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Addressing the problem of student engagement in the classroom

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Abstract

The problem of student engagement is one that is faced by teachers everywhere. While multiple strategies exist for combating this issue, project-based learning and inquiry-based learning are two that stand out in the multitude of research. Additionally, these strategies are ideal in the science classroom as they align very well with the Next Generation Science Standards that are used in Michigan, including rural Southwest Michigan school, Eau Claire High School. This project explores these instructional strategies and their various benefits which include improved critical thinking, improved social skills, and improved questioning skills.

Table of Contents

Chapter One: Introduction

Problem Statement

Lack of student engagement is an issue that many teachers face. Various studies have looked at the issue of student engagement in the classroom (Bennett & Boesdorfer, 2020; Conner, 2011; Denessen et al., 2015). There are several reasons as to why this issue persists. A significant part of a lack of engagement in the classroom may be due to teacher attitudes and classroom environment (Denessen et al., 2015). The same study also concluded that teacher attitudes directly affect the attitudes of their students, and that students felt more positively about the subject they were learning when their teacher was enthusiastic about the topics. The idea that student perception of the teacher correlates with engagement is supported by Wang et al. (2020) who showed that classroom engagement and student success are positively correlated with classroom quality. Classroom quality was defined by emotional support from the teacher, instructional support, and classroom organization.

Other classroom practices, such as textbook-based work, repetitive exercises, and memorization of facts have also been shown to have a negative impact on student engagement (Lyons, 2006). Furthermore, teachers may not be adequately prepared, or skilled in areas regarding student academic and emotional support required to maintain student engagement (Dar, 2015).

Importance and Rationale

High school graduates are less likely to pursue science, technology, engineering, and mathematics (STEM) majors after high school due to a loss in interest in their earlier school years (Brewer et al. 2021). Maltese et al., (2014) supports the idea that student interest plays a primary role in student persistence in STEM subjects, and goes on to add that students are also partially motivated to continue STEM beyond high school when they see it as a viable career option.

Lack of engagement in classrooms could also have larger, global consequences that may stem from a lack of engagement as well, specifically in STEM subjects. Global issues such as pandemics, climate change, pollution, and healthcare will require young people to choose scientific careers (Denessen et al,. 2015). The lack of interest in these topics at a young age in students is cause for concern as it may be related to young people choosing scientific career paths less often. Lack of interest in science has also had an effect on lack of understanding (Sezen-Barrie et al., 2019). Students from elementary up through high school have shown a trend in climate change denial. Sezen-Barrie (2019) attributes this to a lack of understanding of the topic by their teachers since it is unlikely they learned about the topic in their own schooling. It is reasonable to assume that if students are in denial about problems that exist such as climate change, then they will not be compelled to solve that problem. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) has determined this to be problematic, and consequently designed a roadmap for educating youth on climate issues and preparing for a sustainable future (United Nations, 2014).

Lack of student engagement presents a huge problem if it is positively related to achievement as studies suggest (Faris, 2008; Vaughn & Winner, 2000; Maltese et al., 2014; Maltese & Tai, 2010). In 2015, the Programme for International Student Assessment (PISA) did a study comparing the US to various other countries, and found that the US placed only 38th among 71 countries in math, and 24th in science. The National Assessment of Educational Progress (NAEP) also found that in 2015, average math scores for fourth and eighth graders fell for the first time since 1990 (United Nations, 2014).

Background

The early years of the 20th century revealed an increase in the need for STEM jobs in large part due to World War II and the increased dependence on industrial and agricultural products. The new economy was now experiencing a shortage in these newly desired fields (DeBoer, 1991, as cited in Wissehr et al., 2011). Various efforts since the war have been made to boost interest in education. One of the early efforts at this time was the implementation of the National Science Foundation (NSF) in 1950, which sought to act as a funding agency for educational research in the sciences. In 1957, the NSF added social sciences to their list of eligible fields for funding and scholarships (Alpert, 1957).

Other education initiatives such as the President's Scientific Research board, the National Science Foundation, and the environmental movement were all at the center of the United States' attention as well. And in 1957, the launch of Sputnik and the consequential space race that resulted, spawned a plethora of scientific interest as the United States focused on not being outdone by the Soviets (Wissehr et al., 2011). In 1958, President Eisenhower, signed the National Defense Education Act, a bill aimed at providing assistance to fields deemed relevant to military defense such as science, mathematics, and foreign language (United States Congress, 1958). Shortly after, the US established the National Aeronautics and Space Administration (NASA) (Harris & Miller, 2005), and then followed by landing on the moon eleven years later in 1969 with the successful voyage of Apollo 11 (Grubbs, 2014).

Still, after various attempts to compete with the modern world, the US struggled to elevate science education in the US. Reports show slow progression in STEM education. The National Commission on Excellence in Education published the following (1983): from the years 1969-1977, a steady decline is shown in science education among 17-year-olds in the US, from

1975-1980, remedial mathematics courses in universities increased by 72 percent, mathematical reasoning and the ability to draw inferences is low. More recently, students in the US have improved in mathematics and science over the past two decades, but are still behind when compared to other developed nations (Harris & Miller, 2005).

