. Even with this limited amount of data about fourth grade students it may be beneficial to incorporate more visual and drawing elements to formative assessments in a science classroom, even a secondary science classroom. In addition, it would be beneficial to use this software in a more formative manner to allow for students to increase their understanding over time.
Technology-Enhanced Formative Assessment of Plant Identification.

This study looked into the effectiveness of a technology focused assessment program for plant identification. The program used in this study could be used on any computer, tablet, or mobile device as long as it had an internet connection, was GPS enabled, and was able to scan QR codes. Students using this program were posed questions on plant identification based either on where they physically were or what QR code they had scanned (Conejo, Garcia-Vinas, Gaston, & Barros, 2016). In order to pose questions based on physical location the software that was used to input the questions was GPS enabled. An instructor looking to pose a question at a particular location was able to click a point on a generated Google Map and could then input a question for that exact latitude and longitude (Conejo et al., 2016). When students logged in to the program, a google map of the surrounding area was displayed with “pins” of where to access questions. Students would then need to move with their device to one of those locations so that they could be given a question. Questions could also be accessed via the scanning of a QR code. All questions were enhanced with targeted feedback for both correct and incorrect answers. To determine the effectiveness of this program three separate experiments were conducted. The first experiment aimed at determining if the system operated smoothly and effectively. Another experiment looked into the effectiveness of this program as a formative assessment tool. The final experiment aimed at determining if this program was more effective as a pure assessment tool than a traditional paper and pencil test.

The experiment that looked into the operation of the system showed very clear and concise data. All of the students in the sample took a traditional assessment with photographs of plants while also taking a non traditional test that utilized the GPS function of the testing
program. The students reported no technical problems while taking the non traditional test. In addition, the scores of the non traditional test were higher than the traditional test at a statistically significant level (Conejo et al., 2016). When students were administered a likert-type survey at the end of the assessment they were positive in their evaluation. On average, the students rated their overall experience with the program a 4.36 out of 5. Data from the second test showed that students who used the program as a formative assessment tool showed greater learning gains than a control group of students who just revised their notes as a form of studying (Conejo et al., 2016). Students involved in this particular experiment rated their overall experience a 3.9 out of 5. The last experiment showed similar results to the other two experiments. Gains from pre to post test were significantly higher when students used the program rather than more traditional paper and pencil methods (Conejo et al., 2016). When surveyed about the experience, the students from this experiment rated their experience as a 4.25 out of 5 (Conejo et al., 2016).

This study seems to be a very novel and effective way for students to use technology while also not losing out on access to the natural world. Students are able to examine the world around them while also receiving feedback that they may never have gotten without access to this program. Due to convenience, many teachers often revert to classroom activities and lab exercises that rely on samples that can be presented in class. This is done so that the teacher can be present, while also having an intimate knowledge of the materials being used. High level feedback can be given to students in this type of situation. By using the outside world as the “lab materials” the teacher allows the students to experience more authentic examples of species while also not sacrificing much of the feedback that can be given in class.

A new approach to personalization: integrating e-learning and m-learning.
The researchers in this study looked into the effectiveness of adapting a computer based online learning platform to a mobile friendly format. The platform being adapted is called the Adaptive Learning and Assessment System (ALAS). ALAS is an intuitive web based platform that allows students to work through material at their own pace. Students are initially given an assessment that is used to determine the student’s initial needs and learning level for a variety of topics. After completing the initial assessment, students can log on to ALAS and work on their skills for whatever content area is being provided through the platform. Data is continuously logged for students, so that the teacher always has access to their progress with the material. If students have difficulty with concepts ALAS uses a variety of algorithms to determine the most appropriate next steps for the student. Possible next steps could include continuing similar questions, watching a video, or getting a hint on that particular question. ALAS had previously only been utilized online via a computer. While ALAS works well on a computer the researchers noted that there are many school districts that may have difficulty providing access to computers (Nedungadi & Raman, 2012). The model that was described in the paper involved students having access to a computer lab of 15 computers twice a week for fifteen minutes (Nedungadi & Raman, 2012). This limited time with computers is still greater than other districts that do not have the funds for a computer lab. Because of this, the researchers worked to develop a mobile friendly version of ALAS. This would alleviate concerns about access to technology and would allow for students to do more work and studying at home if needed. A small study was conducted to determine if the mobile version of ALAS was comparable to the computer version. One class of students used the computer and mobile versions of ALAS concurrently while another class used just the computer version. Students were compared via
their data from ALAS along with a 27-item survey. The survey consisted of 25 Likert-type questions and two multiple-choice questions (Nedungadi & Raman, 2012).

When the mobile and computer concurrent students were compared with the students who only used a computer there was a statistically significant difference seen in the amount of time it took to complete questions. The students that used the mobile and computer versions concurrently took longer to complete the questions when compared to the other group (Nedungadi & Raman, 2012). While the students using the mobile version of ALAS took longer to complete questions, they did not score lower than the other students did at a statistically significant level (Nedungadi & Raman, 2012). Their percentage correct was lower but not low enough to be statistically significant. Survey questions showed that students agreed that the mobile devices allowed for more flexibility in their learning. Students also stated that they had enough prior knowledge and technological ability in order to properly utilize the mobile devices (Nedungadi & Raman, 2012). Ease of use was something that students identified could be improved in the mobile version (Nedungadi & Raman, 2012). In addition, students stated that they preferred being able to use a large screen while using ALAS. Some students mentioned that they occasionally would try to press one answer but would end up incorrectly selecting another answer due to the small size.

Implications for this study are wide ranging. Web applications like Khan Academy are already capitalizing on the notion that increased formative assessment is beneficial for learning. A teacher can only be so many places at once, and is bound by the need to provide meaningful and rich feedback to their students. Providing that feedback to students is something that takes time. Technology that reduces the time needed to collect data to help inform feedback is definitely beneficial. Technology that uses that data to provide feedback on its own is even more
beneficial. Nothing will ever replace a teacher in the classroom but tools like ALAS allow for more practice and independent thinking by their students. Mobile integration of already beneficial applications like this one can only help students. There are sure to be some roadblocks to their development but they do not seem to be roadblocks that are impossible to overcome.

**Validation of automated scoring of science assessments.**

In this study Liu, Rios, Heilman, Gerard, and Linn (2016) look into the effectiveness of a program called c-rater-ML. C-rater-ML is a computer program that is designed to assess short answer responses to science questions. Programs that are used to automatically assess student responses to short answer questions are particularly valuable because of the amount of time they would save educators in evaluating those type of questions. The researchers in this study note that there have been many instances in the past where automated programs have been used to grade short answer responses. The researchers also note that many of those programs have been successful to varying degrees in rating student responses. C-rater-ML is unique in that it does not require as much human intervention as some of the other rating software designed in the past. Some of the other programs have required human raters to rate hundreds or even thousands of responses so that an analytic rubric can be created for the program to compare responses against. This study utilized a program (c-rater-ML) that can utilize a human rubric, thus eliminating the need for an analytic rubric to be created. This study utilized eight different items to be scored on a 5 point scale. The range of topics for the items were energy, cell division, plate tectonics, genetics, and graphing. Two human raters assessed each item until consensus was achieved. If
consensus was not achieved, a third rater was involved. After the items were assessed by human raters and by the c-rater-ML program, statistical analysis was performed.

Results of this study generally show that c-rater-ML is capable of rating short answer science responses. When quadratic-weighted kappa analysis was performed, two of the items from the study showed very good agreement between the human scoring and c-rater-ML scoring (Liu et al., 2016). In addition, the other six items showed good agreement (Liu et al., 2016). Another point of interest from the study was that c-rater-ML showed no observable differences to human raters when scoring items from different genders, races, and native languages.