Riegle-Crumb et al., (2011) suggests this shortcoming is, at least in part, due to a lack of interest in STEM from students as they move from primary to secondary school. Riegle-Crumb et al. (2011) states that among fourth grade students, the majority claimed to enjoy learning about science topics. Comparatively, their eighth-grade counterparts reported lower interest in science. Beyond secondary school, students continue to lose interest in following STEM paths. Shapiro and Sax (2011) found that only a small percentage of students go on to choose STEM majors in higher education.

In 2013, the National Research Council (NRC) released the Next Generation Science Standards (NGSS), a framework for teaching science using a three-dimensional approach of scientific and engineering practices, disciplinary core ideas, and crosscutting concepts. NGSS was designed to teach science using inquiry practices to help students understand underlying concepts of science and how we come to know scientific phenomena, rather than just memorizing facts (National Research Council, 2012). In 2015, Michigan officially adopted these standards to replace the previous Michigan Science Standards adopted in 2006 (Michigan Department of Education, 2015) with the goal of preparing students to apply basic scientific knowledge to their lives.

Statement of Purpose

The purpose of this project is to increase student engagement in a high school science classroom. Students will engage in student-centered activities which encourage learning through authentic and engaging teaching strategies and materials.

Objective of the Project

The objectives of this project are to:

- Increase student engagement in the classroom
- Improve student achievement in the classroom
- Expose students to real world problems to facilitate interest in STEM subjects
- Encourage students to be scientific thinkers through engaging practices
- Encourage students to continue their learning beyond high school and bring what they have learned into their real lives outside of the classroom

Definition of Terms

Student engagement - implies that the student is making a psychological investment in learning (Newman, 1992)

Inquiry-based - a method of teaching in which the instructor poses a question. The learner responds by generating and pursuing strategies to investigate those questions by generating data, analyzing and interpreting those data, drawing conclusions from them, communicating those conclusions, applying conclusions back to the original question, and perhaps following up on new questions. (Sandoval, 2005)

Phenomenon - Students observe a phenomenon and develop explanations about why or how that phenomenon occurred (Helsel et al., 2022).

Scope of the Project

Since student engagement is related to student achievement, student proficiency will be used as a measuring tool for success of this project. Students will be surveyed after a unit in a high school physical science course. This will take place over one semester in a single classroom. Success of the project will be measured by the survey results, and whether or not students found learning through constructivist methods useful, meaningful, and enjoyable.

Possibly the most significant constraint for implementing this project will be lack of resources. With a lack of funds, it may be difficult to obtain resources needed to implement a variety of hands-on activities. Another issue may be approval from administration to implement the project in the classroom. Time is also a limitation. Classes at this school are 51 minutes long, meaning that more time-consuming activities must either be split into multiple days, or cannot be completed if they are time sensitive. It is also often difficult to split activities into multiple days since student attendance is also an issue at this school.

Chapter Two: Literature Review

Introduction

Lack of student engagement has been shown to be an issue in various classrooms throughout the US and throughout the world. Chapter One shows that, at least in some cases, this issue arises from unengaging teaching styles or teaching strategies. The aforementioned studies also suggest that a consequence of unengaged students is a lack of interest in pursuing education later in life, which may in turn lead to a lack of qualified professionals in high-need fields. Chapter Two will discuss various teaching strategies that have been shown to increase student engagement in the classroom.

Theory/Rationale

According to constructivist learning theory, learning is more likely to occur when the learning experience has meaning. Through constructivism, the learner connects previously learned ideas to new ones (Westover et al., 2021). When constructivism has been used in pedagogical practices it has been found to influence student achievement positively in almost all subjects, with religious studies being an exception (Ayaz & Sekerci, 2015).

The above points are evident in the various studies that will be discussed in this chapter. For example, students who are able to apply previously obtained knowledge to a new, authentic problem show improvement in critical thinking skills (Wang, 2022). Utilizing these types of skills to solve problems also yields greater enjoyment for learning from students ((Bennett & Boesdorfer, 2020).

Research/Evaluation

Evolving standards in education, such as Next Generation Science Standards (NGSS), have moved away from measuring student understanding through memorization of facts and vocabulary, and instead require that students show understanding through various actions that allow them to apply what they have learned to solve real-life problems. NGSS uses phrases such as, “plan and conduct”, “use a model”, and “construct and revise” (National Research Council, 2012). Since these standards are heavily based in constructivism, classroom teachers can use constructivist theory to allow students to demonstrate proficiency in standards. Effective ways to do this are through inquiry-based learning (IBL), project-based learning (PBL), collaborative learning, and student autonomy.

Inquiry-based learning

> Inquiry-based learning is the process of learning through questioning, seeking and analyzing information, and converting data into useful knowledge. Inquiry implies emphasis on development and nurturing of questioning skills and attitudes that enable individuals to quest for knowledge throughout life (Perry & Richardson, 2001, p.1).

According to the aforementioned publication, learning must take place at multiple levels. The fourth and final level, application and problem solving, must be reached in order for teaching and learning to be impacted. Inquiry-based learning is an effective method for reaching this level.

The effectiveness of inquiry-based learning (IBL) is supported by Divrik et al., (2020). It was found that, when compared to students who had been taught using the traditional method of using the textbook, students taught using the inquiry-based model were more proficient in problem solving and problem posing using the mathematics curriculum. Sutiani et al. (2021) found that inquiry-based lessons in chemistry helped improve students’ ability to think critically, and furthermore, garnered student interest in chemistry. Key components of the lesson in this study included: observing phenomena and then formulating questions, planning and carrying out an investigation in which the students used the scientific method to answer a question, building new knowledge and facilitating discussion, and then applying knowledge to a new concept. Outcomes from each of these studies suggest that concrete curriculum such as math and science can benefit from IBL (Divrik, 2020; Sutiani, 2021). Since the acquired skills mentioned in these two studies are critical in science and math due to the inherent nature of these subjects, and because NGSS requires that learners demonstrate these skills, one could also conclude that IBL is an ideal strategy for curricula that follow NGSS.

Process Oriented Guided Inquiry Learning (POGIL) is a student-directed inquiry-based series of activities for teaching various science topics (Flinn Scientific, 2022). PhET is a series of online interactive simulations designed to engage students in science and math using inquiry (PhET Interactive Simulations, 2002). Students who engage in inquiry-based activities like POGIL and PhET simulations stated that they learned more from these assignments due to useful visualizations and the ability to explore various scenarios related to their assigned topic (Bennett & Boesdorfer, 2020). Students who engaged in these activities enjoyed the activities and retained understanding of the concepts learned, which was evidenced by improved test scores. This once again lends to the hypothesis that engagement yields greater achievement in students. Sahoo and Mohammed (2018) similarly concluded that retention of understanding after an activity may be linked to students' improved ability to think critically after completing inquiry-based activities. The students who engaged in the inquiry-based activities claimed that during completion of their assignment, they were forced to think critically, reflect, and raise questions. Students also mentioned solving complex problems (Sahoo & Mohammed, 2018).

Other positive outcomes from learning through inquiry include refreshing previously obtained knowledge and expanding on it, generating discussion among group members, and learning to visualize ideas (Nash et al., 2018). Due to the nature of science, visualization is a valuable method of learning. This skill could be used to connect ideas, analyze data, or help students build models. These all happen to be indicators for mastery within the Next Generation Science Standards (NGSS) as well (Michigan Department of Education, 2015). This provides further support that inquiry can be a valuable teaching method for science.

Students also find inquiry to be an interesting way to learn and find it to be enjoyable (Nash et al., 2018). Students learning through inquiry think of their learning experience in a more positive way, and also state that they had positive feelings with regard to having freedom in being able to design their own learning experiences through experiments (Wiseman et al., 2020).

Though the sample size of the aforementioned study is relatively small, the percentage of students who mentioned freedom of choice in their learning should be considered as relevant. IBL is not about providing students with answers, but instead teaching them how to be better at generating questions and analyzing the things around them in order to become self-learners (Perry & Richardson, 2001, p.1). This is why IBL is a strong teaching strategy. This is particularly true in science due to the nature of science itself. Generating questions and analyzing is exactly what scientists do, which is consequently supported by NGSS (Michigan Department of Education, 2015). By allowing students to design their own learning experience, the teacher is fostering their creativity and supporting their interests while allowing them to use the scientific method just as scientists do.

Project-Based Learning

Project based learning (PBL) was introduced over a hundred years ago by philosopher and educator, John Dewey as a method of learner-centered instructional strategy in which students “learn by doing” (Dewey, 2009). In more recent years, PBL has been used to encourage students to think more critically by presenting them with real-world relevant topics (Wang, 2022). Critical thinking skills have been shown to improve through the implementation phases of a project-based assignment along with a positive and structured environment involving student-teacher dialogue (Al-Krisha & Mansour, 2021). The authors also suggest that motivation and encouragement play a significant role in student engagement.

Other findings from Al-Krisha & Mansour (2021) include enhanced deduction-making, questioning, and clarifying of results. These are valuable skills when doing research, which is an indicator for mastery in various standards of NGSS (Michigan Department of Education, 2015). Alicapinar (2008) agrees that PBL improves research skills. Other scientific practices relevant to research such as generating questions, planning and carrying out an investigation, and analyzing data also improve (Evans, 2019).

Research skills translated to solving real world problems keeps students engaged (Evans, 2019). Students who are able to apply their skills to issues they encounter in their own lives find their school work to be an intellectual challenge, but also authentic and rewarding. Additionally, because students are not given explicit requirements for projects, PBL allows learners of all abilities to produce a meaningful project and benefit from it (Evans, 2019). Projects that students find meaningful yield positive results in terms of motivation and interest as well. Students who participate in PBL have been shown to have a positive relationship with student commitment to a project, as well as their success (Rodriguez, 2022).

Due to the technical and factual nature of topics in science, technology, engineering, and mathematics (STEM), it can be difficult to promote creativity. While PBL does improve various technical skills, it has also been shown to improve creativity and social skills (Ummah, et al., 2019; Alicapinar, 2008). Additional skills improved through PBL include aspects of communicating, such as pronunciation, grammar, vocabulary, fluency, and social skills. (Tyas & Fitriani, 2021; Alicapinar, 2008). Alicapinar (2008) also found improved ability to use manipulatives, a potentially useful skill in meeting some NGSS standards involving creation and usage of a model, or communicating a mathematical concept through a model.

Furthermore, students who engage in PBL have also been shown to view science more favorably (Faris, 2008). These trends are again supported by Viswambaran and S. Shafeek, (2019), in which students stated that they enjoyed learning through a project and enjoyed working in groups. Moreover, student achievement was also improved in each of the two test groups in the aforementioned study.