This study has a wide range of applications. As the researchers mention in their study, many teachers avoid using short answer questions in their assessments due to the amount of time that it takes to properly grade them and give feedback to the students. While a program like c-rater-ML is not perfect, it has shown to be accurate enough to give feedback to students when needed. As more data is collected to help make the program more accurate, c-rater-ML may be a viable tool to use for teachers that would like to include more short answer questions in their teaching. In addition, if a teacher is not necessarily interested in giving extremely detailed feedback to their students on a short answer question this program could be used to help a teacher implement more formative assessment practices into their teaching. Short answer questions could be assigned to the students throughout a unit and c-rater-ML would make it feasible for the students to get quick and concise feedback on their responses. The research has shown that one of the barriers to implementing formative assessment into teaching has been a lack of available time to design and grade assessments. A grading tool like this one could be a step towards solving that problem.
Implications, Current Use, and Proposal

Software Socrative and Smartphones as Tools For Implementation of Basic Processes of Active Physics Learning in Classroom: An Initial Feasibility Study With Prospective Teachers.

This study looked into the effect of a web-based application on the learning process of students. The application used in this study is named Socratic. Socratic allows students to use their cell phones as a way to keep them actively engaged in a classroom lesson. By entering questions into the web-based interface of Socratic, a teacher can then use the application during their lesson as a way of assessing their students. The application allows for multiple choice, true / false, and short answer questions. This study applied the use of Socratic to a classroom of 36 preservice teachers as a way of observing the application in action while also using it as a way to demonstrate best practices. The students in the study were given multiple choice physics questions through the Socratic app. Students were first asked to answer the multiple-choice questions by themselves. After answering the questions by themselves, the students were placed into groups based on their responses to the multiple-choice questions. Efforts were made to group the students so that there were a variety of question responses in each group. Groups were encouraged to discuss their answers and work through the questions together as a group. After working with a group, the students were allowed to resubmit their answer. Submissions were analyzed for accuracy both before the group work and after.

This study used a mixed methods approach in order to determine the effectiveness of Socrative as an educational tool. Quantitative data was collected in the form of student
responses to multiple-choice questions as well as student responses to a Likert-type survey. Qualitative data was collected in the form of open-ended survey questions along with classroom observations. In the two example multiple choice questions that were given in the study, the percentage of correct answers was increased after the students were grouped based on data that was collected from their first question response. One of the questions showed a small change while the other question saw the percentage of correct responses jump from 24% to 41% (Coca & Slisko, 2013). When students were given the Likert-type survey the most common rating was “agree” with all of the questions asked (Coca & Slisko, 2013). The majority of students agreed that Socrative made them more involved, helped them pay more attention, helped them better understand the material, increased group participation, and helped the students realize the material that they knew. Students were also able to voice their opinions through open-ended questions on the survey. A common statement from students was that they most enjoyed the group participation aspect of this application. A common negative that voiced by students was that the Wi-Fi was inconsistent or that the student in question did not have a smart phone.

Triangulation of all the available data shows that Socrative is definitely a potential tool for use in the classroom. Socrative increased participation in the lesson, allowed students to increase their understanding of the material, and allowed for the integration of already present technology into a lesson.

There are definitely implications from this study for stakeholders. Educators are constantly looking for ways to increase participation along with increase the use of technology in their classroom. While the sample size is extremely small, this study does show that Socrative is worth a trial by a teacher looking for ways to improve their classroom. In addition, Socrative requires no additional materials from the teacher. Most students have access to a cell phone, or
at least could pair with a member of their class who has a smart phone for a period of time. While Socrative may not have a vast amount of research behind it, increased classroom participation and formative assessment are backed by research. If Socrative can increase participation and the amount of formative assessment, it is definitely worthwhile.

**The wear out effect of a game-based student response system.**

This study looked into whether or not a particular student response system lost its effectiveness as it was used over time. The particular student response system used in this study was Kahoot. Kahoot was described as a game based student response system. Kahoot is not only able to collect student response data during a lesson, but does so in a way that resembles a game show. The game show aspect of Kahoot is intended to increase student engagement during its use. The researchers in this study hypothesized that there may be a wear out effect from using a piece of technology like this. Students are likely to be very engaged during initial uses of this software but then significantly less engaged after repeated uses of the software. To test this the researchers applied the use of Kahoot at the end of an informational workshop as well as throughout a college semester. The college semester represented repeated use of the technology while the workshop represented a single use. In both scenarios, participants were surveyed in order to determine their level of agreement with a number of statements that had to do with their engagement and enjoyment with Kahoot. The participants were asked if they agreed or disagreed with the statements while also being given an option to choose neutral.

Analysis of the data showed rather decisively that there was no significant difference in student perceptions after a semester of use when compared to a single use. This was shown
across a number of questions that were posed to the participants of the study. All of the questions posed to the participants of the study had more agreement when compared to disagreement. In addition, there were rarely any questions that showed a statistically significant difference between the single use and use over the course of a semester. The most agreement among participants was when they were asked if they were emotionally engaged while playing Kahoot. When asked that question, both groups had 52% of the participants agree (Wang, 2017). The most disagreement among participants was when they were asked if they communicated with other players while playing Kahoot. When asked that question, 67% of the single use participants agreed compared with only 52% of the semester long participants (Wang, 2017). While the largest discrepancy was 15%, the next largest discrepancy was 7%. This supports the notion that very little wear out effect occurs. A much larger discrepancy between single use and semester long participant opinions would be expected if there were a large wear out effect. In addition, the semester long participants were asked how long they would like Kahoot to be used in the future. They were given the options of every class, once a week, once a month, or never. Supporting the notion that there was little wear out effect, 57% of the students stated that they would like Kahoot used during every class.

This study addresses a number of concerns with integrating student response systems into the classroom. Teachers often vary their practices not only to increase learning, but also to increase student engagement. Students, especially teenage students, are known to have short attention spans and can become tired of certain classroom practices. This is the basis for the hypothesis that increased use of Kahoot would decrease the amount of student engagement. This study, while initial in nature, points to the wear out effect not being as evident as initially thought. If Kahoot can increase participation while also being able to collect formative data
within a lesson, it is definitely a useful tool. Additionally, if the positive effects of Kahoot do not drastically diminish over time, teachers will be much more likely to invest their time into developing games and investments within this web based student response system.
Nearpod Materials for a High School Biology Curriculum

Different Nearpod Functionalities

**Draw It:** Students are presented with a question and/or an image can use various tools to draw their answer. The teacher is able to see all of the responses as they are submitted and can “share” any of the individual responses with the entire class.

**Collaborate:** All of the students are simultaneously presented with a question. Their responses are posted to an online “board” that the entire class can see. Students can type their response, post a picture, or post a link to the board. The teacher can choose to review responses before they are posted.

**Open Ended:** The students are presented with an open ended question that typically requires more of a longer written response. The teacher is able to see all of the responses as they are submitted and can “share” any of the individual responses with the entire class.

**Poll:** Students are presented with a question along with a number of different possible choices. After an appropriate number of students record their responses, the teacher can choose to share the class responses with everyone in the form of a pie chart.

**Quiz:** Students are presented with a set of multiple choice questions that they can complete at their own pace. Once the students have completed their quizzes, the teacher can choose to reveal the individual results to the students.

**3D Model:** A three dimensional image is shown on the student’s device. The image can be enlarged, shrunk, and minimized by the student using their fingers (if on a touch enabled device) or a mouse.

**PHET Simulation:** The student is given access to a simulation program that allows the student to interact with a certain scientific topic.
Introductory Unit Nearpod Materials and Rationale:

Whenever possible, higher level questioning and variety were important to use in these unit materials. The first unit of my Regents Biology course is an introductory one that involves the review of many concepts that students have covered in junior high, intermediate, or even elementary school. Students need to master the use of scientific equipment along with needing to be proficient in the activity of scientific measurement. These materials allow for a significant amount of formative assessment focused on the basic skills that students will need to have for the rest of the year.

Functionalities Utilized:

Collaborate: 1

Draw It: 10

Open Ended: none

Poll: none

Quiz: 2 (11 questions and 10 questions)

3D Model: none

PHET Simulation: none

Link to unit materials: https://share.nearpod.com/U88r9N7bNR
Figure 1a – Collaborate - "What characteristics do you think that all living things share?"