Another interesting concept of PBL is its potential impact specifically on learners of low socioeconomic status. Halvorsen et al. (2012) found that students of low socioeconomic status showed greater academic growth after implementation of PBL than did their peers of high socioeconomic status. Students involved in after school project-based STEM clubs also found that student interest and attitudes toward STEM improved as a result of participation in the club (Yang & Chittoori, 2022).

Student autonomy and choice

Another teaching strategy that has been shown to be a strong predictor of student engagement is providing the option of student choice or autonomy. When students are given autonomy under a teacher-structured environment, engagement is improved (Jang et al., 2010). For example, Jang et al., (2010) showed that in writing, students who were given the ability to choose the topic of genre for a novel-writing assignment reported that the ability to write without constraints enhanced their creativity and also found it enjoyable. Student choice is also a large component of project-based learning (PBL) and inquiry-based learning (IBL) in which students are able to choose how they approach a problem to create a project. In examples where students are able to do this, they gain several valuable skills including improved social interactions, speaking skills, and critical thinking (Al-Krisha & Mansour, 2021; Alicapinar, 2008; Tyas & Fitriani, 2021; Ummah, et al., 2019).

In addition to improved thinking and social abilities, overall increased levels of enjoyment and engagement are also seen in these types of instruction (Wiseman et al., 2020). Students who are found to enjoy their studies are more motivated and engaged. This is because they find value in assignments where they have choices about how they learn, particularly when what they are learning is relevant to their lives (Ford & Roby, 2013). Furthermore, students who are not intrinsically motivated are less likely to find value in their schoolwork. Structured autonomy has also been shown to correlate positively with student participation, confidence, commitment, and motivation (Hernandez et al., 2022). This fosters a more positive learning environment for all students. Rodriguez (2022) found similar results using PBL in terms of generating greater participation and commitment from students. Students who find meaning in their learning are more likely to engage positively in the experience.

Collaboration and discussion

Students report that classroom activities involving collaboration with their peers improves engagement (Conner, 2011). Conner found that students who actively engaged in discussion were also more likely to have a positive relationship with their teacher. Good teachers had qualities such as caring, or trustworthy - each being positively related to student-teacher discussion during school time. Like student choice, collaboration and discussion also play an important role in project-based learning (PBL) and inquiry-based learning (IBL) (Evans, 2019; Nash et al., 2018), and can aid in achieving the various goals listed in the previous sections (improved social skills, speaking skills, critical thinking, etc.) (Al-Krisha & Mansour, 2021; Alicapinar, 2008; Tyas & Fitriani, 2021; Ummah, et al., 2019).

Group work has also been shown to enhance other valuable student skills as well, such as interdependence, interpersonal skills, task processing, and self efficacy (Fung, 2022). When students are delegated to specific responsibilities, they take on a role of responsibility and are given a more active role in the assignment, suggesting that teacher support plays an important role when assigning group work. This suggests that collaboration and student choice are strategies that can be combined effectively, namely in the primary strategies discussed earlier - IBL and PBL (Evans, 2019; Wiseman et al., 2020)

Students also tend to view group work as a growing experience that is rewarding and promotes success (Williamson & Ericksen, 2017). When working in groups in which students designate their roles, they recognize the importance of collaboration and fulfilling one's roles within the group.

Critical thinking

The strategies above all have one common theme – critical thinking. The goal of this project, beyond engagement in the classroom, is to ultimately make students better global citizens who can contribute in solving the world's problems. For example, today's youth will soon be in charge of solving the global climate crisis (UNESCO, 2014). This will require that they become strong problem solvers. Critical thinking skills improve one's ability to solve problems (Murawski, 2014). Inquiry-based learning and problem-based learning are both strategies that present students with a problem that needs solving (Dewey, 2009; Sahoo & Mohammed, 2018). That makes them ideal strategies for meeting the goals discussed in this project.

Summary

Student engagement can be addressed through a variety of methods as outlined in this chapter. However, the reason for improving engagement is much broader. Various skills are improved through the methods discussed in this chapter. Critical thinking is a highlight of these skills in each of the instructional strategies presented. Increasing student engagement is the primary goal of this project; but improved achievement is the reason for this. Helping students improve their ability to think critically can help them achieve more (Murawski, 2014). Critical thinking improves one's ability to solve problems, make decisions, improves judgment overall, think about one's thinking, and improve that thinking process. These skills can be fostered with the strategies proposed in this project.

IBL is one of many teaching strategies that is designed to increase engagement. IBL has been shown in various studies to do just that (Nash et al., 2018; Sutiani et al., 2020; Wiseman et al., 2020). In addition to increasing engagement, IBL has also been shown to enhance various student skills such as generating discussion and visualization of ideas (Nash et al., 2018). Students also find themselves more engaged with IBL in science subjects due to being given the opportunity to design their own experiments (Wiseman et al., 2020).

Like IBL, PBL allows students to have some creative control over their learning experience (Evans, 2019). In addition to improving student engagement, PBL, like IBL, also enhances other skills such as generating questions, planning and carrying out an investigation, and analyzing data. Students also enjoy learning through PBL at least in part due to its authenticity (Evans, 2019).

The last two strategies are not independent of one another, nor are they separate from the previous two strategies discussed above. Group collaboration and discussion, and student choice can coincide with each of these two strategies (Evans, 2019; Wiseman et al., 2020). These strategies have also been shown to improve skills beyond content mastery as well, such as interpersonal skills (Fung, 2022).