Circle the stage on this picture of a microscope

Figure 2a - Draw It - "Circle the stage on this picture of a microscope"

Circle the ocular lens on this picture of a microscope

Figure 3a – Draw It - "Circle the ocular lens on this picture of a microscope"
Figure 4a – Draw It - "Circle the base on this picture of a microscope"

Figure 5a – Draw It - "Circle the objective lenses on this picture of a microscope"

Figure 6a – Draw It - "Circle the diaphragm on this picture of a microscope"
Figure 7a - Draw It - "Circle the coarse adjustment knob on this picture of a microscope"

Figure 8a - Draw It - "Circle the fine adjustment knob on this picture of a microscope"

Figure 9a - Draw It - "Circle the arm on this picture of a microscope"
Circle the stage clips on this picture of a microscope

Figure 10a - Draw It - "Circle the stage clips on this picture of a microscope"

Circle the light source on this picture of a microscope

Figure 11a - Draw It - "Circle the light source on this picture of a microscope"

Which of these phrases has the terms in order from most simple to most complex?

- cells, tissues, organelles, organs, organ systems, organism
- organism, organ systems, organs, tissues, cells, organelles
- organelles, cells, tissues, organs, organ systems, organism
- organism, organ systems, organs, organelles, tissues, cells

Figure 12a - Quiz - "Which of these photos has the terms in order from most simple to most complex?"
Figure 13a - Quiz - “A scientist is comparing a single celled organism to a human. When comparing these organisms, which of the following statements would be correct?”

Figure 14a - Quiz - “Which term best describes these temperature graphs”

Figure 15a - Quiz - “Which statement below describes respiration?”
Figure 16a - Quiz - "The process that removes metabolic waste products from organisms is known as"

- excretion
- respiration
- respiration
- secretion

Figure 17a - Quiz - "In humans, the maintenance of a stable internal temperature is a direct result of"

- diffusion of water and excretion of glucose to the external environment
- diffusion of water and excretion of glucose to the external environment
- diffusion of water and excretion of glucose to the external environment
- diffusion of water and excretion of glucose to the external environment
- transport of ATP and locomotion through the environment

Figure 18a - Quiz - "The breathing rate, heart rate, and blood hormone levels of a human would most likely provide information about human"

- cells
- nutrition
- hydration
- metabolism
Figure 19a - Quiz - "The absorption of fluids by various cells of the human body is part of the life function known as"

- transport
- growth
- secretion
- respiration

Figure 20a - Quiz - "Which of these life functions could be eliminated without affecting the ability of a shark to survive while food was scarce?"

- digestion
- reproduction
- excretion
- circulation

Figure 21a - Quiz – "Which of these observations would lead you to believe that something is nonliving?"

- It performs asexual reproduction
- It cannot perform metabolic reactions and processes
- It is a single cell and does not have tissues or organs
- It carries out synthesis
Which of the following is a possible result of an organism not maintaining homeostasis?

- death
- reproductive success
- metabolism
- synthesis

Figure 22a - Quiz - "Which of the following is a possible result of an organism not maintaining homeostasis?"

Why are hypotheses valuable?

- A hypothesis may lead to further investigation even if it is not supported by the experiment
- A hypothesis can be used to explain a conclusion even if it is not supported by the experiment
- A hypothesis requires no further investigation
- A hypothesis requires further investigation if it is supported by the experiment

Figure 23a - Quiz - "Why are hypotheses valuable?"

A scientist is investigating the effect of a certain fertilizer on the growth of plants. Which of the following choices would be the most appropriate dependent variable in his investigation?

- Color of the plants
- Height of the plants
- Type of plants
- Type of fertilizer

Figure 24a - Quiz - "A scientist is investigating the effect of a certain fertilizer on the growth of plants. Which of the following choices would be the most appropriate dependent variable in his investigation?"
Without a control group in an experiment it would be difficult to

- Draw a valid conclusion
- Record data
- Make a hypothesis
- Make observations

Figure 25a - Quiz - "Without a control group in an experiment it would be difficult to"

In what direction would you move the slide to center the following image in a microscope?

- to the left and down
- to the right and up
- to the left and up
- to the right and down

Figure 26a - Quiz - "In what direction would you move the slide to center the following image in a microscope?"

Which sentence is a hypothesis?

- Environmental conditions affect the pollination of plants.
- Do environmental conditions affect the pollination of plants?
- Plants were measured for their amount of pollination.
- Environmental conditions are good.

Figure 27a - Quiz - "Which sentence is a hypothesis?"
In an appropriately designed experiment a scientist is able to test the effect of:

- one independent variable
- multiple independent variables
- the hypothesis
- observations

**Figure 28a - Quiz - “In an appropriately designed experiment a scientist is able to test the effect of”**

Which activity might lead to damage of a microscope and/or slide?

- Focusing the image using low power before high power
- Adjusting the diaphragm to allow more light to hit the slide
- Using the coarse adjustment while the microscope is on high power
- Using the fine adjustment while the microscope is on low power

**Figure 29a - Quiz - “Which activity might lead to damage of a microscope and/or slide?”**

A scientist measures an organism to be 73 cm long. How many meters is that?

- 7.3
- 0.73
- 0.7
- 7.3

**Figure 30a - Quiz - “A scientist measures an organism to be 73 cm long. How many meters is that?”**
What unit of length would be the most appropriate to measure the length of a cell?

- centimeters
- millimeters
- micrometers
- nanometers

**Figure 31a - Quiz - "What unit of length would be the most appropriate to measure the length of a cell?"**

A student was looking at pollen under the microscope. The student used both low and high power on the microscope. Which statement most accurately describes what they would have seen?

- low power: 100 large pollen grains / high power: 25 small pollen grains
- low power: 25 large pollen grains / high power: 100 small pollen grains
- low power: 100 small pollen grains / high power: 25 large pollen grains
- low power: 25 small pollen grains / high power: 100 large pollen grains

**Figure 32a - Quiz - "A student was looking at pollen under the microscope. The student used both low and high power on the microscope. Which statement most accurately describes what they would have seen?"**
Biochemistry Unit Nearpod Materials and Rationale:

This unit lends itself to much more higher level questioning than the previous unit. Students are challenged to think about the implications of certain biochemical properties and how they relate to life. These are challenging questions but they allow students to think outside the box and express their thoughts without the fear of having to speak out during class. In addition, Biochemistry lends itself to experimentation, which makes it so simulations were utilized in these unit materials. Students will be able to experiment with the chemical structure of atoms along with experiment with acids and bases. In addition, some of the materials could be used multiple times during a unit. For instance, polls are great to use multiple times during a lesson. Students can be asked what they think early on in a lesson and then can be polled after a lesson to show what they have learned. That is the true purpose of formative assessment.

Functionalities Utilized:

Collaborate: none

Draw It: none

Open Ended: 6

Poll: 5

Quiz: 1 (10 questions)

3D Model: none

PHET Simulation: 5

Link to unit materials: https://share.nearpod.com/GpBI5vbU8R
Figure 1b - Poll - “How many atoms do you think could fit in one period at the end of a sentence?”

What about carbon makes it so essential for building organisms and organic compounds? Would life work with another important element instead of carbon? What properties would that element need to have?

Figure 2b - Open Ended - “If atoms are mostly empty space why do you think that we don’t just walk right through objects?”

There must be some kind of force between the parts of the atom that makes it so we cannot walk right through them.

Figure 3b - Open Ended - “What about carbon makes it so essential for building organisms and organic compounds? Would life work with another important element instead of carbon? What properties would that element need to have?”
Figure 4b - PHET Simulation - "Build an Atom"

Figure 5b - PHET Simulation - "Build an Atom Game"

Life on Earth is water based. When we look for life on other planets we start by looking for water. Do you think life would be possible without water? Would we recognize it if we saw it?

Figure 6b - Open Ended - "Life on Earth is water based. When we look for life on other planets we start by looking for water. Do you think life would be possible without water? Would we recognize it if we saw it?"
Water has a pH of 7. That is exactly in the middle of the pH scale, meaning that water sometimes behaves as an acid and sometimes behaves as a base. Do you think water would be so important if it had a different pH, like 5 or 9? Why do you think that?

Figure 7b - Open Ended - “Water has a pH of 7. That is exactly in the middle of the pH scale, meaning that water sometimes behaves as an acid and sometimes behaves as a base. Do you think water would be so important if it had a different pH, like 5 or 9?”

Figure 8b - PHET Simulation - “pH Scale”

Figure 9b - PHET Simulation - “pH Scale”
Figure 10b - PHET Simulation - “Acid Base Solutions”

If a protein that was usually involved in moving molecules across a cell wall changed in shape, how do you think that would affect the ability of the cell to move molecules across the membrane? Explain your answer.

Figure 11b - Open Ended - “If a protein that was usually involved in moving molecules across a cell wall changed in shape, how do you think that would affect the ability of the cell to move molecules across the membrane? Explain your answer.”

Think about the molecular structure of simple carbohydrates as opposed to complex carbohydrates. What about their structure is a hint about which one provides longer lasting energy?

Figure 12b - Open Ended - “Think about the molecular structure of simple carbohydrates as opposed to complex carbohydrates. What about their structure is a hint about which one provides longer lasting energy?”
Figure 13b - Poll - "Which of these are mostly made of protein?"

Figure 14b - Poll - "Which of these are mostly made of carbohydrates?"

Figure 15b - Poll - "Which of these are mostly made of nucleic acids?"
Figure 16b - Poll – "Which of these are mostly made of lipids?"

Enzyme molecules normally interact with substrate molecules. Some medicines work by blocking enzyme activity in pathogens. These medicines are effective because they

- Are the same size as the enzyme
- Are the same size as the substrate and the molecules
- Have a shape that fits into the enzyme
- Have a shape that fits into all cell receptors

Figure 17b - Quiz - "Enzyme molecules normally interact with substrate molecules. Some medicines work by blocking enzyme activity in pathogens. These medicines are effective because they"

Which substance is inorganic?

- starch
- DNA
- water
- salt

Figure 18b - Quiz - "Which substance is inorganic?"
Figure 19b - Quiz - "Which statement best describes carbohydrates, lipids, proteins, and nucleic acids?"

- They are used to store genetic information
- They are complex molecules made of smaller molecules
- They are used to assemble larger inorganic molecules
- They are simple molecules used as energy sources

Figure 20b - Quiz - "Which statement describes all enzymes?"

- They control the transport of materials
- They provide energy for chemical reactions
- They affect the rate of chemical reactions
- They absorb oxygen from the environment

Figure 21b - Quiz - "More energy can be released from a fat molecule than a glucose molecule because the fat molecule contains more

- mitochondria
- organic compounds
- chemical bonds
- inorganic compounds
Figure 22b - Quiz - "Which ph value indicates the most acidic condition?"

Figure 23b - Quiz - "An energy rich organic compound needed by organisms is"

Figure 24b - Quiz - "A fully functioning enzyme molecule is arranged in a complex three-dimensional shape. The shape determines the"
Figure 25b - Quiz - "Which of these compounds contain nitrogen?"

- Lipids
- Proteins
- Carbohydrates
- Sugars

Figure 26b - Quiz - "What are the building blocks of lipids?"

- Glucose
- Fatty acids and glycerol
- Amino acids
- Nucleic acids
Cells Unit Nearpod Materials and Rationale:

The materials in the cells unit focus on building fluency in the identification of cell organelles. This is material that students have some prior knowledge with so the focus is not necessarily where organelles are and what they do but being able to recall that information at a fairly accelerated pace. The first activity that helps students accomplish this is 3D models of cell organelles. This allows students to see these structures as much more than scribbled objects on a page and appreciate their internal details. In addition, students work on their fluency by looking at pictures and quickly circling the cell organelles that they are asked to identify. Cell transport is another very important concept in this unit. Students are able to practice their skills by drawing and visualizing cells in various states of osmosis (hypertonic, hypotonic, and isotonic). Students are also asked to make inferences about what would happen to cells in various concentration situations.

**Functionalities Utilized:**

- Collaborate: 1
- Draw It: 11
- Open Ended: 6
- Poll: none
- Quiz: 1 (10 questions)
- 3D Model: 11
- PHET Simulation: none

**Link to unit materials:** [https://share.nearpod.com/j3Q1SjjU8R](https://share.nearpod.com/j3Q1SjjU8R)
Figure 1c - 3D Model - "Animal Cell"

Figure 2c - 3D Model - "Plant Cell"

Figure 3c - 3D Model - "Red Blood Cells"
Figure 4c - 3D Model - "Cell Membrane"

Figure 5c - 3D Model - "Nucleus"

Figure 6c - 3D Model - "Golgi Apparatus"
Figure 7c - 3D Model - "Ribosome"

Figure 8c - 3D Model - "Mitochondria"

Figure 9c - 3D Model - "Endoplasmic Reticulum"
Circle all of the mitochondria on this cell
Figure 13c - Draw It - "Circle the nucleus on this cell"

Figure 14c - Draw It - "Circle the centrioles on this cell"

Figure 15c - Draw It - "Shade the cell membrane on this cell"
Figure 16c - Draw It - "Circle the chloroplasts on this cell"

Circle 5 ribosomes on this cell

Figure 17c - Draw It - "Circle 5 ribosomes on this cell"

Draw a plant cell. Label the vacuole, mitochondria, nucleus, and cell wall.

Figure 18c - Draw It - "Draw a plant cell. Label the vacuole, mitochondria, nucleus, and cell wall"
Figure 19c - Draw It - "Draw an animal cell. Label the mitochondria, nucleus, cell membrane, and ER."

Figure 20c - Open Ended - "Muscles need to use more energy than the average cell. Because of that, what do you think is different about the composition of muscle cells? What organelles should they have more of? What organelles should they have less of?"

Figure 21c - Open Ended - "What do you think is the purpose behind plant cells having a very large, water filled, central vacuole? Why are animal cell vacuoles much smaller?"
Figure 22c - Open Ended - "Why do you think that plants shrivel up when they are low on water?  *Hint* It has something to do with their cellular structures!"

Draw this cell in equilibrium with water molecules on either side of the cell membrane.

Figure 23c - Draw It - "Draw this cell in equilibrium with water molecules on either side of the cell membrane"

Draw this cell in a hypotonic solution. Use circles for water molecules and squares for salt molecules.

Figure 24c - Draw It - "Draw this cell in a hypotonic solution. Use circles for water molecules and squares for salt molecules"
Figure 25c - Draw It - "Draw this cell in a hypertonic solution. Use circles for water molecules and squares for salt molecules"

Figure 26c - Open Ended - "How do you think your cells get very large molecules into and out of themselves? I am talking about molecules that are too large to naturally fit through the cell membrane. Think of some ideas!"

Figure 27c - Open Ended - "When patients are in the hospital they are often given saline solution in order to maintain a proper level of hydration. Why do you think that patients are not just given water in the IV? What effect would flooding cells with water have on cell transport and osmosis?"
Figure 28c - Open Ended - "Why are these blood cells swelling and eventually bursting? Explain your answer using the terms water, concentration, and movement."

The concentration of water was higher outside of the cells than inside so there was a net movement of water into the cells.

Figure 29c - Quiz - Which statement describes an exception to the cell theory?"

- Plants and animals are made up of structural units called cells.
- Mitochondria and chloroplasts contain genetic material and can replicate.
- All cells come from preexisting cells.
- The cell is the basic unit of function in living things.

Figure 30c - Quiz - "The function of which cell part is most similar to that of the human excretory system?"

- cell membrane
- nucleus
- cytoplasm
- mitochondria
**Figure 31c - Quiz** - "In a cell, all organelles work together to carry out "

- diffusion
- active transport
- information storage
- metabolic processes

**Figure 32c - Quiz** - "A white blood cell ingests, then digests, a number of bacteria. Which cell organelles were directly responsible for the digestion of the bacteria?"