Conclusion

Each teaching strategy mentioned in this chapter carries some common themes. First, each strategy is carefully moderated by the teacher. Additionally, all strategies share some component of providing choice or decision-making ability to the student, allowing students to have some control over their own learning. Each strategy mentioned also encourages students to use critical thinking skills in order to be successful.

Additionally, while IBL and PBL differ in some ways, each utilizes aspects of discussion, collaboration, and student choice. Moreover, all of these strategies enhance multiple student skills that will benefit students in the classroom and beyond.

Chapter Three: Project Description

Introduction

Student engagement is an issue that many teachers face. The consequences of poor student engagement affect school performance (Faris, 2008; Vaughn & Winner, 2000; Maltese et al., 2014; Maltese & Tai, 2010), but also stretch beyond the classroom. Students not engaged in science are less likely to pursue science in post-secondary school (Shapiro & Sax, 2011), and are also less likely to take on scientific problems in the real world (Sezen-Barrie et al., 2019). This could present real problems if we are to combat issues facing the world related to environmental health and sustainability, for example (UNESCO, 2014).

The focus of this project has been to identify solutions for this issue, so that teachers can increase student engagement through effective teaching strategies which have been shown to do so. Chapter Two discussed four different strategies which have been shown to improve student engagement: Project-Based Learning (PBL), Inquiry-Based Learning (IBL), allowing for student choice or autonomy, and discussion and collaboration.

Chapter Three will focus on the specific details of the project and how the strategies discussed in this paper will be implemented in the classroom to improve student engagement. The appendices will contain all materials required for a unit plan that has been designed using the four strategies mentioned above. In addition, assessment materials and rubrics will be provided, corresponding to the standards taught. Students will also take a survey to end the unit giving their thoughts on learning through the strategies used in the unit, which will be found in the appendices as well.

Project Components

Piaget's research in learning led to his development of the constructivist theory, which states that learning is more effective when meaning is attached, and that learning takes place when connecting old ideas to new ones (Westover et al., 2021). Constructivist learning practices have also been shown to yield positive outcomes in terms of student achievement (Ayaz & Sekerci, 2015). The verbage used in Next Generation Science Standards (NGSS) requires students to apply previous knowledge to real-world problems in order to show proficiency. Examples of this are "plan and conduct", "use a model", and "construct and revise" (National Research Council, 2012). Because of the nature of the indicators within NGSS, constructivist-based strategies provide excellent opportunities for students to demonstrate proficiency.

This project will include a unit for physical science in which students learn about reaction rates. The unit will consist of learning tasks, formative assessments, a summative assessment, and rubrics for self-assessment. These materials will be found in the appendices. The unit will be primarily based in Inquiry-Based Learning (IBL) and Project-Based Learning (PBL), with components involving student choice, and discussion and collaboration.

The rationale behind this project is that by improving student engagement, student achievement will also be improved. Achievement can be measured in a variety of ways. While student achievement has been shown to improve in terms of assessment scores, students should also improve various other skills beyond the primary goal that can be carried out into other areas of their lives as well. These include: questioning, critical thinking, speaking, and social skills (Tyas & Fitriani, 2021; Al-Krisha & Mansour, 2021: Alacapinar (2008).

Project Evaluation

The unit described in this project will take place over the course of two weeks. Students involved in the project will take a post-survey after the unit, in which they will be allowed to discuss their own feelings on the methods of learning in which they took part. The facilitating teacher will analyze student discussions about the project. The survey will measure student engagement based on how students respond to questions involving personal enjoyment, meaningfulness of the assignments, and whether or not they thought it benefited them, personally.

The teacher will facilitate all learning tasks. During inquiry-based and project-based activities, the teacher will provide guidelines that allow students to approach the assignment how they see fit. The teacher will record observations during this time on factors such as meaningful discussion related to the topic, formulation of questions, and ability to approach problems with prior knowledge and formulating a solution.

Project Conclusions

Student engagement is a prevalent issue in classrooms. This issue stems at least in part from the underlying issue of lack of student interest. Based on Piaget's theory of constructivism, lack of interest stems from unauthentic learning experiences, not allowing the learner to apply their knowledge to their own lives. Thus, by generating intrinsic motivation through pedagogy, students should be more likely to engage, and therefore succeed.

Inquiry-based learning (IBL) and project-based learning (PBL) are instructional strategies which meet the criteria of constructivist learning. Therefore, it is expected that learners who engage in IBL and PBL based activities should learn more, as well as improve other various skills as well.

Although a multitude of research has been conducted on student engagement, the problem still persists. Various factors should be considered when addressing student engagement. Socioeconomic status and race are two areas in which student engagement should be considered since these are underrepresented groups (Hemmler, 2022).

Plans for Implementation

This project will initially be shared with the administrators at Eau Claire High School in Eau Claire, MI. Upon completion of the project, data will be analyzed for interpretation. If successful, a further project could be proposed, involving training educators on the benefits of project-based and inquiry-based learning. Most likely this would, at least initially, be used to benefit the teachers and students within Eau Claire Public Schools. If continued success is seen, it could be used to guide professional development for schools, or teachers wishing to improve student engagement in their classrooms. This could be done locally, or on a widespread basis, at a conference for educators, for example.