- centrioles
- lysosomes
- ribosomes
- mitochondria

**Figure 33c - Quiz** - "Which of these molecules will most likely diffuse through a membrane?"

- starch
- water
- protein
- DNA
Cells were placed in a mystery liquid. After being placed in the mystery liquid, the cells had shriveled. What liquid was the most likely mystery liquid?

```
- salt water
- distilled water
- pond water
- tap water
```

Figure 34c - Quiz - "Cells were placed in a mystery liquid. After being placed in the mystery liquid, the cells had shriveled. What liquid was the most likely mystery liquid?"

Which of these statements best describes this diagram?

```
- transpiration
- diffusion
- phagocytosis
- osmosis
```

Figure 35c - Quiz - "Which of these statements best describes this diagram?"

Which percentage would explain the net movement of water into a cell through the process of osmosis?

```
- water was 90% inside the cell and 90% outside the cell
- protein was 30% inside the cell and 30% outside the cell
- water was 95% inside the cell and 95% outside the cell
- water and protein were equal inside and outside of the cell
```

Figure 36c - Quiz - "Which percentage would explain the net movement of water into a cell through the process of osmosis?"
Figure 37c - Quiz - "ATP is being used to move the molecules out of the cell by"

- cell A only
- cell B only
- both cell A and cell B
- neither cell A nor cell B

Figure 38c - Quiz - "Both of these cells were placed in distilled water. What is the best explanation for the red blood cell bursting but not the onion cells?"

- the red blood cells have only a cell membrane, which does not protect them from bursting
- the onion cells do not have a cell wall that could protect them from bursting
- the onion cells have a cell membrane, which can protect them from bursting
- the red blood cells have a cell wall, which does not protect them from bursting
Cell Metabolism Nearpod Materials and Rationale:

The materials for this unit challenge students to think past just the formulas for photosynthesis and cellular respiration. For instance, a drawing activity is utilized in order to show students where the energy is stored in an ATP molecule. Students are also challenged to think about how light energy enters a plant and how it is then utilized by the chloroplasts within the cell. Another way that students are challenged to think past the formulas is by asking them to draw graphs that relate the amount of certain formula variables to the amount of photosynthesis. Lastly, while higher level questioning helps to enforce student learning, there is also a quiz included to help students practice the basic facts of the photosynthesis and cell respiration formulas.

Functionalities Utilized:

Collaborate: 2

Draw It: 5

Open Ended: 3

Poll: 1

Quiz: 1 (10 questions)

3D Model: 2

PHET Simulation: none

Link to unit materials: https://share.nearpod.com/vDG1CTilNR
Figure 1d - Draw It - "Indicate on this picture of an ATP molecule where you think most of the energy is stored"

Figure 2d - Collaborate - "What do we know about Photosynthesis?"

Figure 3d - Poll - "What colors of light do plants absorb best? Pick two"
Figure 4d - Open Ended - "Why do plants need light energy?"

Figure 5d - 3D Model - "Plant Cell"

Figure 6d - Collaborate - "Why are thylakoids stacked?"
Figure 7d - Open Ended - "Why can the “dark” reactions of photosynthesis occur without sunlight? If the "light" reactions depend on sunlight for their energy where do the "dark" reactions get their required energy?"

Figure 8d - Draw It - "Draw the graph for how light intensity affects the rate of photosynthesis. Put light intensity on the x axis and rate of photosynthesis on the y axis."

Figure 9d - Draw It - "Draw the graph for how temperature affects the rate of photosynthesis. Put temperature on the x axis and rate of photosynthesis on the y axis."
Figure 10d - Draw It - “Draw the graph for how the amount of carbon dioxide affects the rate of photosynthesis. Put the amount of carbon dioxide on the x axis and the rate of photosynthesis on the y axis.”

Show the gases that enter and leave the cell through this stoma. Show this by using labeled arrows.

Figure 11d - Draw It - “Show the gases that enter and leave the cell through the stoma. Show this by using labeled arrows.”

Figure 12d - 3D Model - "Mitochondria"
Figure 13d - Open Ended - “Compare and contrast anaerobic and aerobic cellular respiration. Give at least two similarities and two differences.”

Figure 14d - Quiz - "Which substance is the most direct source of the energy that an animal cell uses for the synthesis of materials?"

Figure 15d - Quiz - "During the process of cellular respiration, energy is released from"
In the cells of the human body, oxygen molecules are used directly in a process that

- digests fats
- alters the genetic traits of the cell
- synthesizes carbohydrate molecules
- releases energy

Figure 16d - Quiz - "In the cells of the human body, oxygen molecules are used directly in a process that"

These graphs show the changes in the relative concentrations of two gases in the air surrounding a group of mice. Which process in the mice most likely accounts for the changes shown?

- photosynthesis
- active transport
- respiration
- evaporation

Figure 17d - Quiz - "These graphs show the changes in the relative concentrations of two gases in the air surrounding a group of mice. Which process in the mice most likely accounts for the changes shown?"

The formation of lactic acid in human muscle cells is most closely associated with

- an increase in alcohol consumption
- an increase in glucose production
- muscle fatigue
- protein synthesis

Figure 18d - Quiz - "The formation of lactic acid in muscle cells is most closely associated with"
Figure 19d - Quiz - "Much of the carbon dioxide produced by green plants is not excreted as a metabolic waste because it"

- is too large to pass through cell membranes
- can be used for the creation of proteins
- can be used for photosynthesis
- is needed for cellular respiration

Figure 20d - Quiz - "Plants in areas with short growing seasons often have more chloroplasts in their cells than plants in areas with longer growing seasons. Compared to plants in areas with longer growing seasons, plants in areas with shorter growing seasons most likely"

- have a higher rate of proteolysis metabolism
- have a different method of respiration
- grow taller
- make and store food more quickly

Figure 21d - Quiz - "Which sequence represents structures organized from most complex to least complex?"

- oak tree -> guard cell -> leaf -> chloroplast
- chloroplast -> guard cell -> leaf -> oak tree
- oak tree -> leaf -> guard cell -> chloroplast
- guard cell -> chloroplast -> leaf -> oak tree
Figure 22d - Quiz - “This graph represents the absorption spectrum of chlorophyll. The graph indicates that the energy used in photosynthesis is most likely absorbed from which regions of the spectrum?”

- orange red and violet blue
- yellow and orange red
- green and yellow
- violet blue and green

Figure 23d - Quiz - “To separate leaf pigments, a biologist should use”
Human Body Unit Nearpod Materials and Rationale:

The materials in this unit are focused on allowing students to visualize the complex interactions made between all of the systems of the human body. In order to understand those interactions students need to have a high amount of visuals along with opportunities to practice thinking about these body systems in real life scenarios. Visualization is provided through the use of 3D models along with having the students identify various organs on pictures provided to them. In addition, concepts like the flow of blood through the heart is practiced explicitly with a drawing question in these unit materials. Real life scenarios are practiced with short answer questions that challenge the students to think about the body systems in the context of disorders, anatomy, and connections between systems.

Functionalities Utilized:

Collaborate: 2
Draw It: 11
Open Ended: 11
Poll: 1
Quiz: none
3D Model: 7
PHET Simulation: 1

Link to unit materials: https://share.nearpod.com/2EM9uurb7R
Figure 1e - 3D Model - “Human Body”

Figure 2e - Collaborate - “What are some tasks that the cerebrum would control?”

Figure 3e - Collaborate - “What is the function of the nervous system?”
Draw a neuron. Point (draw an arrow) to the spot where it would receive signals from other neurons. Circle the spot where it would send signals to other neurons.

Figure 4e - Draw It - "Draw a neuron. Point (draw an arrow) to the spot where it would receive signals from other neurons. Circle the spot where it would send signals to other neurons."

Figure 5e - PHET Simulation - "Neuron"

The lower body nerves connect to the lower part of the spinal cord. Higher parts of the body connect at higher points of the spinal cord. Because of this, why do you think people with spinal cord injuries have a much higher chance of survival if their cord is severed lower rather than higher?

Figure 6e - Open Ended - "The lower body nerves connect to the lower part of the spinal cord. Higher parts of the body connect at higher parts of the spinal cord. Because of this, why do you think people with spinal cord injuries have a much higher chance of survival if their cord is severed lower rather than higher?"

Figure 7e - Poll - “Someone who is intoxicated usually has a hard time balancing and performing detailed physical tasks. What part of their brain do you think is most affected?”

Figure 8e - Draw It - “Show the circulation of oxygenated blood through the heart in this picture by using arrows. Make sure to show where the blood enters the heart, moves through chambers in the heart, and leaves the heart.”

Figure 9e - Draw It - “Show the circulation of deoxygenated blood through the heart in this picture by using arrows. Make sure to show where the blood enters the heart, moves through the chambers in the heart, and leaves the heart.”
Figure 10e - 3D Model - "Circulatory System"

Shade this heart diagram red for areas with oxygenated blood and blue for areas with deoxygenated blood.

Figure 11e - Draw It - "Shade this heart diagram red for areas with oxygenated blood and blue for areas with deoxygenated blood"

Figure 12e - Open Ended - "Why do you think that arteries are more muscular than veins?"

Because they have to transport blood that is moving faster and under higher pressure.
Figure 13e - Open Ended - "Why do you think that veins have valves that prevent the back flow of blood but arteries do not?"

Because blood is pushed by the heart when it enters the arteries. It has lost much of that force by the time it enters veins and has the possibility of moving backwards.

Figure 14e - 3D Model - “Respiratory System”

Draw a picture of what the diaphragm looks like during exhalation.

Figure 15e - Draw It - “Draw a picture of what the diaphragm looks like during exhalation.”
Figure 16e - Draw It - "Draw a picture of what the diaphragm looks like during inhalation."

Figure 17e - Open Ended - "Why do you think that capillaries line the alveoli and not other parts of the respiratory system?"

Figure 18e - 3D Model - "Digestive System"
Figure 19e - Open Ended - "Why do you think that so many parts of the digestive system have so many "folds"?"

Figure 20e - Open Ended - "What do you think would be the symptoms for someone that has "smooth gut" disease? This is a disease that involves a person's small intestine having less folds than a normal person's intestine."

Figure 21e - Open Ended - "Compare and contrast mechanical and physical digestion."
Figure 22e - Open Ended - "The large intestine absorbs water from our food. What would be a symptom of the large intestine not doing its job correctly?"

Figure 23e - 3D Model - "Endocrine System"

Figure 24e - Open Ended - "Explain a negative feedback loop using your own words."
Figure 25 - Open Ended - Explain a positive feedback loop in your own words.

Figure 26 - 3D Model - "Skeletal System"

Circle the humerus on this skeleton diagram.

Figure 27 - Draw It - "Circle the humerus on this skeleton diagram"
Circle the pelvis on this skeleton diagram

Figure 28e - Draw It - "Circle the pelvis on this skeleton diagram"

Circle the femur on this skeleton diagram

Figure 29e - Draw It - "Circle the femur on this skeleton diagram"

Point to the radius on this skeleton diagram

Figure 30e - Draw It - "Point to the radius on this skeleton diagram"
Point to the ulna on this skeleton diagram

Figure 31e - Draw It - “Point to the ulna on this skeleton diagram”

Why do you think that children have more bones than adults?

Because children are more likely to break bones so they need more

Figure 32e - Open Ended - “Why do you think that children have more bones than adults?”

Figure 33e - 3D Model - "Muscular System"
Genetics Unit Nearpod Materials and Rationale:

This unit has a mix of skills that need to be practiced along with more higher level questioning practice. For instance, students need to be familiar with using a portion of DNA to determine an RNA sequence, determine the correct amino acid from that sequence, and then assemble a protein. Explicit practice of that skill is included in these materials. In addition, students are asked to practice a wide variety of word problems that involve the utilization of a Punnett Square. They are required to draw the square, add the variables, and determine the most appropriate answer to the word problem. Often the answer to the problem is a percent chance that a set of parents will have a child with a particular genetic trait. Questions about the shape, structure, and importance of the DNA molecule help to strengthen the student’s knowledge of the material.

**Functionalities Utilized:**

Collaborate: 1

Draw It: 8

Open Ended: 6

Poll: 1

Quiz: none

3D Model: 1

PHET Simulation: 3

**Link to unit materials:** [https://share.nearpod.com/WyNITtrb7R](https://share.nearpod.com/WyNITtrb7R)
Figure 1f - 3D Model - “DNA Molecule”

Draw a nucleotide and label the base, phosphate, and sugar.

Figure 2f - Draw It - “Draw a nucleotide and label the base, phosphate, and sugar.”

Point to some of the hydrogen bonds in this DNA molecule.

Figure 3f - Draw It - “Point to some of the hydrogen bonds in this DNA molecule.”
Figure 4f - Open Ended - “If a person’s DNA is 23% adenine how do I know that they also have 27% guanine? Explain!”

Because if that person has 23% adenine they must have 23% thymine. Adenine and Thymine are complementary. That leaves 54% of the DNA left to be either guanine and cytosine. Because they are complementary that percentage must be split in half, leaving 27%.

Figure 5f - Open Ended - “Why does the shape of DNA allow for easy copying of the molecule? Also, why do we need to copy the DNA so much?”

The two strands of DNA are held together by relatively weak hydrogen bonds that can be easily broken and then reformed. DNA needs to copy so much because every new cell needs a copy of the same DNA molecule.

Figure 6f - Open Ended - “Do you think that Rosalind Franklin was robbed of a Nobel Prize? Why do you think that way?”

I think that her work definitely should have been recognized and she should have been able to share the award with the men that she helped make the discovery with.
Why is using a copying machine a good analogy for DNA replication?

Because a copy does not look exactly like the original. There are minor imperfections.

Transcribe and then translate the following DNA sequence using the chart provided. TACGCAAT

Transcription: AUGCGUUA
Translation: Met - Pro - Leu

What information can you determine based on this karyotype?

I know that this is a male that has Down's Syndrome. I know this because there is a Y chromosome along with an extra 21st chromosome.
Figure 10f - PHET Simulation - “Gene Expression Essentials”

Figure 11f - PHET Simulation - “Gene Expression Essentials 2”

Figure 12f - PHET Simulation - “Gene Expression Essentials 3”
Figure 13f - Collaborate - “What do we know about Gregor Mendel?”

Figure 14f - Poll - “Which of these traits do you think are single gene traits? Choose as many as you think!”

Figure 15f - Draw It - “Assume eye color is a single gene trait and brown is dominant. Can two people with brown eyes have a child with blue eyes? Show the Punnet Square!”
Show the Punnet Square for two individuals that are carriers for Huntington’s disease. What are the chances that they have a child with the disease? Huntington’s disease is an autosomal recessive disease.

Figure 16f - Draw It - “Show the Punnet Square for two individuals that are carriers for Huntington’s disease. What are the chances that they have a child with the disease? Huntington’s disease is an autosomal recessive disease.”

If a homozygous red flowered plant mates with a homozygous white flowered plant what percentage of offspring would be pink? Assume intermediate inheritance.

100% chance

Figure 17f - Draw It - If a homozygous red flowered plant mates with a homozygous white flowered plant what percentage of offspring would be pink? Assume intermediate inheritance.”

A roan cow is mated with a white cow. What are the possible genotypes of their offspring and what are their percentages? Assume codominance.

50 Roan & 50% White

Figure 18f - Draw It - “A roan cow is mated with a white cow. What are the possible genotypes of their offspring and what are their percentages? Assume codominance.”
Figure 19f - Draw It - "A couple that both have type AB blood have a child. What are the odds that the child has type O blood? Draw a Punnet Square to prove your answer."

Figure 20f - Draw It - "A color blind man marries a woman that is not color blind. Can they have daughter's who are color blind? Use a Punnet Square to prove your answer. Color blindness is a sex linked trait."
Reproduction Unit Nearpod Materials and Rationale:

This unit has two main goals. One of the goals is student understanding of the human reproductive system. That involves knowledge of the anatomy of the system along with the function of the various anatomical parts of the system. In addition, understanding of the system is strengthened through higher level questioning that challenges the students to think about possible scenarios that could occur that relate to the human reproductive system. The other main component of this unit is cell reproduction, or cell division. Understanding of cell reproduction comes with practice, as it is difficult to initially visualize how chromosomes can replicate and then move to different cells in an organized manner. Because of this, explicit practice of the steps of cell reproduction is included in these materials.