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Appendix A

Unit Plan

Teacher	Levi Urias
School	Eau Claire High School
Class/Grades	Physical Science/10,11
Unit	Reaction Rates
Unit duration	2 weeks
NGSS	
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	
Essential Questions	
• How do chemical reactions follow the law of conservation of matter? • How are new molecules (products) formed in a chemical reaction? • What are the factors that affect the rate of reaction?	
Unit Description	
Before beginning this unit, students will have already learned about the conservation of matter (HS-PS1-7). This unit is meant primarily to teach reaction rates (HS-PS1-5) and assess student understanding. However, the unit builds on the previous one, and students must have an understanding of conservation of matter in order to be proficient in this unit. In the unit, students will do a series of inquiry-based, and project-based activities to answer the essential questions. The unit will begin with a pre-test and end with a summative assessment, which will be the same test.	
Learning Targets	

Students will be able to …

- define a chemical reaction
- cite a chemical reaction as evidence that matter is conserved
- correctly identify the reactants and products of a chemical using a written chemical reaction as a reference
- state variables that affect reaction rate
- remember the difference between atoms and molecules
- remember that molecules are held together by bonds that can be broken and reformed
- explain that reaction rate increases as a result of more particles colliding with one another which is due to increased concentration and/or added energy
- explain that a reaction has occurred by providing evidence from my observations
- explain that chemical reactions form new molecules by the breaking/making of bonds resulting from collisions of particles
- explain that since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.
- design an experiment that tests a question
- design and build a model that demonstrates the conservation of mass
- perform a chemical reaction and write the balanced chemical equation of that reaction
- use observations to correctly identify the reactants and products of a chemical during an experiment
- identify and describe evidence of a pattern that increases concentration, increase the reaction rate and vice versa
- identify and describe evidence of a pattern that increases in temperature usually increase the reaction rate and vice versa

Assessment

Formative

- Warm-ups/Bell questions
- Quizzes
- Inquiry lab
- Project
- Observations

Summative

- Unit Test

Resources
● Lab supplies (Reaction Rates Lab) ○ Beakers ○ Antacid tablets ○ Ice ● Assessments

Appendix B

Unit Supplemental Materials

Title of Lesson: Conservation of mass
Timeline: 2 class periods

Purpose

The purpose of this assessment is to gauge students' deeper understanding of the conservation of mass. Students will have already learned about this topic. In this lesson, they will be asked to design a model. The teacher will look for students to have a conceptual understanding of mass and matter, and how it is conserved within a chemical reaction. After the project, students will be given the opportunity to apply what they have learned to explain how conservation of mass can be shown with a real chemical reaction.

Standards

HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Learning Targets

- cite a chemical reaction as evidence that matter is conserved
- correctly identify the reactants and products of a chemical using a written chemical reaction as a reference
- design and build a model that demonstrates the conservation of mass

Accommodations

Accommodations will vary depending on learner need and mandated remediation plans.

Possible accommodations/modifications

- Extended time on assessment
- Assessment read aloud
- Option for oral completion of assessment instead of written
- Dictionary for ESL students
- For students with reduced workloads, the teacher will provide a modified lab with specific guidelines and probing questions to ensure that students are able to write the procedure. The teacher will also provide data tables for the lab for these students rather than requiring them to make their own.

Conservation of Mass: Building a Model

Directions

In this project, you will need to design a model that demonstrates the property of the conservation of mass. First you will be given a chemical equation, that you will have to balance. Then you will decide what materials you will use for your model. On your model, you should be able to identify the: products, reactants, particles involved in the reaction. You should also be able to explain how your model is demonstrating the conservation of mass.

Day 1

- balance a chemical equation
- determine what materials you will used to design a model
  - how will you represent the particles (what particles need to be represented)?
  - how will you show that mass has been conserved from reactants to products?

Day 2

- build your model
- explain your model and what it represents/how it demonstrates the conservation of mass
- Complete extension question if time allows

Chemical equation: balance the chemical equation. This chemical reaction will be the one that you model in your project.

$$FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$$

After you have balanced the equation, write out the reaction in words. In other words, what is meant by the equation above? What is reacting? What is being produced? Be specific and don't forget your coefficients!

____

____

Identify the reactants and the products from your reaction.

*Reactants:*____

*Products:*____

Materials

Start thinking about what materials you could use to model the reaction above. Remember that you need to include in your model the reactants, the products, and all the particles. You also need to think about how your model will demonstrate the conversion of reactants to products.

Make a list of materials that you will use, and discuss how you will use them to build a model of a chemical reaction while meeting the requirements listed on the rubric. Once the teacher has approved your project, you may begin building your model.

Molecular Collisions Model Rubrics

Rubric 1

Learning Target	5	3	1
cite a chemical reaction as evidence that matter is conserved	I have discussed how the model represents the chemical reaction and how it represents matter being conserved	I discussed the chemical equation, but did not discuss how matter was conserved	I did not reference the balanced equation as an explanation for my model

Rubric 2

Learning Target	5	3	1
correctly identify the reactants and products of a chemical using a written chemical reaction as a reference	I discussed on a particle level how the reactants are transformed into the products	I discussed reactants or products, but did not discuss how they are related	I made no reference to distinguish between reactant and product

Rubric 3

	5	3	1
design and build a model that demonstrates the conservation of mass	I am able to explain in detail how my model demonstrates particles undergoing a chemical reaction and how mass is conserved from the reactants to the products	My model might demonstrate a chemical reaction and the conservation of mas, but I am unable to explain it	I have no model, or my model does not demonstrate properly that mass in conserved in a chemical reaction

Extension

Now let's see if you can apply the principles you have learned to a real chemical reaction.

$$NaHCO_3(s) + CH_3COOH(aq) \rightarrow CO_2(g) + H_2O(l) + CH_3COONa(s)$$

The above equation is the reaction that takes place between vinegar (CH_3COOH) and baking soda ($NaHCO$). Can you think of a way that you could, in the lab, *prove* that mass is conserved in the above reaction? Hint – pay attention to the phases. They are important.