**Functionalities Utilized:**

Collaborate: 2
Draw It: 14
Open Ended: 3
Poll: none
Quiz: none
3D Model: none
PHET Simulation: none

**Link to unit materials:** [https://share.nearpod.com/iT4eBMrb7R](https://share.nearpod.com/iT4eBMrb7R)
Figure 1g - Collaborate - "What is the function / purpose of meiosis?"

Figure 2g - Collaborate - "Why is sexual reproduction an advantage over asexual?"

Why do you think that it is important that fertilization occurs in the fallopian tube and not in the uterus?

Figure 3g - Open Ended - Why do you think that it is important that fertilization occurs in the fallopian tube and not in the uterus?"
Figure 4g - Open Ended - "If a woman had a low amount of ovulation hormone how do you think that would affect her body?"

The release of her eggs would probably be affected.

Figure 5g - Open Ended - "If two people had intercourse before ovulation would there be a chance for fertilization? Why / why not?"

There would be no chance of fertilization because there would be no egg for the sperm to fertilize.

Figure 6g - Draw It - "Draw interphase of mitosis. Assume your starting cell has 2 chromosomes."

Draw interphase of mitosis. Assume your starting cell has 2 chromosomes.
Figure 7g - Draw It - "Draw prophase of mitosis. Assume your starting cell has 2 chromosomes."

Figure 8g - Draw It - "Draw metaphase of mitosis. Assume your starting cell has 2 chromosomes."

Figure 9g - Draw It - "Draw anaphase of mitosis. Assume your starting cell has 2 chromosomes."
Figure 10g - Draw telophase and cytokinesis of mitosis. Assume your starting cell has 2 chromosomes.

Figure 11g - Draw interphase of meiosis I. Assume your starting cell has 2 chromosomes.

Figure 12g - Draw prophase of meiosis I. Assume your starting cell has 2 chromosomes.
Draw metaphase of meiosis I. Assume your starting cell has 2 chromosomes.

Figure 13g - Draw It - "Draw metaphase of meiosis I. Assume your starting cell has 2 chromosomes."

Draw telophase and cytokinesis of meiosis I. Assume your starting cell has 2 chromosomes.

Figure 14g - Draw It - "Draw telophase and cytokinesis of meiosis I. Assume your starting cell has 2 chromosomes."

Draw metaphase of meiosis II. Assume your starting cell has 2 chromosomes.

Figure 15g - Draw It - "Draw metaphase of meiosis II. Assume your starting cell has 2 chromosomes."
Figure 16g - Draw it - "Draw anaphase of meiosis II. Assume your starting cell has 2 chromosomes."

Figure 17g - Draw it - "Draw telophase and cytokinesis of meiosis II. Assume your starting cell has 2 chromosomes."
Evolution Unit Nearpod Materials and Rationale:

This unit does not have as many requisite skills as required in other unit, allowing it to have more open ended and higher level questions. The questions in this unit challenge students to think about the theory of evolution by natural selection in its application. For instance, some of the questions force students to challenge their own misconceptions about terms like “survival of the fittest”. In addition, the concept of analogous and homologous structures is explored in detail and used as evidence for Darwin’s theory.

**Functionalities Utilized:**

Collaborate: 1

Draw It: none

Open Ended: 7

Poll: none

Quiz: 1 (10 questions included)

3D Model: none

PHET Simulation: none

**Link to unit materials:** [https://share.nearpod.com/dLfqQLrb7R](https://share.nearpod.com/dLfqQLrb7R)
Figure 1h - Collaborate - "What are some traits that would be beneficial for a human?"

Figure 2h - Open Ended - "Why are scientists able to assume that organisms buried further down in the Earth are older than organisms buried further up?"

Figure 3h - Open Ended - "What would be an example of homologous structures?"
What would be an example of analogous structures?

A dolphin fin and a fish fin would be examples of analogous structures.

Why do you think that homologous structures point towards a common ancestor but analogous structures do not?

Homologous structures have similar composition while analogous structures are built very differently even if they have a similar function.

Whales have the remains of back leg bones in their skeleton even though they live their entire life in water. Why is this evidence towards them being more related to mammals than fish?

Because there is no real purpose to having back leg bones if an organism is going to spend its entire life in water. If they were more related to fish there would be no way that they would have those bones.

Whale have the remains of back leg bones in their skeleton even though they live their entire life in water. Why is this evidence towards them being more related to mammals than fish?
Figure 7h - Open Ended - "The male peacock carries around a tremendous amount of brightly colored feathers. Those feathers do not help the peacock survive or obtain food. Why would evolution have selected for this trait?"

Because while the feathers do not help it survive or obtain food the feathers do help the peacock reproduce.

Figure 8h - Open Ended - "Compare and contrast natural and artificial selection."

Natural selection is when certain organisms are more likely to survive and reproduce based on their traits and the environment that they live in. Artificial selection is when certain organisms are more likely to survive and reproduce because they have traits that are desirable to humans, and those organisms are forcibly bred together by humans.

Figure 9h - Quiz - "Some behaviors such as mating and caring for young are genetically determined in certain species of birds. The presence of those behaviors is most likely due to the fact that"

- Birds do not have the ability to learn
- Individual birds need to learn to survive and reproduce
- These behaviors helped birds survive in the past
- Within their lifetimes, birds developed these behaviors
Figure 10h - Quiz - “Which concept includes the other three?”

- competition
- survival of the fittest
- natural selection
- overpopulation

A trait with low survival value to members of a population will most likely

- undergo a series of mutations in succeeding generations
- cause the reproduction rate in individual organisms to increase
- decrease in frequency from one generation to the next
- remain unchanged in frequency through many generations

Figure 11h - Quiz - “A trait with low survival value to members of a population will most likely”

Certain antibacterial soaps kill 99.9% of the bacteria present on hands. Constant use of these soaps could be harmful over time because

- more pathogens may be resistant to the soap
- microbes prevent viral diseases
- large populations of pathogens are beneficial to the hands
- the soap stimulates skin cell division

Figure 12h - Quiz - “Certain antibacterial soaps kill 99.9% of the bacteria present on hands. Constant use of these soaps could be harmful over time because”
In the early stages of development, the embryos of dogs, pigs, and humans resemble one another. This observation suggests that these animals may have:

- a similar number of chromosomes
- similar habitat requirements
- the same blood components
- a common ancestry

Figure 13h - Quiz - “In the early stages of development, the embryos of dogs, pigs, and humans resemble one another. This observation suggests that these animals may have”

A weakness in Darwin’s original theory of evolution by natural selection was that:

- the genetic basis for evolution was not explained
- overpopulation never occurs in nature
- competition occurs in animals but not in plants
- natural selection does not occur in domestic animals

Figure 14h - Quiz - A weakness in Darwin’s original theory of evolution by natural selection was that”

Sheep and pigs have more enzymes in common than sheep and frogs do. What does this finding indicate?

- none of these animals are related
- frogs are not related to pigs
- sheep are more closely related to pigs than to frogs
- frogs are more closely related to sheep than to pigs

Figure 15h - Quiz - “Sheep and pigs have more enzymes in common than sheep and frogs do. What does this finding indicate?”
Which concept is not a part of the theory of evolution?

- present day species developed from earlier species
- some species die out when environmental changes occur
- complex organisms develop from simple organisms over time
- change occurs according to the needs of an individual organism to survive

Figure 16h - Quiz - “Which concept is not a part of the theory of evolution?”

Which observation provides the best evidence that two different animals most likely have a common ancestor?

- they choose the same plants for food
- they both burrow into the ground for shelter
- they have similarities in early embryonic development
- they both inhabit the same environment

Figure 17h - Quiz - “Which observation provides the best evidence that two different animals most likely have a common ancestor?”

Certain insects resemble the twigs of trees. Based on modern evolutionary theory, the most probable explanation for this is that

- a single gene mutation caused the resemblance
- the insects changed because they ate the wood of the trees
- genes were transferred from the trees to the insects
- natural selection of many variations had occurred

Figure 18h - Quiz - “Certain insects resemble the twigs of trees. Based on modern evolutionary theory, the most probable explanation for this is that”
Ecology Unit Nearpod Materials and Rationale:

The Ecology unit is one that students typically understand fairly well. It contains concepts that students have been exposed to for a number of years and does not require a great deal of practice or drilling to retain the information. Because of this, the materials in this unit are used to expand on the basic ideas of the unit and allow for students to share their thinking about the topics that are being presented to them. Rather than using the materials as a way for students to grasp the content they are being used as a vehicle for expanding discussion beyond the content. Students are asked to share their opinion on government policy, are shown 3D images of oil refineries and solar panels, and are asked to analyze the costs and benefits of using living organisms to control invasive species.

**Functionalities Utilized:**

Collaborate: 3

Draw It: none

Open Ended: 2

Poll: 2

Quiz: none

3D Model: 7

PHET Simulation: none

**Link to unit materials:** [https://share.nearpod.com/FotisNVC8R](https://share.nearpod.com/FotisNVC8R)
In what ways could introducing another organism to control an invasive species be a bad idea?

The introduced organism could become invasive on its own.

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Figure 1 - Open Ended - "In what ways could introducing another organism to control an invasive species be a bad idea?"

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Figure 2 - Collaborate - "What can you do during a normal day to help the environment?"

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Figure 3 - Poll - "Which environmental issue do you think our society should be most focused on moving forward?"
Figure 4i - Poll - "Which one of these renewable energy sources do you think is most promising for the future?"

Figure 5i - Collaborate - "What are some ways that we can reduce our carbon footprint?"

Figure 6i - Open Ended - "Write a paragraph that summarizes the environmental issues presented in this video and include some possible solutions."

Humans are having an unmistakable impact on the environment that we live in. We rely on the environment for a number of things including food, fuel, fiber, and shelter. Without the resources that the surrounding environment provides we would not be able to live on this planet. We can help improve the overall health of the environment and plant by generally making less demands on it. We can harvest less trees, kill less animals, and use less water. Every small contribution by humans on this planet can help reduce our demand on the environment.
Figure 7i - Collaborate - "Should the government be involved in creating / investing in renewable energy sources? Or should that be left to private companies?"

Figure 8i - 3D Model - "Solar Panel"

Figure 9i - 3D Model - "Wind Turbine"
Figure 10i - 3D Model - "Oil Refinery"

Figure 11i - 3D Model - "Nuclear Power Plant"

Figure 12i - 3D Model - "Hydroelectric Generator"
Figure 13i - 3D Model - "Hydroelectric Dam"

Figure 14i - 3D Model - "Fracking"
Summary

As education continues to progress into the 21st century, online aspects of the classroom are only going to increase. Students and society in general are more and more tied to their cell phones, which leaves them permanently connected to the web and the world at large. Internet connections and the web in general make a number of things easier, including formative assessment. Formative assessments allow for the teacher to gauge the various levels of understanding in their classroom while also allowing students to practice and eventually master material. Students consistently show higher achievement and interest when their science instruction is rooted in strong formative assessment pedagogy (Aydin & Urun, 2016). Web based student response systems increase the amount of data that can be collected while also increasing student engagement (Fuller & Dawson, 2017). Formative assessment is notoriously difficult to plan and implement on a daily basis (Copeland Solas & Wilson, 2017). In addition, teachers also struggle with knowing how often to provide feedback and what kind of feedback to provide when using formative assessment (Grob, Holmeier, & Labudde, 2017).

College courses have been quicker to adapt technology enhanced formative assessment. College implementation began with the use of simple “clickers” and now have evolved to applications that are more complicated. For instance, there are college courses that utilize complicated applications that allow students to use their phones to help them identify plant species in the real world (Conejo, Garcia-Viñas, Gastón, & Barros, 2016). There are still high schools and colleges that utilize “clickers” yet various methods of mobile and online formative assessment have become the new norm (Terry et al., 2016). Web based applications have been shown to increase student achievement when compared to more basic methods (Coca & Slisko,
2013). Technology based formative assessment tools allow for easier grouping of students so that peer feedback can be provided (Lopez & Mazario, 2016).

Nearpod is a web based application that is a great tool for formative assessment not only due to its ability to collect a vast amount of data quickly, but also for its ease of use and variety of implementations. When using any formative assessment tool, the questions cannot be solely factual and static, there needs to be a variety of question types and questions that allow for higher level thinking (DeBoer et al., 2014). Nearpod allows for the wide variety of question types needed for an application to be effective in a classroom. Nearpod has a function that allows students to draw their answers to problems. Drawings can be a way to ease the implementation of formative assessment (Copeland Solas & Wilson, 2017). Drawings also allow for high engagement in the classroom (Copeland Solas & Wilson, 2017). There have been instances that student drawings are more predictive of future summative assessment performance than writing (Shelton et al., 2016). Nearpod and other technology based formative assessment tools make it easier to perform routine classroom tasks, easier to administer and grade assessments, and easier to collect student data (Shirley & Irving, 2015). Nearpod questions can even be used as lesson openers, which have been shown to increase engagement and understanding of material (Zertuche, Gerard, & Linn, 2012).

Utilization of Nearpod, just like any new teaching technique, is something that should come with time. For as much time is needed to master the technology aspect of an online app, there is probably double or triple the amount of time needed to become comfortable with using formative assessment a regular amount in the classroom. Questioning and assessment is something that teachers should be constantly working on, and Nearpod enhances the frequency of that thought process (Eshach, Dor-Ziderman, & Yefroimsky, 2014). Feldman and Capobianco
(2008) argue that the implementation of formative assessment technology is something that takes time and patience. Teacher formative assessment skills improve over time (Furtak et al., 2016) and formative assessment practices improve with collaboration between colleagues (Heredia, Furtak, Morrison, & Renga, 2016).

The amount of functionalities within Nearpod (Draw It, Collaborate, 3D Model, PHET Simulation, Open Ended, Quiz, and Poll) allow for a wide variety of uses in the classroom. Teachers can simply generate quizzes within Nearpod to help students prepare for summative assessments, they can choose to write Open Ended questions to consistently start their lessons, or they can utilize a number of other combinations of the available functionalities. Teachers do need to be cognizant of the “wear out effect” of a novel teaching technique. Technology tools normally result in higher than normal student engagement but there is a wear out effect when the tool is used too much or not varied enough in its implementation (Wang, 2015). Students are more likely and willing to utilize mobile technology when presented with varied and challenging questions (Sun, Looi, Wu, & Xie, 2016). Formative assessment questions, no matter what the delivery method, provide more of a benefit when they are reasonably complicated, allow thinking, and are not strictly factual (Weurlander, Söderberg, Scheja, Hult, & Wernerson, 2012).

The Nearpod activities shown in this curriculum were designed with sound pedagogy and the “wear out effect” in mind. There was an effort to not only vary the functionalities utilized but also the questioning types within the same functionality. For instance, when utilizing the Quiz functionality there were questions that were purely factual while also questions that required the student to apply their knowledge of the content. Draw It activities were utilized during highly visual units that require students to have an in depth knowledge of anatomy or parts of scientific equipment. 3D Models and PHET Simulations were appropriately dispersed
by topic. In addition, almost every unit included Open Ended and Collaborate activities in order to expose students to as much higher level thinking as possible. These activities can be used in any high school biology classroom. Teachers should be encouraged to be flexible in their classroom and utilize the flexibility of the Nearpod application. Activities and questions can be skipped when needed, repeated when needed, and questions/activities can be added on the fly. Teachers can also add presentation slides to a Nearpod “unit” when desired, making it so students can keep their attention on one piece of technology rather than multiple.
References

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https://doi.org/10.1002/tea.21145