Briefly discuss what materials you would use, and how you would use them in order to see that mass is conserved in the reaction.

Title of Lesson: Molecular Collisions

Timeline: 3 class periods

Purpose

The purpose of this assessment is to gauge students' deeper understanding of chemical reaction and reaction rate concepts according to the learning targets while also assessing their ability to design an experiment, make relevant observations, and analyze results. The teacher will review assessment data and evaluate for misunderstanding/misconceptions for reteaching/review.

Standards

HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Learning Targets

Accommodations

Accommodations will vary depending on learner need and mandated remediation plans.

Possible accommodations/modifications

- Extended time on assessment
- Assessment read aloud
- Option for oral completion (of written portion) of assessment instead of written
- Dictionary for ESL students
- For students with reduced workloads, the teacher will provide a modified lab with specific guidelines and probing questions to ensure that students are able to write the procedure. The teacher will also provide data tables for the lab for these students rather than requiring them to make their own.

Molecular Collisions

Hook:

In order to introduce students to the idea of reaction rates and molecular collisions, the teacher will use an analogy. This will get students to think about a new idea, and provide them with a visualization of what molecular collisions are, and how they affect reaction rates. The analogy goes like this:

Teacher: I want you all to imagine that you are blindfolded. And I tell you to start walking around the room. What is going to happen?

Students: Answers will vary, but the gist will be that they will run into each other/things in the classroom.

Teacher: Exactly. Now imagine that I tell you to start running! What is going to happen then?

Students: Students will say that they will run into more things/other people more often

Teacher: Yes. Now imagine, you’re walking again, still blindfolded, but I bring in a whole other class and instruct them to do the same. Now what will happen?

Students: Students will say that more people will run into each other/into things in the room.

Inquiry:

The teacher will go on to explain that they will now be applying these principles that they have just discussed to molecules, and will introduce the reaction rates lab.

Reaction Rates Lab

Directions

For this assessment, you will be designing an experiment to test two investigation questions (listed in the **Purpose** section below). Be sure to read all directions and complete each section in order before moving on. Certain sections will require the teacher's initials before you are able to begin the next part. We will spend **2.5** class periods on this assessment.

Day 1: Read the background information, purpose, and review the procedure prompts. Complete your procedure, data tables, and list of materials. You will also discuss any potential safety hazards you may encounter based on your procedure and required materials.

Day 2: If your Day 1 tasks have been approved by the teacher, move on to the investigation portion of the lab. For Day 2, you will follow your detailed procedure and complete your data table. Answer the follow up questions when you are done.

Day 3: You will use your warm-up time on the third day to complete any post-lab questions that have not yet been answered. Once your lab is complete, we will discuss some of the results as a class.

Background

Alka Seltzer is an over-the-counter drug used to treat acid reflux and indigestion. The effectiveness of the drug depends on the conditions in which the drug is used. This is the reason drugs come with a label describing the recommended usage.

Purpose

Your goal is to design an experiment to answer the following investigation questions using Alka-Seltzer as a model.

1. How does temperature affect the reaction rate of Alka-Seltzer?
2. How does concentration affect the reaction rate of Alka-Seltzer?

You should perform 3 tests for each variable.

Procedure

Look at the package the Alka-Seltzer came in. List the active ingredients and the instructions for recommended use.

Active ingredients:

Recommended use:

Below is the chemical reaction for Alka-Seltzer:

$$NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + CO_2 + H_2O$$

1. Balance the equation above. (See *Rubric 1*)
2. Based on the equation, what evidence will you use to determine if a chemical reaction has occurred? That the reaction has run to completion?

Using the information above, begin writing your procedure to answer your investigation questions. Be sure that your investigation answers the following questions:

- How will you test three variables for temperature/concentration? How will this be set up in the lab?
- How will you know when each test is complete?
- What data will you need to collect to answer your investigation questions?
- What materials or lab equipment will you need to complete each test?
- What safety issues might you encounter and how will you be sure to be safe in the lab?

Your procedure must be initialed by the teacher before you begin your investigation in the lab.

Write your procedure in clear, descriptive steps below. Number each step so that they can be easily followed. Make sure to also include your materials list.

Materials

-
-
-
-
-

Safety

Temperature Test Procedure (See *Rubric 2)*

Teacher initials _____

Concentration Test Procedure (See *Rubric 2)*

Teacher initials _____

Data

Create your data tables in the sections below to record all observations. This section must also be initialed by the teacher before you can move on to your investigation.

Temperature Test Data

Concentration Test Data

Teacher initials _____

Post Lab Questions (See *Rubric 3*)

1. Do you see a *trend* in your data? In other words, was there a correlation between increased concentration, or temperature and the amount of time it took for the Alka Seltzer to fully react? Describe each variable below using your results as evidence.

   ____
   ____
   ____
   ____
   ____

2. If you were to take Alka Seltzer in the future, and needed it to work very quickly (you're in a lot of pain), what would you do to make that happen? Explain using your data as evidence.

   ____
   ____
   ____
   ____
   ____

Reaction Rate Lab Rubrics

Rubric 1

Learning Target	**5**	**3**	**1**
perform a chemical reaction and write the balanced chemical equation of that reaction	I have fully balanced the equation and have shown that mass is conserved from the beginning of the reaction to the end.	I have partially balanced the equation. Some atoms are balanced between the products and reactants	I did not balance the equation

Rubric 2

Learning Target	**5**	**3**	**1**
design an experiment that tests a question	My experiment is designed to answer my investigation questions. It is clearly written in steps, mentions specific steps that must be taken, and could be followed and repeated if I or someone else were to attempt to repeat my experiment.	My experiment is designed to answer my investigation questions, but is unclear in steps or details such as lab procedures or materials are not mentioned.	My experiment is designed to answer my investigation questions

Rubric 3

	5	**3**	**1**
identify and describe evidence of a pattern that increases concentration/temperature, increase the reaction rate and vice versa	I have discussed my results and have used evidence and reasoning to discuss how my results are related to collision theory and how it affects the reaction rate.	I have discussed my results but did not use evidence and reasoning to discuss how my results are related to collision theory or reaction rate	I have not discussed my results

Extended Written Response Assessment

Teacher: Levi Urias
Class: High School Physical Science
Topic: Reaction Rates

Purpose

The purpose of this assessment is to gauge students' deeper understanding of chemical reaction and reaction rate concepts according to the learning targets. Students will use reasoning based on evidence and observations to explain these concepts. The learner should include the following basic concepts in their responses:

- Heat is a form of energy
- The energy from heat is transferred to the particles involved in the chemical reaction (kinetic energy)
- More particle motion means collisions will happen at a faster rate
- Higher levels of energy among the particles means there is a higher amount of energy available to overcome the energy of chemical bonds
- Chemical reactions require that new substances are formed which occurs by the making and breaking of chemical bonds (which are held together by energy between atoms)

The teacher will evaluate student responses to look for misconceptions or misunderstandings about chemical reactions. Outcomes may include reteaching and reassessing if necessary.

Standards

HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Learning Targets

- Explain that chemical reactions form new molecules by the breaking/making of bonds resulting from collisions of particles
- Explain that since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.

Accommodations

Accommodations will vary depending on learner need and mandated remediation plans.

Possible accommodations/modifications

- Extended time on assessment

- Assessment read aloud
- Option for oral completion of assessment instead of written
- Dictionary for ESL students

Written Response - Chemical Reactions

Respond to the following questions in paragraph form. Be as detailed as possible in your response. Pay attention to the rubric to make sure you are on the right track in your responses.

1. We have seen several examples of chemical reactions. For example, we saw a demonstration in which lead nitrate was combined to form a bright yellow solution. Explain on a molecular level why the solution turned from colorless to yellow. Be sure to include in your response the molecular difference between the *reactants* and *products*, and *how* this change occurred (what is the role of chemical bonds in this phenomenon?).

2. When you cook food, you are performing a chemical reaction. You might even experience some aromas during this process. Explain what is happening on a molecular level to the food while you cook. Include in your response what these aromas indicate as well as *how* this happens in terms of the reaction.

Written Response Rubric

Question #1

Target	5	3	1
Explain that chemical reactions form new molecules by the breaking/making of bonds resulting from collisions of particles	I have explained how chemical reactions involve the making/breaking of bonds to form new products and provided specific details about how the example shows this phenomenon	I have explained that reactions involve the making and breaking of bonds, but did not relate my explanation to the example given	I have not explained clearly how chemical reactions occur by making and breaking bonds to form new molecules

Question #2

Target	5	3	1
Explain that since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.	I have explained that changes in temperature have an effect on the number of collisions that occur in a reaction over time and have discussed how this is related to the provided example in the prompt.	I have explained that changes in temperature have an effect on the number of collisions that occur in a reaction over time.	I have not explained how temperature affects the number of collisions that occur in a chemical reaction

Appendix C

Project Evaluation

Project Evaluation Form

Please rate the following areas based on your own personal experience with the *Reaction Rates Unit* that was just finished in your physical science class. Rate on a 1-4 scale, with 1 being strongly disagree, and 5 being strongly agree. Please include any comments you feel would be helpful. This survey will be anonymous. Please do not write your name on this paper.

	(1) I strongly disagree with this statement - (3) I have no feelings on this - (5) I strongly agree with this statement
I found this unit interesting *Additional Comments:*	1 2 3 4 5
I feel like I could use the skills learned in this unit in other classes. *Additional Comments:*	1 2 3 4 5
I feel like I could use the skills learned in this unit in areas outside of school. *Additional Comments:*	1 2 3 4 5
I feel like I could continue to use the skills learned in this unit in the future. *Additional Comments:*	1 2 3 4 5

	(1) I strongly disagree with this statement - (3) I have no feelings on this - (5) I strongly agree with this statement
I appreciated the overall way the unit was presented throughout the two week period. *Additional Comments:*	1 2 3 4 5
The unit made me think critically. *Additional Comments:*	1 2 3 4 5
The unit was challenging. *Additional Comments:*	1 2 3 4 5

Are there any other comments or thoughts you would like to add to this survey? Please list or describe any in the space below: