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Effectiveness of project-based learning in a junior high science classroom

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ABSTRACT

Project-based learning (PjBL) is an instructional approach that promotes active participation and helps students develop their skills and knowledge through engaging in real-world problems or situations. The success of PjBL is dependent on a well-defined method or plan, such as the 21st-century project learning bicycle model or the engineering design model, both of which emphasize the importance of teacher-student relationships. PjBL can be used in any class size and has shown to be effective in building 21st-century skills and deepening students' understanding of the learning content through real-world experiences. PjBL can be successfully integrated into STEM subjects, and research has shown positive changes in student perceptions, self-efficacy, critical thinking, experimentation, collaboration, and problem-solving skills. Case studies and research have demonstrated PjBL's effectiveness, including the successful implementation of an 8th-grade integrated science photosynthesis unit in a suburban charter school. Overall, PjBL provides an effective teaching approach that prepares students for success in the 21st-century through hands-on learning experiences.

Keywords: project-based learning, 21st-century skills, STEM, applied learning, hands-on approach, higher-level thinking

INTRODUCTION: LITERATURE REVIEW

Introduction

Lecture-based learning has been one of the longest-used teaching methods, but this specific teaching style does not allow for much, if any, differentiation (Ismail, 2021; Merritt, 2017). Within the last decade, there has been a shift in instructional strategies to allow for all types of student learning, one of the prominent approaches being project-based learning (PjBL) (Merritt, 2017). PjBL is an important teaching method because it allows for several different learning styles, including cognitive, visual, kinesthetic, aural, and verbal (Markula & Aksela, 2022).

A common goal shared among educators is to have active engagement within each lesson, which means each lesson must be interesting to the students (Carrabba & Farmer, 2018). By using PjBL, teachers are implementing high quality instruction that relates to real world issues and situations, in turn allows for student choice and application. This promotes academic achievement and growth within abilities, interest, and motivation (Carrabba & Farmer, 2018). PjBL has also been found to positively affect academic performance, especially within the science field (Balemen & Keskin, 2018; Basche et al., 2016; Schneider et al., 2022; Viro et al., 2020). PjBL in STEM improves creative thinking skills and strategies that then promote high level-thinking (Poonsin & Jansoon, 2021).

The purpose of this literature review is to identify, using research, best practices involved in preparing and delivering effective PjBL assessments. Several studies address student success, motivation, and importance of PjBL. This review will first describe what PjBL is, then the benefits of implementing PjBL in the classroom and how integration is achieved. Finally, this project will focus on the effectiveness of integrating PjBL in a junior high science classroom.

Literature Search Method

Research was done through the databases of Utah Valley University's Fulton Library. Terms such as PjBL, PBL, PBL in science classrooms, PBL in middle schools, and PBL integration were searched. Academic journals, books, and peer reviewed articles were set as parameters. While finding these articles I was also able to find several additional articles through their references. In total 36 articles were reviewed and 26 were included in this review.

What is project-based learning?

PjBL is an instructional approach that is designed to give students opportunities to grow their knowledge and skills throughout engaging projects that are centered on real world situations and/or problems (Pusztai Kovácsné, 2021; Schuetz, 2018). PjBL is used to promote active participation while learning and building on 21st-century skills, including but not limited to, critical thinking, collaboration, and creativity (Arwatchananuku, et al., 2022; Ismail et al., 2021; Pusztai Kovácsné, 2021; Trilling & Fadel, 2009; Viro et al., 2020). When PjBL is presented well it can be energizing and motivating for the audience (Lattimer & Riordan, 2011). Projects vary by teacher and the needs of the students, but to create a beneficial project the teacher must know what the students are interested in and then design accordingly to promote engagement and meaningful learning (Lattimer & Riordan, 2011).

Benefits of project-based learning implementation in the classroom

21st-century skills are used and defined as a design model for lifelong learning (Arwatchananuku, et al., 2022; Ismail et al., 2021; Trilling & Fadel, 2009). There are several ways to implement lifelong learning strategies and PjBL happens to be one (Arwatchananuku, et al., 2022; Ismail et al., 2021). PjBL allows implementation for several different learning styles including, but not limited to cognitive, visual, inaesthetic, social, and verbal (Indrawan, 2019). An overall benefit of PjBL is allowing students to learn and use 21st-century skills that prepare them for real world scenarios and problems (Capraro, 2013; Pusztai Kovácsné, 2021). This teaching method can enhance student motivation, improve academic success, and deepen the understanding of the assigned topic (Carrabba & Farmer, 2018; Indrawan et al., 2019; Markula & Aksela, 2022; Pusztai Kovácsné, 2021). PjBL allows for deeper thinking, understanding, and awareness of real-world situations (Knezek & Christensen, 2020). Capraro (2013) lists several benefits towards STEM PjBL, which include higher order thinking, furthering the ability to break down complex problems and find solutions, making connections, developing stronger interests in core subjects (math, science, and technology), and promoting ownership through development and solutions. These benefits are supported by Reid-Griffin et al. (2020) who found that PjBL allows for engagement in real-world challenges and collaborative learning. Their research has shown that students will learn from peers (and themselves) that are contributing ideas and collaborating.

Six key outcomes of project-based learning

There are six key outcomes of PjBL: academic rigor, authenticity, applied learning, active exploration, adult connections, and assessment practices (Lattimer & Riordan, 2011). Academic rigor allows for learning the concepts and standards. In their research, Lattimer and Riordan (2011) explained that a US history class had centered a project around recurring themes in immigration debates; they did this by asking questions, researching, and collecting information and data from research and then interviewing first generation Americans. After the project was completed, they joined as a class an insightful and meaningful discussion that displayed academic rigor. The second outcome, authenticity, was shown through a carpentry project. Students had learned of an Israeli game, like dodgeball, called Gaga and the teacher allowed the students to brainstorm, design, and build a Gaga pit for the school. This allowed the students to practice math concepts like measuring, angles, volume, and area. The students were able to design and create an authentic real-world project. Applied learning, the third outcome, examines the use of teamwork, communication, and problem solving. A humanities teacher challenged his class to create an original film. Previously, they had worked in small groups to create short films but had not worked as a whole class on a single long film. The teacher had explained that to be successful the students must communicate with one another respectfully and effectively. In turn the students must provide feedback and share the responsibility for this film. Through this process there had been miscommunication between students in their groups, but with the teacher's guidance the issues were solved, and the film was completed; students were enthralled with their work. The fourth outcome, active exploration, is meant to connect students with field-based investigation within their communities. A middle school science teacher created a project that had his students out of the classroom and learning about local watersheds. The purpose of this project was to learn about water conservation and pollution; the students created a topographical map of their local watersheds and presented this research to the community. The fifth outcome, adult connection, was achieved in a humanities class project. This teacher's goal was to introduce entrepreneurship; the students were to work closely with an adult mentor who is an expert in their chosen topic, develop an action proposal, and act upon that proposal. One student put on a 5K run in efforts to raise money for breast cancer research. The result in these projects increased confidence, and ability to create positive changes within their community. Finally, the last outcome, assessment practices, are supposed to involve students showcasing their projects as an assessment of their work. Two teachers collaborated on this project and the end goal was for students to create a magazine on green technologies. This project demanded research, design, awareness, and attention to detail. Throughout the project the teachers provided thoughtful feedback and assessment. When the project was completed, the students shared their projects with friends, family, and the community during an exhibition night.

Preparation for teaching with project-based learning

To make a PjBL work successfully and work for your students, teachers must have a method and plan in place. Specifically, within the science classroom this includes dissecting a phenomenon, building, and testing models that help address said phenomenon, analyzing patterns, researching, and singling out connections in data, and being able to see relationships within information and data (Schneider et al., 2022). Balemen and Keskin (2018) found that PjBL is most effective in small class sizes, but it is still effective in medium to large class sizes as well. They found that PjBL is effective due to successful academic performance. PjBL shows to be highly effective both on its own and with other teaching strategies (Balemen & Keskin, 2018).

The 21st-century project learning bicycle: Trilling and Fadel (2009) have adapted "the 21st-century project learning bicycle". This bicycle has four main components that are placed in the wheel of the bicycle: define, plan, do, and review (**Figure 1**). The first step is to define the assigned project. Defining the project means to look at what the topic is, what question, problem, issue, or challenge is being looked at …

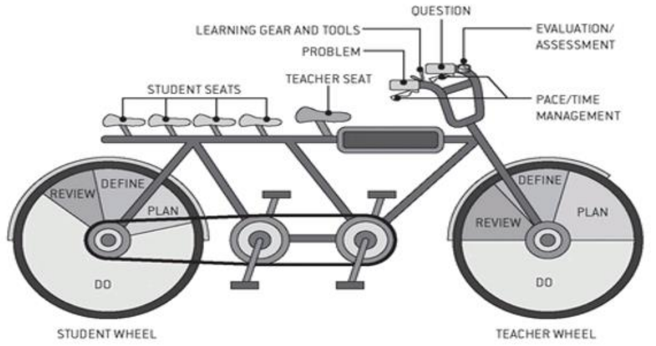


Figure 1. Trilling bicycle model (Trilling & Fadel, 2009)

whichever one it is, it must be stated clearly and concisely. Planning is second. To efficiently plan, the teacher will need to provide all the necessary materials and resources for the assigned project. Basically, anything that is necessary for the student's success should be out and made available for the students.

For a teacher to be an effective learning coach during a project (and not just a lecturer), learning activities must be designed so that the students own much of the learning and teaching. Students planning their work, doing research, sharing findings with other team members, asking questions, designing procedures, taking on leadership and group facilitation roles, analyzing their own results, getting feedback from others, and so on are all important parts of a good project design that builds 21st-century skills and deepens understanding of the learning content (Trilling & Fadel, 2009).

After planning comes doing and reviewing. Students of course must create and finish their project. After finishing the project, the results and lessons learned are presented and reviewed. Often, the finished product is presented to the class, displayed in an exhibition, or featured in a learning fair to receive feedback and evaluations.

Now, looking at the bike full circle in **Figure 1** (& **Figure A1** in **Appendix A**) we can see the criteria that a successful project needs. After the wheels, we need a frame to hold them together. This 'frame' will include the students' roles, teacher's role, the problem, question, the learning gear and tools, pace, time management, and finally, evaluations and assessments.

Engineering design model: While this concept was created by Trilling and Fadel (2009), the steps are widely accepted by other researchers including Capraro et al. (2013) and Reid-Griffin et al. (2020) who agree that it is important to have a teacher-student relationship to allow for support within the project.

Capraro et al. (2013) has a similar yet different approach when it comes to STEM based projects. They use the engineering design process, which is a widely known project strategy in the STEM community. The process includes seven steps:

1. identify problem and constraints,
2. design,
3. research,
4. ideate,
5. analyze ideas,
6. build, test and refine, and
7. communicate and reflect.

To identify a problem and its constraints on a specific topic, the process will need critical questions asked. Including what problem needs to be solved? What do we want to design? Who or what is this for? What are our goals? What requirements or stipulations are there? While thinking and answering these questions that will be researched. Research can include reading and analyzing articles on the chosen topic, talking to credible people who can provide beneficial answers and information, or using in-school resources, such as the library or teachers. The next steps are to ideate then analyze those ideas. Brainstorming is a very important step to ideation and doing this freely, without being criticized, will allow further interest and creative ideas. After brainstorming, it is time to refine and develop the ideas. This can include going back to step one and reanalyze any needs or constraints, and then further research the solution and/or answers. When finished with those two steps students begin building the project. The teacher, you must have all materials and supplies students may need made available. The goal of this step is to be creative and use what has been researched to one's advantage. The building process can be anything from a group presentation, slide presentation, short video, prototype, model, etc. After finishing the build, it is time to test and refine. Normally one would only think of a model or prototype to test and refine, but this can be done within various mediums. If students made a slide presentation, criteria might include ensuring that everything in the presentation relevant? Is there something that should be taken out or added? If there was a short video made, is there editing needed? Is it coherent to the audience? As for a prototype and model, is it working the way it was envisioned to work? Is it solving the problem? The final step is to communicate and reflect. Any type of project, especially one focused on engineering design needs to be effectively communicated. In a classroom this can be done through presenting it to the class and teacher, it could even be presented in an academic fair, or any other opportunity that might arise. These types of options allow for reflection, feedback, and revisions to continue deeper learning.

How is integration achieved?

To have a successful PjBL outcome there should be a driving question or problem, the project should be based on a common theme or topic and relate to real world scenarios (Haatainen & Aksela, 2021). Below are efforts in tracking progress while using PjBL and examples of how some teachers have implemented PjBL.

Reid-Griffin et al. (2020) surveyed their students on self-efficacy during a two-year period. The first year was a lack of PjBL instruction, and the second-year data had PjBL integrated. There were three areas they looked at self-assertiveness, academic achievement, and self-regulated learning. Questions asked within the self-assertiveness category were "I express my opinions when other classmates disagree with me", "I stand up for myself when I feel I am being treated unfairly", I get others to stop annoying me or hurting my feelings" and "I stand firm to someone". Within academic achievement, the questions asked were in relation to success in specific classes like math, science, language arts, computers, foreign language, and social studies. Lastly, some of the questions related to self-regulated learning were "I finish my assignments", "I get myself to study when there are many other interesting things to do", "I take good notes", "I organize my schoolwork", and "I remember information". The results of their study showed that more research on PjBL should be done, because there were positive changes in student perceptions of themselves and school with PjBL integrated.

DeWaters and Powers (2011) worked with 13 physical science teachers and 6 technology teachers and their students; two out of the 19 teachers had already been using PjBL extensively in their curriculum. Looking at those two teachers the unit the students were on was energy. Teacher A had students play a board game on energy they use at the start of the unit and then worked on energy conversions and sources. The end of unit project was to reflect and track their own home energy usage and to create an audit either on a poster, display, or model. Teacher A's students were found to have a 12-13% increase on home energy use and 9% increase on basic energy concepts on post-unit test results. Teacher B had their students engage in categorizing pictures of circuits, batteries, and bulbs, track their waste and recycling activity, discuss pros and cons of wind power, all to finally build up to the end project of a debate. Students were given energy dilemmas and needed to provide two facts that support and oppose the situations given. Teacher B student's post-unit test mean scores were higher in every section of the unit. Both teachers' students demonstrated an increase in post-unit test results and interest in the topic. DeWaters and Powers (2011) noted that 40% of teacher A student's and 63% of teacher B students have adopted energy saving habits and increased awareness of their consumptions. This shows that PjBL aids in developing a deeper understanding and respect of the topic.

Schneider et al. (2022) connected with a team of teachers that were teaching specific chemistry and physics units for 4-6 weeks. The units had PjBL integrated within them, which required a driving question that was applicable to students lives, then having the students create a model and connect it with evidence-based claims of the issue. The modeling part of PjBL is essential for success in the unit. After the students created their model, the teachers then graded them with a specific rubric to assess their knowledge and growth. At the end of Schneider et al. (2022) study they found that PjBL is an effective way to improve students understanding and interest in STEM.

Zhao and Wang (2022) collected data through classroom observations. Before collecting data, they coded objectives to track students' competencies. Codes included understanding of core ideas, problem solving, use of scientific practices, collaboration, motivation to learn, creativity, environmental awareness, and perseverance. The unit specific to their research was on soil. The leading question of the project was the effect of nitrogen fertilizer on plant growth. The students were to then pot plants and "explore the relationship between soil acidity, alkalinity, soil fertility, and plant growth" then write an experimental report and present to the class. Their results showed that there was an increase in motivation to learn, success in collaboration and use of scientific practices, and ability to understand core concepts and problem solve.

Mutakinati et al. (2018) conducted descriptive research on 160 middle school students. These students were learning about wastewater. They were given foreknowledge on this topic and then were asked to design a product for wastewater treatment. This unit consisted of six lessons. Lesson one, went over what wastewater is and what's in it; lessons two through four were on solutions and product development. The fifth lesson was a video on wastewater treatment and the last lesson was presenting the students projects and conducting a class discussion. Mutakinati et al. (2018) collected data through observation and worksheets; they analyzed the data by using Paul and Elder's critical thinking rubric. Their analyses showed evidence of critical thinking and experimentation. For example, some students decided they could simply just boil water to purify it but later realized this uses an exorbitant amount of energy and there are simpler ways. Mutakinati et al. (2018) concluded that 41.6% of their sample were in the advanced thinker stage, 30.6% were in the practicing (average) thinker stage, 25% were in the beginning thinker stage, and 2.8% were in the challenged thinker stage. This shows that PjBL benefits critical thinking skills.

Discussion

PjBL is an efficient teaching strategy that has been progressing and becoming more common but has not reached all targeted audiences. It is possible and prominent that PjBL can change the scientific learning environment in a positive way by increasing academic achievement (Schneider et al., 2022). PjBL requires authentic questions to encourage participation and interest from the students (Carrabba & Farmer, 2018). There is a need for PjBL to occur in classrooms due to addressing societal issues, social development, and development of pivotal skills (Lopera et al., 2022).

Limitations

PjBL has shown to increase student achievement but has yet to be used in most schools across the nation (Dunbar & Yadav, 2022). A limitation noted by several researchers was that there is a lack of teacher training on PjBL (Carrabba & Farmer, 2018; Schneider et al., 2022). With this limitation it is necessary to allow time for teachers to become comfortable with using PjBL before using their class(es) in a study. Further limitations include a small-time frame and small sample size, which can hinder results as they are not providing rigorous qualitative data (Carrabba & Farmer, 2018; Johnson & Cuevas, 2016; Reid-Griffin et al., 2020; Viro et al., 2020; Zhao & Wang, 2022). Schneider et al. (2022) recognizes that conducting research on the effectiveness of PjBL is most beneficial when having a large-scale sample size, but that can also be quite costly. The researchers do believe that this strategy in teaching is well worth the effort and cost due to the positive academic and personal outcomes in students.

Johnson and Cuevas (2016) addressed the issue of students lacking the foundation of taking notes, research, and finding reliable information. They suggest building that framework first before diving into PjBL. Viro et al. (2020) mentions that students must also be able to work together as a team to effectively collaborate during a PjBL. Students that might need scaffolding should receive instruction and guidance from the teacher as PjBL is being used (Carrabba & Farmer, 2018; Haatainen & Aksela 2021).

Limitations to my own research can include articles being limited to the Fulton Library database. There may have been articles not included that could have been of some value.

Future Research

PjBL curriculum and resources created for teachers is a necessity for the future (Reid-Griffin et al., 2020; Schneider et al., 2022; Viro et al., 2020), To promote and support this claim there should be further research done on PjBL (Johnson & Cuevas, 2016; Reid-Griffin et al., 2020). Ideas for future research have included using a control group that uses PjBL practices implicitly and specifically; to see if there is correlation or differences between success and academic growth (Reid-Griffin et al., 2020).

Johnson and Cuevas (2016) suggest researching the suitability of different types of inquiry to allow for student success; they note that research should assess student motivation and perception, but also PjBL effect on academic measures. Carrabba and Farmer (2018) add to this idea by suggesting future qualitative research focusing on the students' perceptions on PjBL versus direct instruction.

Dunbar and Yadav (2022) propose that further research should focus on what teachers struggle with implementing in PjBL and how teachers can support students throughout the process. This future research can discover what teachers might be hesitant on while practicing PjBL and how to work around those setbacks (Dunbar & Yadav, 2022; Haatainen & Aksela 2021).

Conclusions

After exhaustive research there has been a plethora of support towards PjBL. This teaching method is promising and effective in many aspects for student's academic and personal success. PjBL is a teaching method that allows for growth in many 21st-century skills and that is why it there is push for it to be utilized in the classroom. PjBL must have a driving question that follows the theme of what is being taught and relate to real world scenarios, to be effective. As further research is conducted and teachers learn how to better implement PjBL, the more engaged learning and deeper understanding there will be.

EVIDENCE OF APPLICATION: LESSON DESIGN

This 8th grade integrated science photosynthesis unit was built upon the idea of using PjBL. I taught the unit to my two science classes; B2 has 13 students and B3 has 14 students, in total 27 students. The ratio of girls to boys is 10:17 respectively. There are two students with a 504, four students with an IEP, and one student this is an ELL. This school is a suburban K-9 charter school in Utah County, Utah.

This unit will include three 90-minute lesson plans (**Appendix B**). This project will span over seven weeks due to the plant growth timeline; meaning I will be providing a start-of-project lesson plan (growing plants part 1), during project lesson plan (growing plants part 2), and end-of-project lesson plan (growing plants part 3). This project will align with the 8.3.1 Utah SEEd standard, which was derived from the life science and physical science categories within the next generation science standards (NGSS). This standard asks the students to "plan and investigate and use the evidence to construct an explanation of how photosynthetic organisms use energy to transform matter. Emphasize molecular and energy transformations during photosynthesis". A PjBL approach was used to develop investigation, analysis, and explanatory skills as well as using knowledge learned throughout the unit in a real-world application.

Narrative Description of Lessons

Lesson plan 1 provided the foundation of this unit. Students were able to learn key concepts and vocabulary through a slides presentation and think about how plants grow and where they get their mass. After molding the foundation of the unit, we moved on to investigate how photosynthetic organisms use energy to transform matter through the "growing plants" project. Lesson plan 2 took place after the seven points of data (sixteen classes) were taken and focused on starting part 3 and part 4 of the packet. At this point the students have been monitoring their plants as they grow and adjusting their methods to what they predict to be most beneficial for the growth timeline. Students have deepened their knowledge on photosynthesis throughout the seven classes, through other activities as described in lesson plan two and because of this project. The daily exit tickets provided information on what each student learned that day and tracked their motivation levels. Lesson plan 3 focused on presentation day (part 4), which brings together their reflection questions in part 3, the pre-test questions, and explaining how photosynthetic organisms use energy to transform matter. Students were able to adequately create their presentations based on the information gathered from the unit's project, discussions, handouts, and activities.

Analysis of Connections to Research

PjBL uses high quality instruction that relates to real world situations all the while they must be interesting to students (Carrabba & Farmer, 2018). If PjBL is successful this will promote academic achievement and promote higher-level thinking and critical thinking (Balemen & Keskin, 2018; Basche et al., 2016; Carrabba & Farmer, 2018; Schneider et al., 2022; Balemen & Keskin, 2018; Poonsin & Jansoon, 2021; Viro et al., 2020).

This PjBL was able to apply the method of Trilling and Fadel (2009) "the 21st-century project learning bicycle", as well as a nod to the engineering design model (EDM) as described by Capraro et al. (2013). The steps of project learning bicycle are define, plan, do, and review. As for EDM the steps are identify the problem and constraints, research, ideate, analyze ideas, build, test, and refine, and communicate, and reflect.

The first two steps required teacher planning and preparation. First, the project must be defined, with either a question, problem, issue, or challenge. In this case the project was defined as a question, "How do photosynthetic organisms use energy to transform matter?" This can also be applied to the "identify problem and constraints" step in EDM suggested by Capraro et al. (2013). Before we got into the whole project, I gave my students background knowledge and vocabulary. As laid out in lesson plan 1, students first completed a pre-test (**Figure A1** in **Appendix A**) covering what their learning goals will be. Following the pre-test students were introduced to where plants get their mass and how they grow. The students watched a time lapse of a bean plant grow from seed and were able to make energy and mass connections; subjects we have learned about in the previous units. The objective of this was to understand that plants need (light) energy to grow and as a plant grows it also grows in mass. I wanted the students to question, where that mass came from, as we already know, from a previous unit, mass cannot be created nor destroyed. Then the students were given key vocabulary terms and concepts through a slide presentation. Following that activity, we watched a video on photosynthesis and students were to fill out a guiding questions worksheet (**Figure A2** in **Appendix A**). Finally, students were able to grasp the basic concept of the process of photosynthesis.

Second, required planning following project learning bicycle. To prepare for this project I made a "growing plants project" packet for each student (**Figure A3** in **Appendix A**) that allowed them to keep all their work and data together. I created the "8.3.1 unit pre-test" (**Figure A1** in **Appendix A**), "8.3 slides" (**Figure A4-A7** in **Appendix A**) and "8.3 slide notes" (**Figure A4-A7** in **Appendix A**). I also had to purchase materials, such as seeds, a variety of plant pots, and soil. Every class period I had a large pitcher of water available for students to water their plants.

Following planning, came doing, regarding project learning bicycle, and then build, test, and refine in EDM. During lesson plan 1, I had my students fill out part 1 of their "growing plants" packet which, consisted of five questions. Throughout the seven weeks students filled out a data chart every day that we had class; this was included in their packet. Every class period I also gave my students five minutes to water their plants and record their data.

The last step of Trilling and Fadel's (2009) method is to review; "meaning the project results and lessons learned are presented and reviewed". As well as EDM step, communicate and reflect. In lesson plan 2, I explain that at the end of the project timeframe students will wrap up. In this case, my students finished part 3 of the packet and started on part 4. Part 3 has six reflection questions that asked about what materials were used, how many days were tracked, what was changed throughout the project, what photosynthesis is, how photosynthesis plays a role in the growth of plants, and what they would do differently.

Conclusions

In conclusion, this 8th grade integrated science photosynthesis unit was designed using PjBL, which following my research should prove to be successful in promoting academic achievement and developing higher-level thinking and critical thinking skills. The unit included three 90-minute lesson plans, which spanned over seven weeks, aligning with the 8.3.1 Utah SEEd standard, derived from NGSS. Through PjBL approach, investigation, analysis, and explanatory skills were developed in a real-world application, culminating in presentation day, where students were able to reflect on their learning and understanding of the process of photosynthesis. The project applied the method of Trilling and Fadel's (2009) "the 21st-century project learning bicycle" and a nod to EDM described by Capraro et al. (2013), resulting in a well-structured and comprehensive learning experience for the students. Overall, PjBL approach allowed the students to deepen their knowledge on photosynthesis and apply it in a real-world context.

ASSESSMENT FOR LEARNING

Formative Assessment Tool

This integrated science unit was designed to evaluate student understanding and application of Utah SEEd standard 8.3.1 plan and investigate and use the evidence to construct an explanation of how photosynthetic organisms use energy to transform matter. This project also included two different NGSS being: LS1.C: Organization for matter and energy flow in organisms–Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. As well as PS3.D: Energy in chemical processes and everyday life–The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

Students were given a "growing plants packet" (**Figure A3** in **Appendix A**) that they had to keep and maintain for almost a two-month period. This packet had four parts, each worth 25 points. Part one consisted of preliminary questions and plant set-up. Part two was the section students tracked their plant growth data. Part three allowed the students to write their final reflection and write-up of their project. Lastly, part four required students to create their individual presentation on what they learned during and because of this project.

Students used the knowledge they gained from several previous lessons. Before I gave any of the student's assignments I had them take a pre-test over the upcoming unit. Class B2 had an average of 56% and B3 had an average of 57%. I introduced this standard through the 8.3 slides (**Figure A4-A7** in **Appendix A**) and gave students the 8.3 slide notes packet (**Figure A4-A7** in **Appendix A**), so they had resources to go back to throughout the unit. This allowed the students to understand vocabulary and basic concepts.

For this project students were given three options for their plant pot: one being a plastic solo cup, a decomposable mini pot, and a plastic-colored mini pot. The students were also given three different seed options: a sweet pea, a tickle me plant, and snap peas. All students used the same type of soil but were given the option to use soil or just water; one student chose just water. During the growing process students were encouraged to change their plant decisions (i.e., water amount, pot placement, soil to water ratio) if necessary. For at least ten class days students were to track their data in part 2

Part 4: Presentation

The last part of this project will be creating a presentation. If you and someone else did the same exact methods throughout the project you may work together, if there is anything that differs you may not. Below is the rubric to follow if you want full points.

Description	Excellent (5 pts)	Almost (3-4 points)	Needs Work (1-2 points)	Nothing included (0 points)
Presentation is 5-7 minutes long	5-7 minutes long	3-4 minutes long	1-2 minutes long	Less than 1-minute long
Presentation addresses all reflection questions from part 3	All 5 points were addressed	3-4 points were addressed	1-2 points were addressed	No points were addressed
At least one photos of your plant throughout the growing process.	1 photo included			No photos included
Presentation reflects back to the 8.3.1 pre-test questions and answers them all accurately.	All 16 questions were addressed.	7-15 questions were addressed.	1-5 questions were addressed.	No questions were addressed.
The final slide addresses how photosynthetic organisms use energy to transform matter.	The slide is present and is an accurate explanation.			The slide is not present or is inaccurate.

Figure 1. Part 4–Presentation (Source: Author's own elaboration)

of the packet. This included writing the date, soil condition, if water was added and how much water was added, the weather, the height of the plant (if any), and a sketch of the plant.

After the almost two month growing period (started January 4th-February 21st, 2023) students were to create a presentation about their results. This presentation required a 5-7-minute time frame that addressed all reflection questions from part 3, reflects to the 8.3.1 pre-test questions and answers them all accurately and addresses how photosynthetic organisms use energy to transform matter. See **Figure A8**-**Figure A17** in **Appendix A** for more detail.

Evaluation Criteria

In educational research, pre-test and post-unit test data are commonly used to evaluate the effectiveness of a specific intervention or program on student learning outcomes. Pre-test data refers to the measurements taken before the implementation of the intervention, while post-unit test data refers to the measurements taken after the intervention has been completed. By comparing pre-test and post-unit test data, I was able to assess the extent to which the intervention has impacted student learning.

In this analysis of class results, I have already collected both pre-test and post-unit test data from my two groups of students. My goal is to examine the extent to which the intervention has improved student learning outcomes, as reflected in the post-unit test scores. I analyzed the data to determine if there were any significant differences between the pre-test and post-unit test scores, and to identify any patterns or trends in student performance. Ultimately, this analysis will help me to evaluate the effectiveness of the teaching intervention and inform future instructional practices. In terms of grading students got 5 points credit for taking the pre-test while the post-unit test was worth 25 points; each question equally scored.

Below is the rubric for the part 4 presentation in the "growing plants" packet. This rubric was a tool used to evaluate student work based on predetermined criteria. It outlined the expectations for the project, including the specific requirements and grading criteria.

By providing a rubric, students were able to better understand what was expected of them and what they needed to do to succeed in the project. In the context of a project focused on growing plants and understanding photosynthesis, a rubric can be especially useful. In this case it outlined the specific steps students need to take to grow their plants successfully, including the necessary materials and equipment. Additionally, the rubric provided a clear understanding of what the students should have learned about photosynthesis and how energy is transformed within photosynthetic organisms, as well as, following the rubrics and assignments standards. For example, this rubric included criteria such as:

1. **Scientific understanding:** Did the student demonstrate an understanding of photosynthesis and the role it plays in plant growth? Did they explain how energy is transformed within photosynthetic organisms? Were the students able to answer the pre-test questions accurately?
2. **Communication:** Did the student clearly and effectively communicate their ideas and findings? Did they use appropriate scientific vocabulary and grammar?
3. **Reflection:** Did the student provide a thoughtful and thorough reflection on their learning experience? Did they address the reflection questions from part 3 in the "growing plants" packet?
4. **Time management:** Did the students use their time effectively during the project? Did they complete all necessary tsks within the two-month period? Was their presentation long enough to meet the rubric standards?

Overall, this rubric helped students stay focused and on track during their project. It also was used to provide a clear understanding of what they needed to learn and accomplish to succeed in the assignment.

Analysis of Class Results

PjBL is an innovative teaching approach that allows students to engage with content in a meaningful way, building their knowledge and skills through hands-on projects and real-world situations. However, to ensure that this approach is effective research and analysis should be conducted. It is important to analyze the results of student performance and use them to inform and improve teaching practices. Furthermore, the analysis of the "growing plants" packet average, which was 85.7% and 84%, provides additional evidence of the effectiveness of this approach (**Figure 2**).

Pre- & post-unit test analysis

A recent analysis of student results from the "growing plants" packet provided valuable insights into how this approach can be used to improve student learning outcomes. At the start of PjBL unit, the pre-test data (**Figure 3** & **Figure 4**) revealed an average score of 57% and 58%, indicating a need for improvement in their understanding and comprehension of the topic. However, following the completion of PjBL unit, students showed significant improvement with post-unit test scores of 93.75% and 79.46%, respectively.

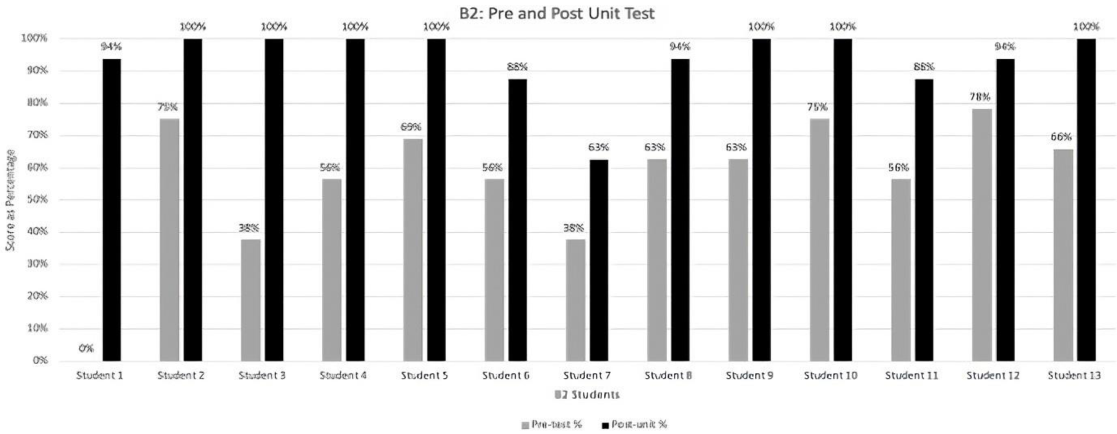


Figure 3. B2: Pre- & post-unit test (Source: Author's own elaboration)

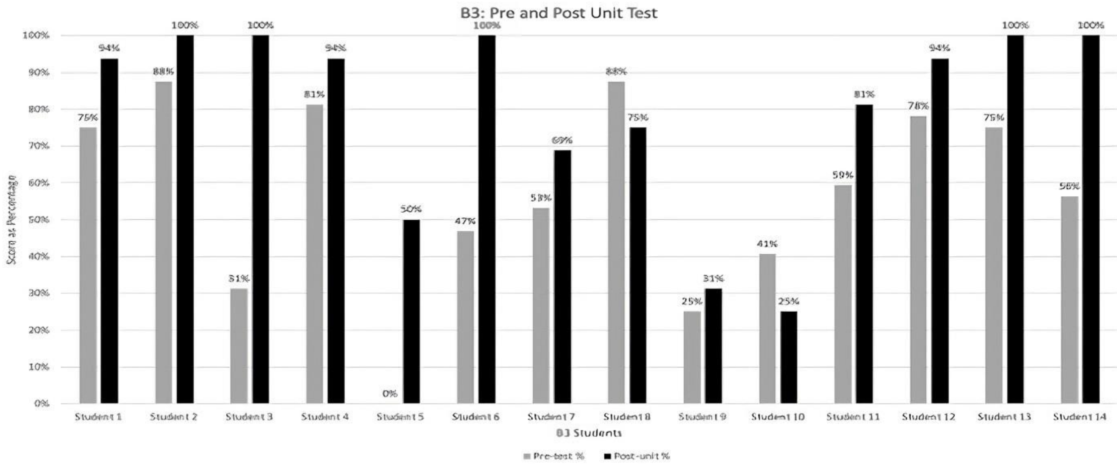


Figure 4. B3: Pre- & post-unit test (Source: Author's own elaboration)

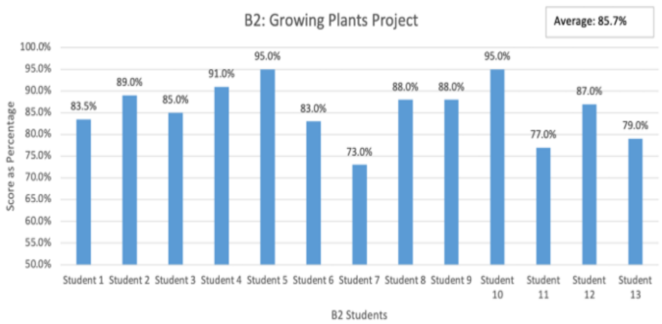


Figure 5. B2: Growing plants project (Source: Author's own elaboration)

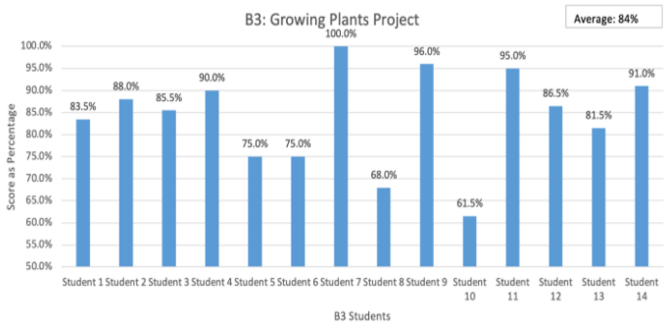


Figure 6. B3: Growing plants project (Source: Author's own elaboration)

This significant increase in post-unit test scores suggest that PjBL approach was effective in engaging and motivating students to learn about photosynthetic organisms and the process of photosynthesis. By providing hands-on experiences (growing plants packet) as well as real world situations, students were able to better understand the material and apply their knowledge in a meaningful way.

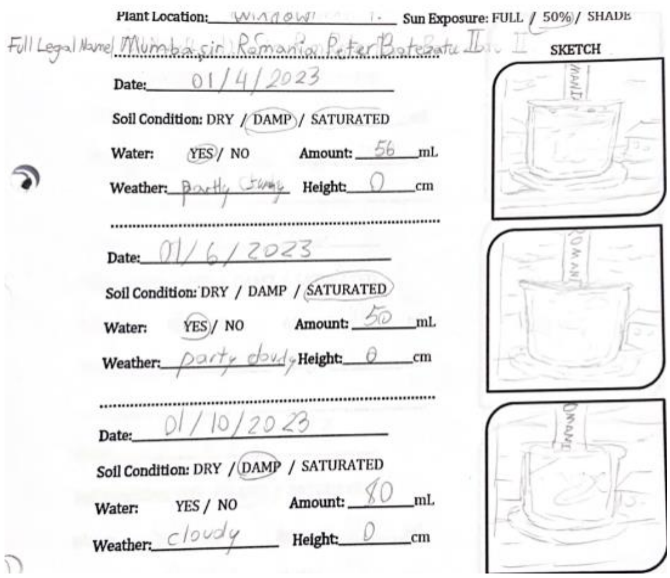
The data also suggests that PjBL learning approach was particularly effective in improving student comprehension and application of knowledge, rather than simply memorization of information. The increase in post-unit test scores indicates that students were able to retain and apply the information learned in PjBL unit, indicating a deeper level of understanding and critical thinking skills.

Overall, the analysis of pre-test and post-unit test data suggests that PjBL is an effective teaching approach for engaging students and improving their understanding of complex topic, such as photosynthetic organisms and the process of photosynthesis. By incorporating more hand-on learning experiences into the curriculum teachers can better prepare their students for success in the 21st-century.

Growing plants packet analysis

The analysis of the "growing plants" packet average (**Figure 5** & **Figure 6**), which was 85.7% and 84%, provides additional evidence of the effectiveness of this approach.

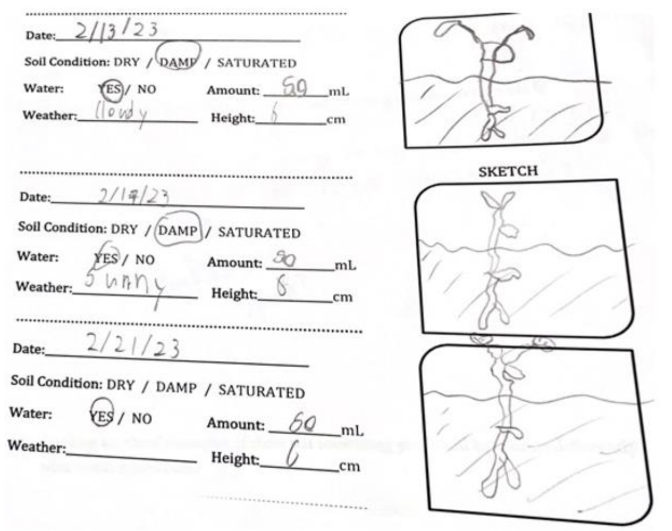
This packet included various parts and steps to insure comprehension of the unit. To provide a complete picture of


Plant Location: Window Sun Exposure: FULL / 50% / SHADE
Full Legal Name: Mumbasir Romanian Peter Batezate II
SKETCH
Date: 01/4/2023
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 56 mL
Weather: Partly Sunny Height: 0 cm

Date: 01/6/2023
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: party cloudy Height: 0 cm

Date: 01/10/2023
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 80 mL
Weather: cloudy Height: 0 cm

Figure 7. B3 student 14 (reprinted with permission of student)


Date: 2/13/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: cloudy Height: 6 cm
SKETCH
Date: 2/14/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: Sunny Height: 6 cm

Date: 2/21/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 60 mL
Weather: Height: 6 cm

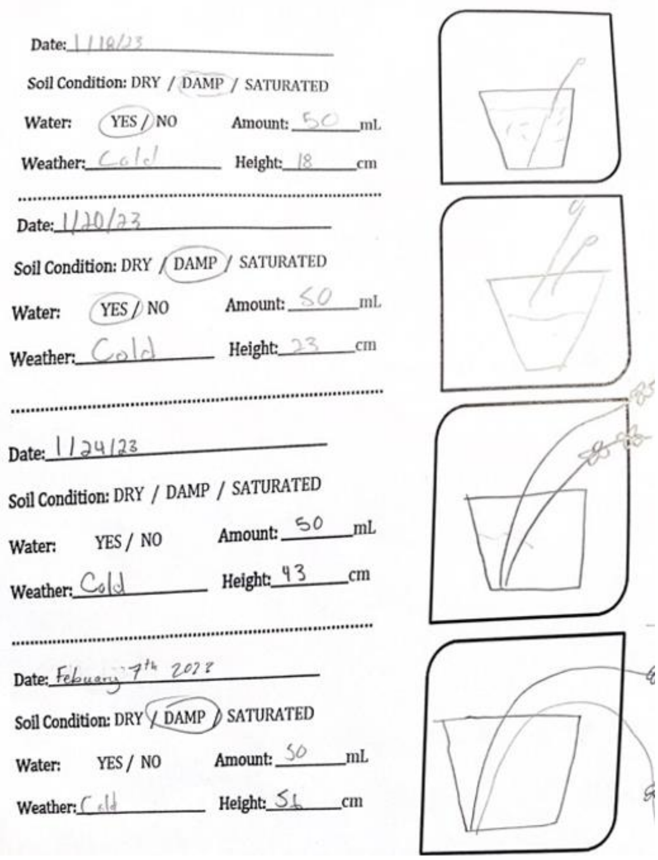
Figure 8. B3 student 2 (reprinted with permission of student)

student learning outcomes, I will include several students' work such as data tracking from part 2 of the packet, responses to the reflection questions in part 3, and presentation slides from part 4. This will help showcase the depth of students' understanding and the creativity and thoughtfulness they put into their projects. To allow coherence the student work will be labeled to match the graphs above. For example, I would label B2 student 3 with 85% as B2 student 3.

Part 2–Student work: The following student work examples are in the "growing plants" packet in part 2 data collection (Figure 7, Figure 8, & Figure 9).

This shows three data points the student took. These were the first three days of the data collection, so you will not see growth, but the completion and effort this student showed was exceptional.

Like above, this shows three data points the student took (Figure 8). This was further along in the project, and you can observe the plant growth. The data points were 99% filled in, but the last weather was not; I assumed it to be a forgotten piece of data when evaluating the packet.


Date: 1/18/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: Cold Height: 18 cm

Date: 1/20/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: Cold Height: 23 cm

Date: 1/24/23
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: Cold Height: 43 cm

Date: February 7th 2023
Soil Condition: DRY / DAMP / SATURATED
Water: YES / NO Amount: 50 mL
Weather: Cold Height: 51 cm

Figure 9. B2 student 1 (reprinted with permission of student)

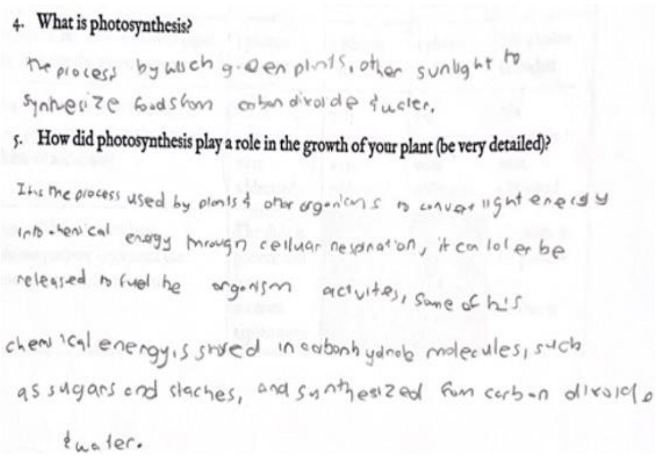

4. What is photosynthesis?
The process by which green plants, other sunlight to synthesize foods from carbon dioxide & water.
5. How did photosynthesis play a role in the growth of your plant (be very detailed)?
This the process used by plants & other organisms to convert light energy into chemical energy through celluar respiration, it can later be released to fuel the organism activities, some of this chemical energy is stored in carbohydrate molecules, such as sugars and staches, and synthesized from carbon dioxide & water.

Figure 10. B3 student 2 (reprinted with permission of student)

The last part 2 data collection student work includes 4 data points. In this student's work you can see in the sketches how the plant grew over those 20 days. This student was able to see progress and connect it with real world situations.

Part 3–Student work: The following student work examples are in the "growing plants" packet in part 3 reflection questions number 4 and number 5.

Student response 1 to question 1 (Figure 10): The student response provides a brief definition of photosynthesis as the process by which plants use sunlight to produce glucose from carbon dioxide and water. The response correctly identifies the role of sunlight as a source of energy and the raw materials used to create glucose.

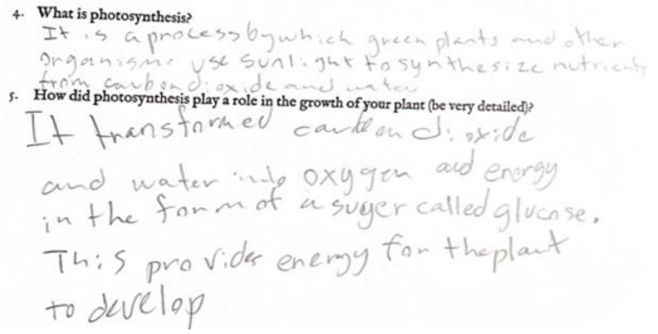


Figure 11. B3 student 3 (reprinted with permission of student)

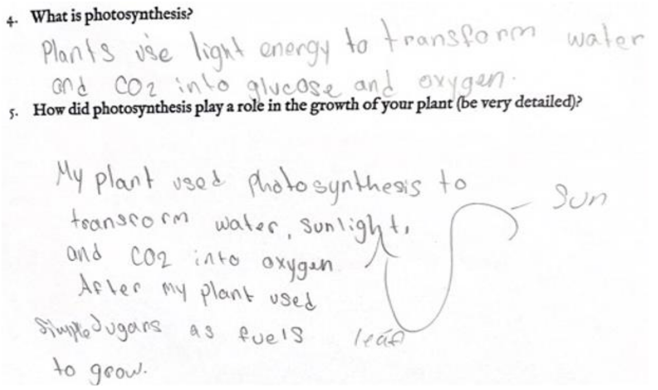


Figure 12. B2 student 10 (reprinted with permission of student)

Student response 2 to question 2 (**Figure 10**): The student response appears to be discussing the role of photosynthesis in creating chemical energy through cellular respiration, which is incorrect. Cellular respiration is the process by which cells convert glucose and other nutrients into energy, and it occurs after photosynthesis has taken place. The response does correctly identify that some of the chemical energy produced during photosynthesis is stored in carbon and hydrogen molecules such as sugars and starches. However, it is unclear how this relates to the growth of the student's plant.

Overall, the student shows some understanding of photosynthesis in response to question 1 but demonstrates some confusion in response to question 2. The student could benefit from further clarification and understanding of the relationship between photosynthesis and plant growth. This evaluation was given to this student as feedback.

Student response 1 to question 1 (**Figure 11**): The student's response is accurate and provides a clear definition of photosynthesis at this level. The response demonstrates an understanding that photosynthesis is a process that converts light energy into chemical energy, which is then used by plants and other organisms to produce nutrients from CO_2 and water.

Student response 2 to question 2 (**Figure 11**): The student's response also shows an understanding of the role of photosynthesis in plant growth. The student correctly explains that photosynthesis transformed carbon dioxide and water into glucose, which provided energy for the plant to develop. However, the response could be improved by specifying that glucose is the primary source of energy for plant growth and development; this was verbal feedback.

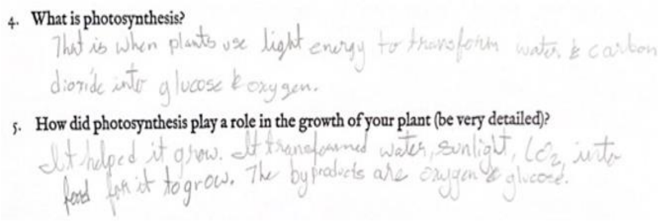


Figure 13. B2 student 5 (reprinted with permission of student)

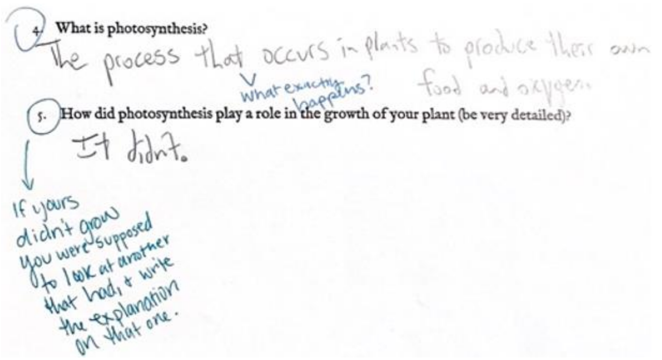


Figure 14. B2 student 8 (reprinted with permission of student)

Overall, the student demonstrates a good understanding of photosynthesis and its role in plant growth.

Student response 1 to question 1 (**Figure 12**): This response demonstrates a good understanding of the process of photosynthesis. They correctly identify that plants use light energy to convert water and CO_2 into glucose and oxygen.

Student response 2 to question 2 (**Figure 12**): This response also shows a good understanding of the role of photosynthesis in plant growth. They correctly note that photosynthesis allows plants to produce oxygen, and that this process involves the transformation of water, sunlight, and carbon dioxide. The student also correctly identifies that the plant uses simple sugars as fuel to support its growth.

Overall, the student's responses suggest a strong grasp of the basic concepts of photosynthesis and its important in plant growth. They demonstrate an ability to articulate their understanding clearly and concisely, using appropriate scientific terminology.

Student response 1 to question 1 (**Figure 13**): This student response accurately describes the process of photosynthesis, where plants use light energy to transform water and carbon dioxide into glucose and oxygen. The response is concise and demonstrates a good understanding of the topic.

Student response 2 to question 2 (**Figure 13**): This response is also accurate and demonstrates an understanding of the role of photosynthesis in plant growth. The response explains that photosynthesis helps plants grow through transformations as described with B2 student 10. Additionally, the response mentions that oxygen is a byproduct of the process, which is also correct.

Overall, both responses are accurate and show a good understanding of photosynthesis and its role in plant growth.

Student response 1 to question 1 (**Figure 14**): This student's response is somewhat accurate. The response correctly identifies photosynthesis as a process that occurs in

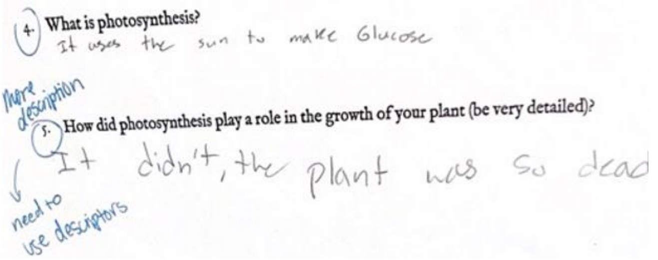


Figure 15. B2 student 9 (reprinted with permission of student)

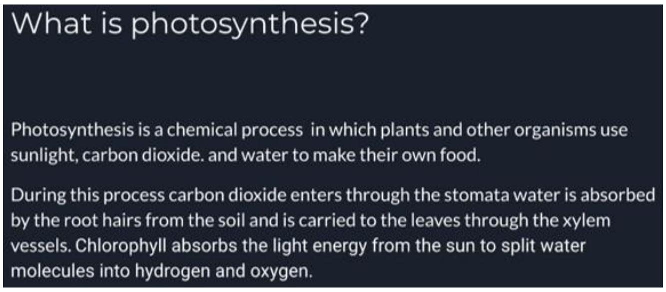


Figure 16. B2 student 3 (reprinted with permission of student)

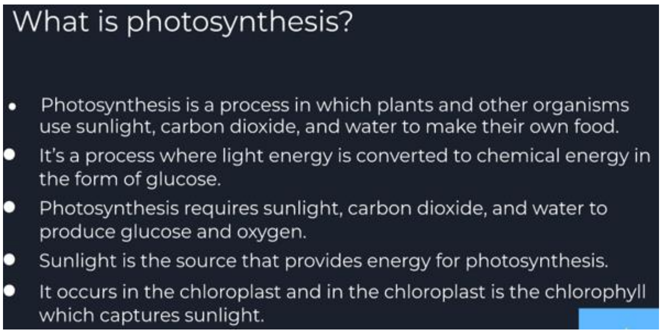


Figure 17. B2 student 5 (reprinted with permission of student)

plants to produce food and oxygen. However, the response lacks in-depth explanation and may be considered a brief overview of the process.

Student response 2 to question 2 (**Figure 14**): The student's response is incomplete and lacking detail. The response simply states that photosynthesis did not play a role in the growth of their plant, because it did not grow. The instructions given to each student was to use someone else's plant as their reference if theirs did not grow.

Student response 1 to question 1 (**Figure 15**): This student's response demonstrates a basic understanding of photosynthesis. However, the response is lacking in detail and does not fully explain the complex process of photosynthesis.

Student response 2 to question 2 (**Figure 15**): Like the student above, B2 student 8, instructions were not followed and resulted in an incomplete reflection question.

Part 4–Student work: The following student work examples are presentation slides from part 4 in the "growing plants" packet.

This slide was part of addressing the reflection questions on photosynthesis and what it is (**Figure 16**). This student's response provides a comprehensive and accurate explanation of the process. The student accurately describes photosynthesis as a chemical process that plants and other organisms use to produce their own food. Furthermore, the

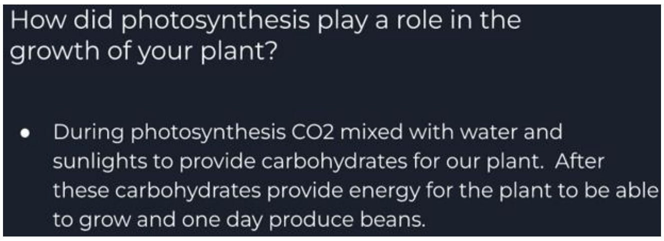


Figure 18. B2 student 10 (reprinted with permission of student)

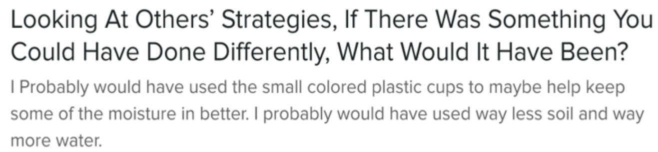


Figure 19. B2 student 7 (reprinted with permission of student)

student provides additional details regarding the inputs of carbon dioxide and water and the output of oxygen, which demonstrates a deeper understanding of the process. This student provided a detailed response that demonstrates a good understanding of photosynthesis.

This slide is also addressing the reflection question on photosynthesis (**Figure 17**). These two students provided a detailed and accurate description of photosynthesis. This slide has a thorough explanation of photosynthesis as a process that involves the conversion of light energy into chemical energy in the form of glucose. The student correctly identified the three key inputs required for photosynthesis: sunlight, water, and carbon dioxide. Additionally, the response highlights the role of chloroplast and chlorophyll in capturing sunlight and converting it into energy that can be used by the plant. This response demonstrates a strong understanding of the basics of photosynthesis, including its inputs, outputs, and the role of key structures and molecules in the process.

This slide also addresses a reflection question, "how did photosynthesis play a role in the growth of your plant?" (**Figure 18**). The student's response to this question is partially correct but lacks detail. The response correctly highlights that photosynthesis produces carbohydrates, which do provide energy for the plant. However, the response does not provide a complete explanation of how photosynthesis is directly linked to plant growth. These students demonstrate basic understanding of photosynthesis but lack sufficient detail to fully answer the question.

This student's response is related to a reflection question as well, "looking at others' strategies, if there was something you could have done differently what would it have been?" (**Figure 19**). This student's reflection is specific and demonstrates an ability to reflect on past experiences and identify areas for improvement. The response suggests that the student would have used small colored plastic cups to help retain moisture, which is a reasonable strategy for promoting plant growth. Additionally, the student suggests that they would have used less soil and more water, which could also be a helpful approach form ensuring adequate hydration for the plant. The student's response suggests that the student is willing to learn from the experiences of others and apply that knowledge to improve their own strategies.

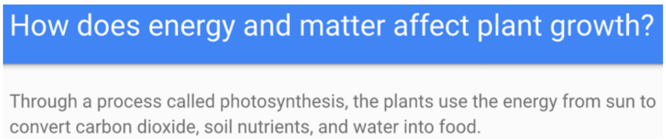


Figure 20. B2 student 12 (reprinted with permission of student)

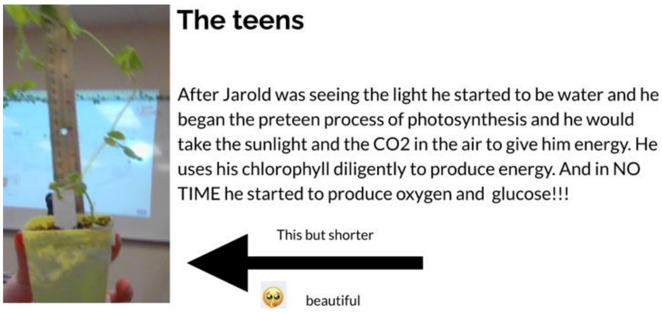


Figure 21. B3 student 12 (reprinted with permission of student)

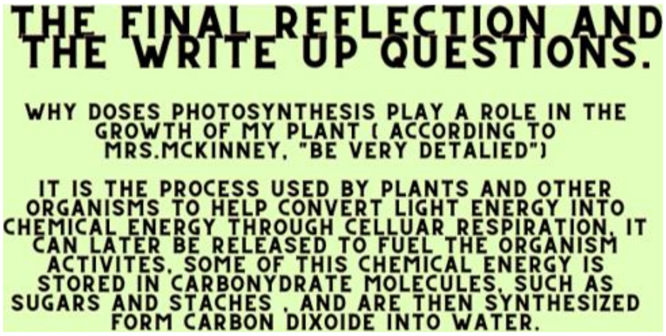


Figure 22. B3 student 7 (reprinted with permission of student)

This slide is part of the pre-test questions requirement. The pre-test question was "how does energy and matter affect plant growth?" (**Figure 20**). The answer provided is correct in terms of the multiple choices. The other choices were, energy and matter in plants use only the sun to grow, energy and matter affect plant growth by converting glucose and carbon dioxide to oxygen and water, and energy and matter do not affect plant growth.

This student provided a photo of their plant and answered the reflection question, "how did photosynthesis play a role in the growth of your plant?" in a storytelling way (**Figure 21**). Jarold being the name of this student's plant and the plant growing up in a "pre-teen sort of way". This student was able to show what molecules go in the plant in terms of photosynthesis, how sunlight energy is used, and what the products of photosynthesis are. Although, the response does not provide a detailed explanation of how photosynthesis plays a role in the growth of the plant, but it does show an understanding enough to create a creative story theme to the response.

As shown in this slide this response addresses the final reflection question on "how does photosynthesis play a role in the growth of my plant?" (**Figure 22**). This student's response is accurate but not entirely detailed. The student provides a general description of the role of photosynthesis in producing chemical energy in the form of carbohydrates, but it does not explain how this process specifically contributed to the growth of the student's plant.

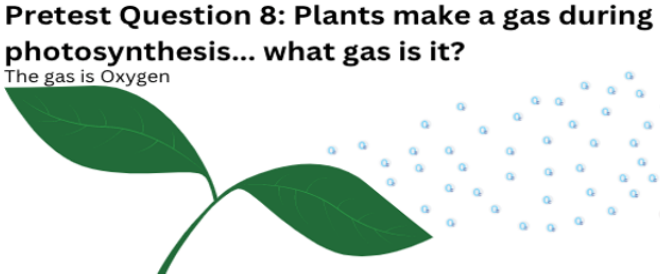


Figure 23. B3 student 11 (reprinted with permission of student)

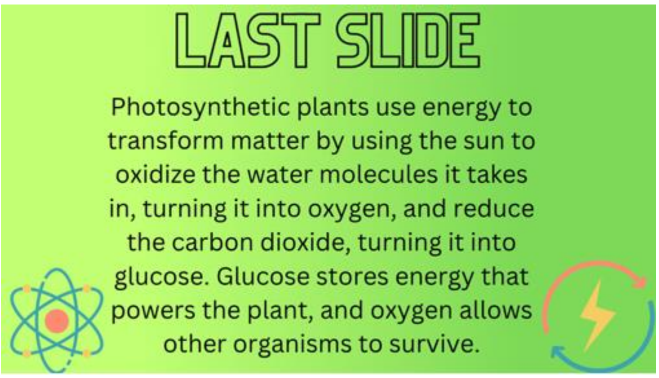


Figure 24. B3 student 1, student 2, & student 13 (reprinted with permission of student)

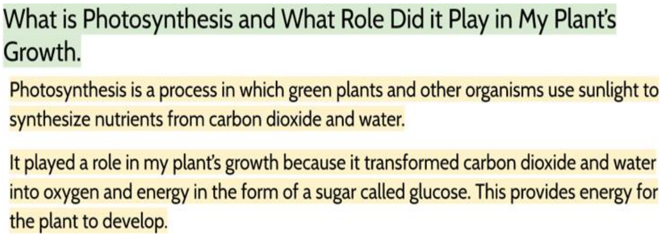


Figure 25. B3 student 3 (reprinted with permission of student)

This slide addresses the pre-test question on "plants make a gas during photosynthesis … what gas is it?" (**Figure 23**). This students answer was accurate, but the detail and effort of this slide is worth noting. I asked the student if they created the art of this slide, and they did. Each bubble is oxygen exiting the leaves of the plant. The student spent a great amount of time on his slides, and this is one of my personal favorites.

These three students addressed the last required point of the slides presentation (**Figure 24**). The question was, "how do photosynthetic plants use energy to transform matter?" Their response is partially correct and provides a basic understanding of the process of photosynthesis. The students correctly identified that photosynthetic organisms use energy from the sun to transform matter, specifically water and carbon dioxide. The response accurately describes the process of water oxidation and carbon dioxide reduction, which ultimately results in the production of glucose and oxygen. This response is limited in its detail and does not fully explain the process, but it is acceptable for eighth graders.

This slide addresses two reflection questions, "what is photosynthesis?" and "what role did photosynthesis play in my plant's growth?" (**Figure 25**). The first addressed reflection question accurately describes the key components of photosynthesis, and that photosynthesis is not limited to

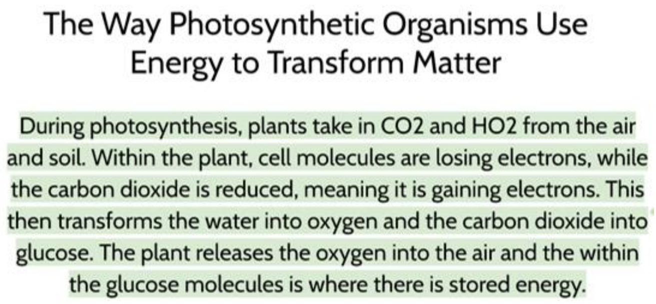


Figure 26. B3 student 3 (reprinted with permission of student)

green plants. This response demonstrates a good understanding of the basics of photosynthesis and shows that the student has likely studied the topic in some depth.

The second addressed reflection question correctly identifies that photosynthesis is a process that transforms carbon dioxide and water into glucose and oxygen (**Figure 25**). The response is relatively brief, but it still provides a clear and concise explanation of how photosynthesis plays a crucial role in plant growth. The response indicates that the student has a basic understanding of the relationship between photosynthesis and plant growth.

This response addresses the last required slide presentation point; "how do photosynthetic organisms use energy to transform matter?' (**Figure 26**). The student's response is quite detailed and shows a good understanding of the process of photosynthesis. The response correctly identifies that during the process, plants take in carbon dioxide and water, and through the process of photosynthesis, transform these molecules into glucose and oxygen. The response also describes how electrons are lost and gained, leading to the reduction of carbon dioxide and the release of oxygen. The response further explains that the energy is stored in the glucose molecule, which is a key product of photosynthesis. Overall, this response shows that the student has a good understanding of the role of energy in photosynthesis and how it is used to transform matter.

Finally, at the end of each class I gave the students an exit ticket. Dates January 4th through February 17th (**Table 1**) had the same three questions:

(1) do you see value in growing your own plant,

(2) are you motivated to learn more about this unit because of the "growing plants" project, and

(3) have you been interested in what you are learning.

Throughout these 15 class periods we had absences, students checked out during class, and questions left blank so there will not be the same number of responses for each question.

As seen above, question one had 381 total responses. Of that amount, yes was answered 348 times, no was answered 29 times, and kind of was answered four times. That shows that 91.3% of the time students felt they saw value in trying to grow their own plant. 7.6% of the time students felt they did not see value, and 1.1% of the time they kind of saw value.

Question two had 369 total responses. Of that amount, yes was answered 321 times, no was answered 28 times, and kind of was answered 20 times. That shows that 87% of the time students were motivated to learn more about the unit due to the "growing plants" project, 7.6% of the time students felt they were not motivated, and 5.4% of the time they were kind of motivated.

Lastly, question three had 367 total responses. Of those responses, yes was answered 323 times, no was answered 15 times, and kind of was answered 29 times. This shows that 88% of the time students were interested in what they were learning, 4.1% of the time they were not interested, and 7.9% of the time they were kind of interested.

In **Table 2**, it shows the 2/21 exit ticket data. This was the last exit ticket given out to the students containing four different questions and one repeated question. Those questions being

(1) do you see value in growing your own plant,

(2) as the unit progressed were you more interested in learning about photosynthesis and cellular respiration,

(3) if yes, was this because of our "growing plants" packet,

(4) were you excited more than usual to come to class each day because of the project, and

(5) do you enjoy project like these.

Each question had a total of 25 responses. Question one had yes answered 22 times and no answered three times. That shows that overall, 88% of the time students saw value in growing their own plant (at least trying too) and 12% of the time they did not see value.

Question two had yes answered 21 times and no answered four times. That shows that overall, 84% of the students progressively became more interested in learning about photosynthesis and cellular respiration and 16% did not. The third question is tied to question two. Overall, question three

Table 1. Exit ticket analysis-I

1/4-2/17 exit tickets		Yes	No	Kind of
B2; B3	Do you see value in growing your own plant?	348; 91.3%	29; 7.6%	4; 1.1%
	Are you motivated to learn more about this unit because of "growing plants" project?	321; 87%	28; 7.6%	20; 5.4%
	Have you been interested in what you are learning?	323; 88%	15; 4.1%	29; 7.9%

Table 2. Exit ticket analysis-II

2/21 exit ticket		Yes	No
B2; B3	Do you see value in growing your own plant?	22; 88.0%	3; 12.0%
	As unit progressed were you more interested in learning about photosynthesis & cellular respiration?	21: 84.0%	4; 16.0%
	If yes, was this because of our "growing plants" project?	22; 88.0%	3; 12.0%
	Were you excited more than usual to come to class each day because of the project?	20; 80.0%	5; 20.0%
	Do you enjoy projects like these?	23; 92.0%	2; 8.0%

had yes answered 22 times and no answered three times. That shows that overall, 88% of the students believe that they were interested due to the project and 12% did not.

Question four had yes answered 20 times and no answered five times. This shows that overall, 80% of the students were more excited than usual to come to class due to the project and 20% were not more excited.

Finally, question five had yes answered 23 times and no answered two times. This shows that overall, 92% of the students enjoy projects like these and 8% do not.

Connecting Theory, Research and Practice

PjBL is a teaching approach that involves students working on a project over an extended period. This approach allows students to apply and integrate knowledge and skills from multiple subject areas to develop a solution or product and in this case our product was growing a plant (Carrabba & Farmer, 2018). PjBL is argued to increase student engagement, motivation, and achievement; especially within STEM subjects (Capraro et al., 2013). PjBL is especially effective in science education. This teaching strategy not only leads to higher levels of student achievement, as mentioned above, but it fosters positive attitudes towards science and better retention of science knowledge (Balemen & Keskin, 2018).

The best practices of implementing PjBL include encouraging student-centered learning, collaboration, providing scaffolding, assessing student learning, and connection to real-world contexts (Haatainen & Aksela, 2021; Ismail et al., 2021). The lesson plans were developed using this research. This project allowed students to eventually define how photosynthetic organisms use energy to transform matter in their presentation. I was able to create my lesson plans using Trilling and Fadel's (2009) "the 21st-century project learning bicycle" and EDM described by Capraro et al. (2013).

First, there was a pre-test given in lesson plan one to each student to track the growth at the end of the unit; B2 had a class average increase of almost 37% and B3 had just over 21% growth. The "growing plants" project (**Figure A1** in **Appendix A**) had four parts that were able to provide scaffolding for how the project will be set up. Throughout the project students were to monitor their own plants as well as observe what their peers are doing. This was a hands-on project that involves growing plants, which allowed the students to apply the knowledge and skills they have learned in real-world contexts. Part 3 in the "growing plants" packet gave the students the opportunity to engage in critical thinking and problem solving. During part four, students were able to work collaboratively on their presentations if they had the same exact procedures and materials; students were given full creativity for their presentation (example: **Figure 33** & **Figure 35**). This allowance let students apply what they have learned in a real-world situation and to present their findings in a way that is meaningful to them personally.

Throughout this unit I was assessing the students formatively and finally formally. As mentioned above I gave the students a pre-test (**Figure A3** in **Appendix A**) to monitor growth after the unit. I also, used exit tickets each class period to monitor their engagement and motivation. The exit tickets are also used to give time to students to reflect on their own progress and how they are feeling about the unit. The presentation day (lesson plan 3) allowed the students to showcase what they learned and communicate what they found to work and not work along with their findings throughout the unit. This strategy promoted public speaking skills and fostered a sense of community in the classroom (Lattimer & Riordan, 2011).

There are many steps to creating an effective PjBL unit as described in chapter one; especially under Trilling and Fadel's (2009) "21st-century bicycle" and EDM from Capraro et al. (2013). The photosynthesis unit was formed from PjBL strategies described in chapter one with other possible implementations and outcomes. The results of PjBL implementation shows growth and effectiveness. Each strategy will most likely look different in each classroom, which may require modification on how instruction is given or presented.

Using Assessment for Learning

The teaching strategies used were gathered from the literature and implemented. After analyzing student data and outcomes from the formative assessments and projects there is shown growth and comprehension. Following this unit, students were able to continue to cellular respiration. Photosynthesis and cellular respiration both occur in plants, while only cellular respiration occurs in mammals. Connecting these two processes explains energy flow in a greater amount and allows students to understand how energy moves through ecosystems and how organisms use and benefit from these two fundamental processes.

Three students did not pass the post-unit test. Of those three, one of the students still had a 50% growth in what they learned, another was an outlier who decreased in their score; this specific student had five absences during the unit, and the last student, had a 6% growth, which is huge due to their severe learning disability. Otherwise, each student had some sort of growth in this unit. The data from this unit (pre- and post-unit test, exit tickets, and the packet) showed that the students were ready to move on from the unit and continue to cellular respiration.

Conclusions

PjBL can be an effective teaching method for promoting lifelong learning and developing skills that prepare students for real-world scenarios and problems. While implementing this strategy an increase in post-unit test results occurred as well as interest in the topic. Overall, PjBL aids in developing a deeper understanding and respect for the topic, making it an effective way to improve students' learning outcomes. Further research on PjBL is needed to explore its full potential.

Ultimately, the 8th grade integrated science photosynthesis unit, based on PjBL, was successfully implemented to two classes of 30 students with a diverse set of needs in a suburban charter school in Utah County, Utah. The project aligned with the Utah SEEd standard, which aims to promote students' investigation, analysis, and explanatory skills while emphasizing molecular and energy transformations during photosynthesis. Three lesson plans were created to span over seven weeks, allowing for real-world applications and investigation of photosynthesis. Daily exit tickets were used to track students' progress and motivation levels, while a "growing plants" project packet was created to keep all their work and data together. The project demonstrated connections to research that suggests PjBL promotes academic achievement, higher-level thinking, and critical thinking. The project also applied Trilling and Fadel's (2009) "the 21st-century project learning bicycle" and Capraro et al.'s (2013) EDM. Overall, PjBL approach provided an engaging and informative way to teach photosynthesis to students.

The data presented strongly suggests that PjBL is an effective teaching approach for improving student learning outcomes. The analysis of pre-test and post-unit test scores showed a significant increase in comprehension and application of knowledge after completing PjBL unit on photosynthetic organisms and the process of photosynthesis. The hands-on approach and real-world situations allowed for a deeper understanding of the material, and the analysis of the "Growing Plants" packet showed a high level of student engagement and success. By incorporating PjBL and other hands-on learning experiences, teachers can better prepare students for success in the 21st-century.

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Ethical statement: The author stated that the study was approved by Utah Valley University's Institutional Review Board on January 20, 2023, with the approval code of 1218. Excerpts of student responses from the author's classroom are used with permission of the students.

Declaration of interest: No conflict of interest is declared by the author.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the author.

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APPENDIX A: FIGURES

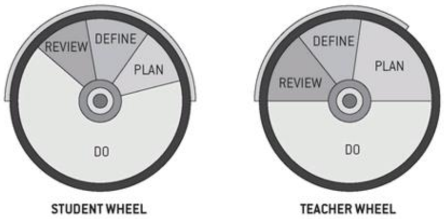
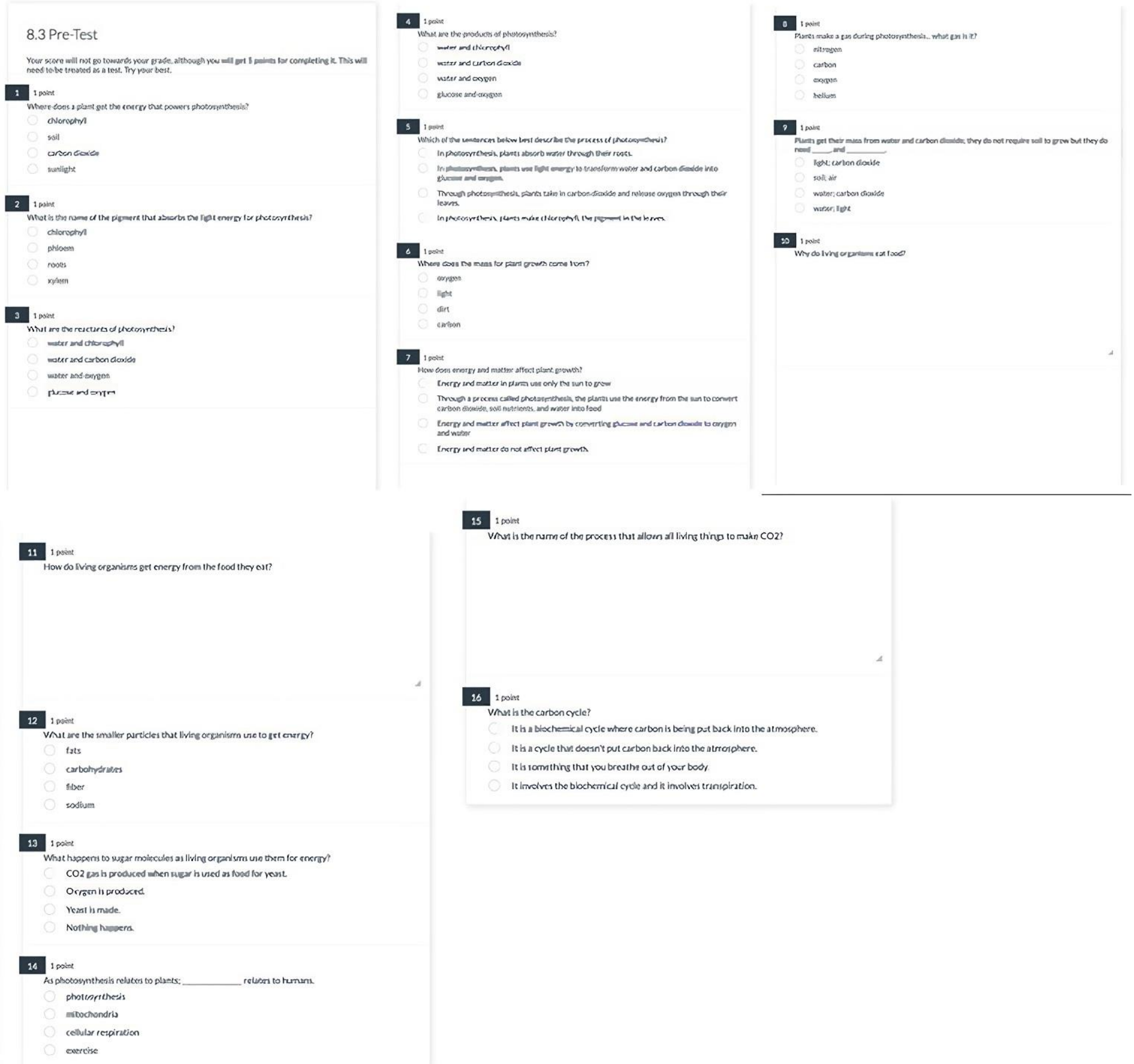


Figure A1. Trilling bicycle model (Trilling & Fadel, 2009)



8.3 Pre-Test

Your score will not go towards your grade, although you will get 5 points for completing it. This will need to be treated as a test. Try your best.

1 — 1 point
Where does a plant get the energy that powers photosynthesis?
- chlorophyll
- soil
- carbon dioxide
- sunlight

2 — 1 point
What is the name of the pigment that absorbs the light energy for photosynthesis?
- chlorophyll
- phloem
- roots
- xylem

3 — 1 point
What are the reactants of photosynthesis?
- water and chlorophyll
- water and carbon dioxide
- water and oxygen
- glucose and oxygen

4 — 1 point
What are the products of photosynthesis?
- water and chlorophyll
- water and carbon dioxide
- water and oxygen
- glucose and oxygen

5 — 1 point
Which of the sentences below best describe the process of photosynthesis?
- In photosynthesis, plants absorb water through their roots.
- In photosynthesis, plants use light energy to transform water and carbon dioxide into glucose and oxygen.
- Through photosynthesis, plants take in carbon dioxide and release oxygen through their leaves.
- In photosynthesis, plants make chlorophyll, the pigment in the leaves.

6 — 1 point
Where does the mass for plant growth come from?
- oxygen
- light
- dirt
- carbon

7 — 1 point
How does energy and matter affect plant growth?
- Energy and matter in plants use only the sun to grow
- Through a process called photosynthesis, the plants use the energy from the sun to convert carbon dioxide, soil nutrients, and water into food
- Energy and matter affect plant growth by converting glucose and carbon dioxide to oxygen and water
- Energy and matter do not affect plant growth.

8 — 1 point
Plants make a gas during photosynthesis... what gas is it?
- nitrogen
- carbon
- oxygen
- helium

9 — 1 point
Plants get their mass from water and carbon dioxide; they do not require soil to grow but they do need _____ and _________.
- light; carbon dioxide
- soil; air
- water; carbon dioxide
- water; light

10 — 1 point
Why do living organisms eat food?

11 — 1 point
How do living organisms get energy from the food they eat?

12 — 1 point
What are the smaller particles that living organisms use to get energy?
- fats
- carbohydrates
- fiber
- sodium

13 — 1 point
What happens to sugar molecules as living organisms use them for energy?
- CO2 gas is produced when sugar is used as food for yeast.
- Oxygen is produced.
- Yeast is made.
- Nothing happens.

14 — 1 point
As photosynthesis relates to plants; ___________ relates to humans.
- photosynthesis
- mitochondria
- cellular respiration
- exercise

15 — 1 point
What is the name of the process that allows all living things to make CO2?

16 — 1 point
What is the carbon cycle?
- It is a biochemical cycle where carbon is being put back into the atmosphere.
- It is a cycle that doesn't put carbon back into the atmosphere.
- It is something that you breathe out of your body.
- It involves the biochemical cycle and it involves transpiration.

Figure A2. Example questions (Source: Author's own elaboration)

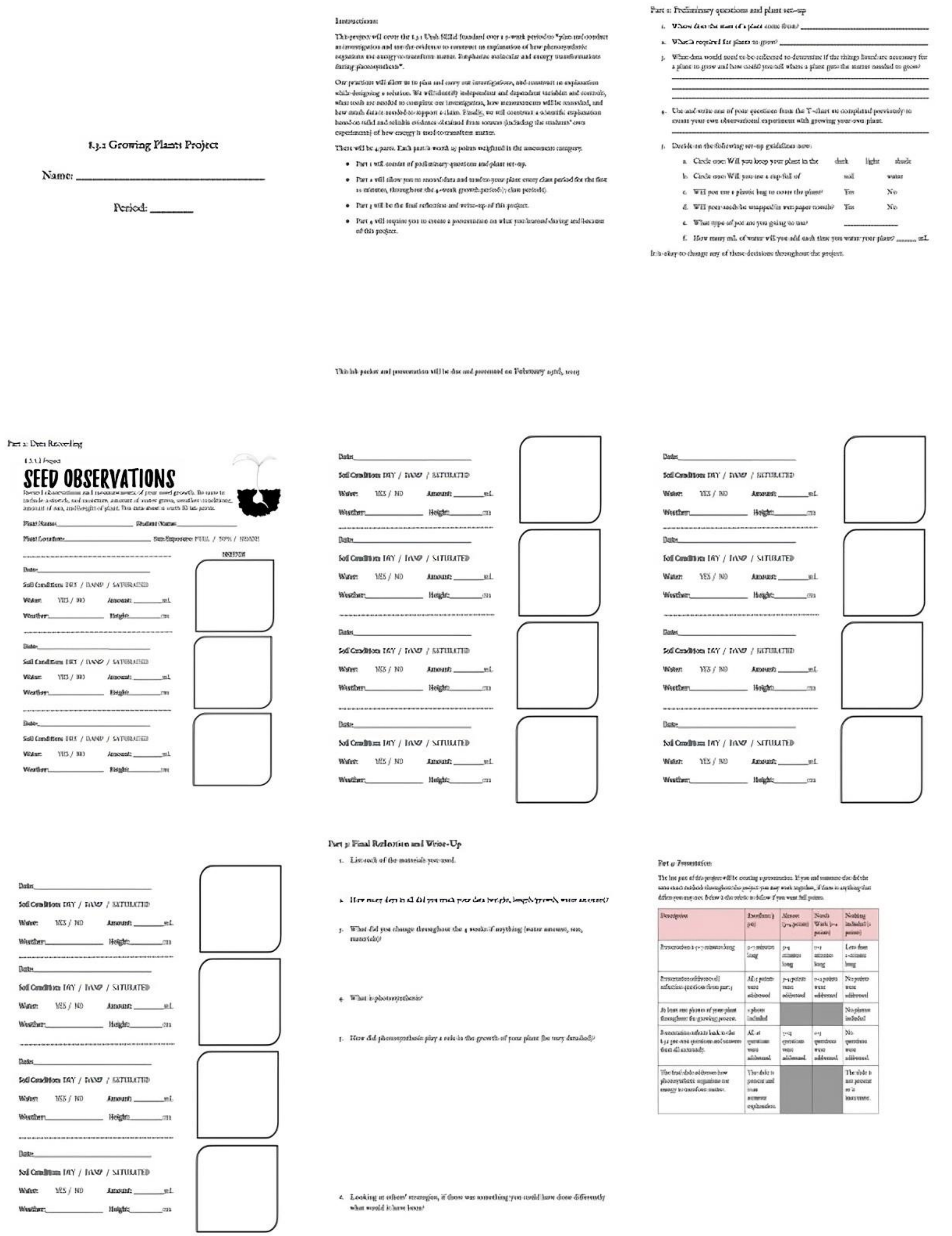


Figure A3. Growing plants project (Source: Author's own elaboration)

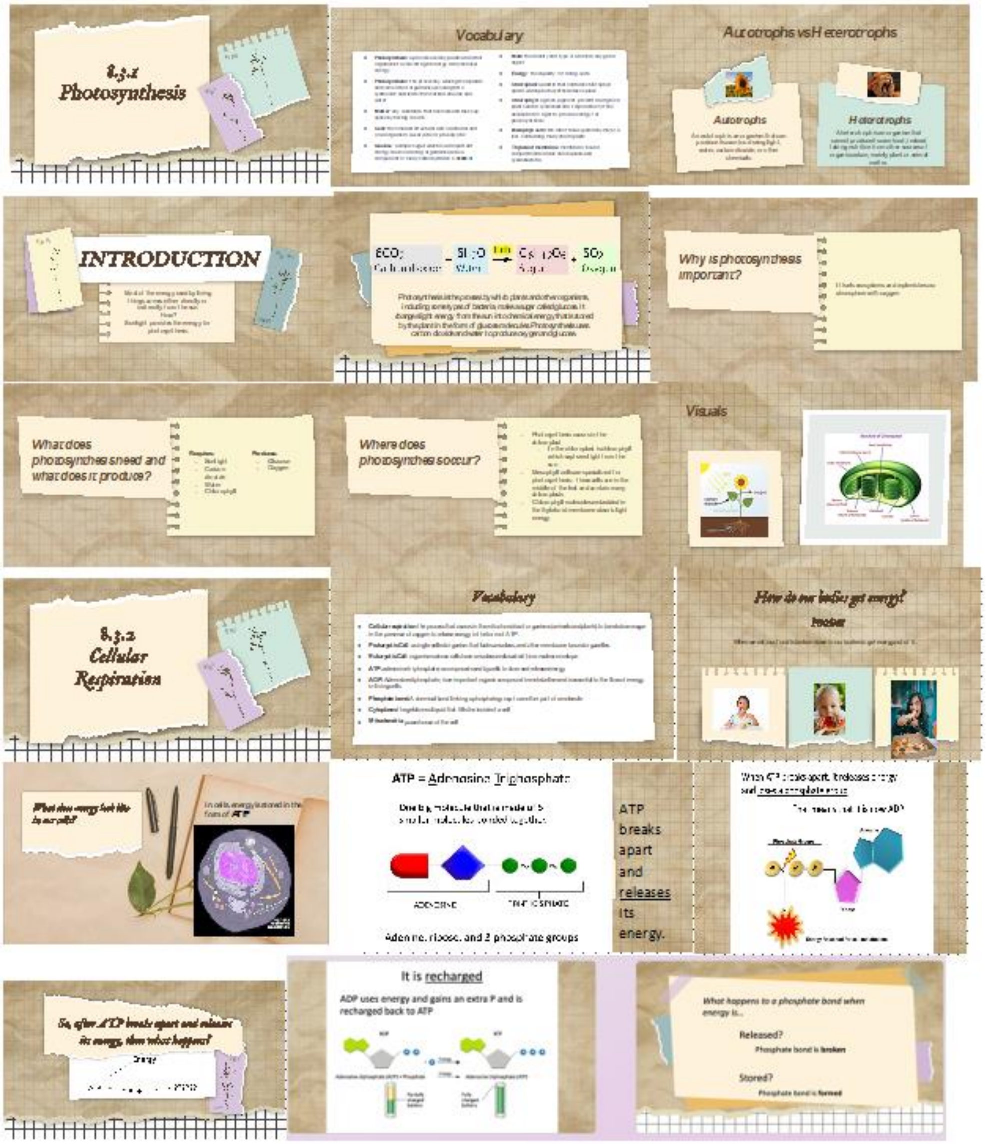


Figure A4. Photosynthesis-1 (Source: Author's own elaboration)

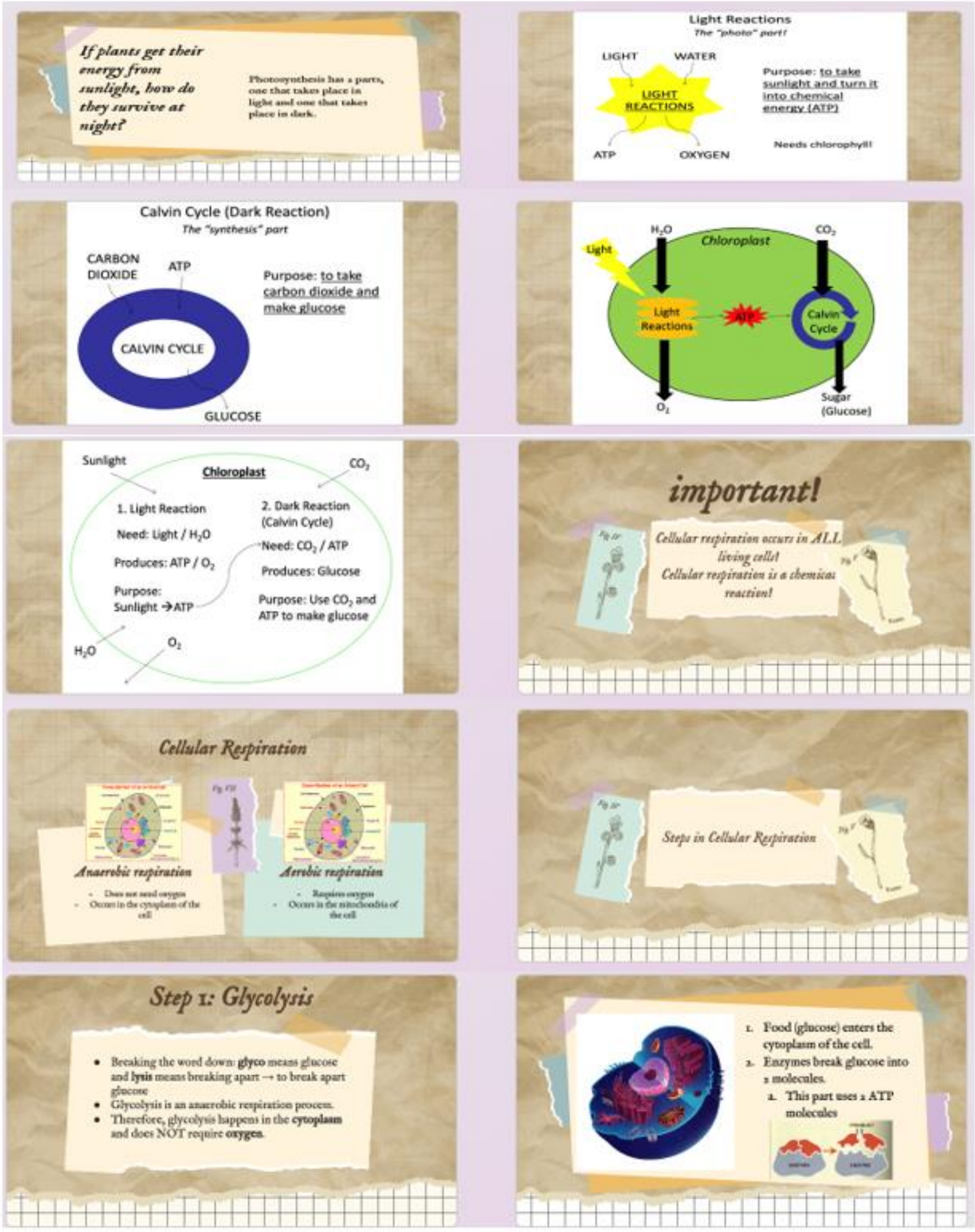


Figure A5. Photosynthesis-2 (Source: Author's own elaboration)

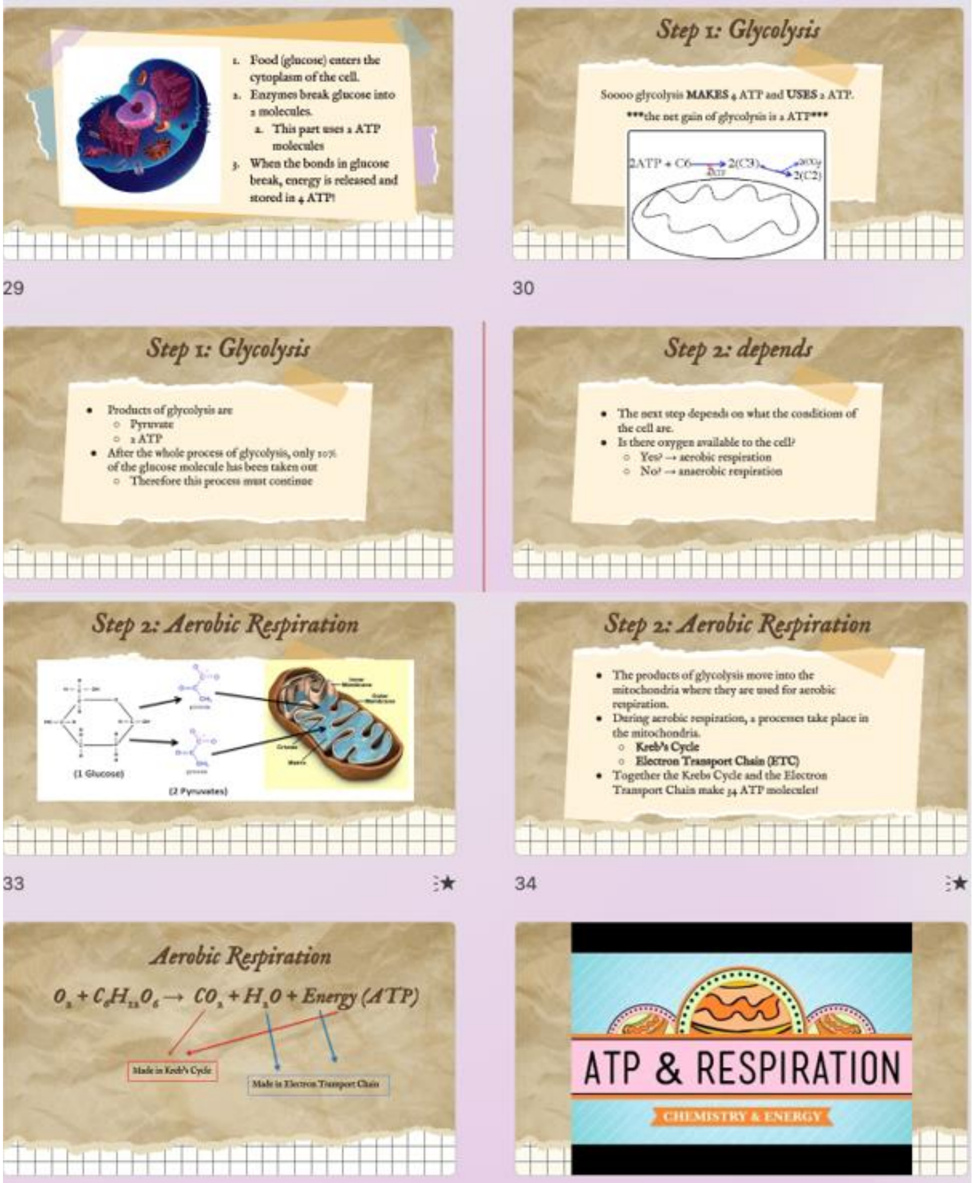


Figure A6. Photosynthesis-3 (Source: Author's own elaboration)

Figure A7. Photosynthesis-4 (Source: Author's own elaboration)

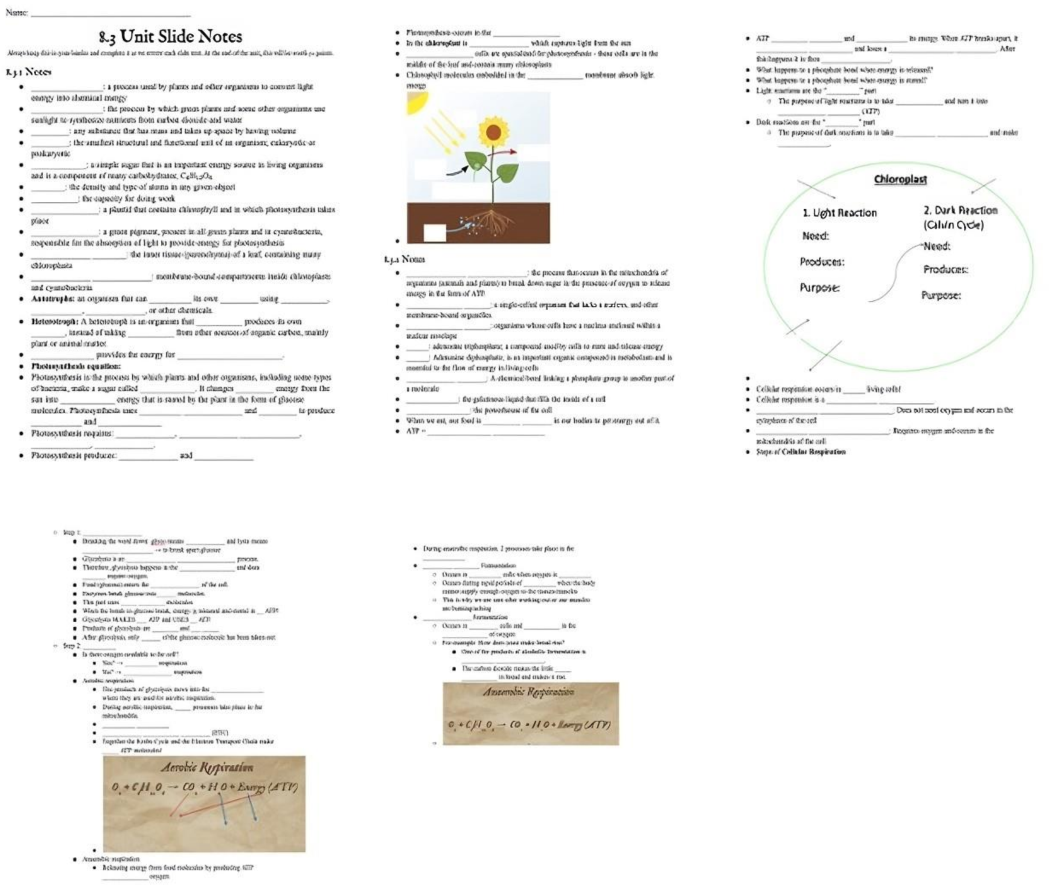


Figure A8. Slide notes (Source: Author's own elaboration)

Part 4: Presentation

The last part of this project will be creating a presentation. If you and someone else did the same exact methods throughout the project you may work together, if there is anything that differs you may not. Below is the rubric to follow if you want full points.

Description	Excellent (5 pts)	Almost (3-4 points)	Needs Work (1-2 points)	Nothing included (0 points)
Presentation is 5-7 minutes long	5-7 minutes long	3-4 minutes long	1-2 minutes long	Less than 1-minute long
Presentation addresses all reflection questions from part 3	All 5 points were addressed	3-4 points were addressed	1-2 points were addressed	No points were addressed
At least one photos of your plant throughout the growing process.	1 photo included			No photos included
Presentation reflects back to the 8.3.1 pre-test questions and answers them all accurately.	All 16 questions were addressed.	7-15 questions were addressed.	1-5 questions were addressed.	No questions were addressed.
The final slide addresses how photosynthetic organisms use energy to transform matter.	The slide is present and is an accurate explanation.			The slide is not present or is inaccurate.

Figure A9. Part 4–Presentation (Source: Author's own elaboration)

Name: ______________________ Date: __________ Period: _______

8.3.1.3: Photosynthesis Video

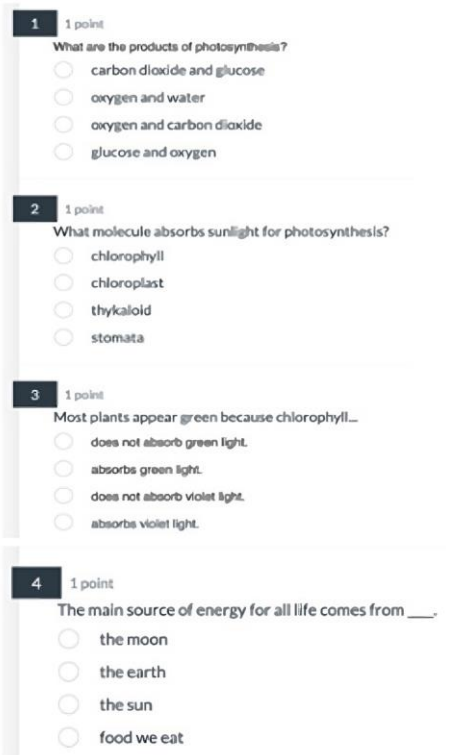
Questions	Response
What else can go through the photosynthesis process, besides plants?	
What two things does photosynthesis produce?	
What is the balanced photosynthesis equation?	
What is the cellular respiration equation?	
What three things does cellular respiration produce?	
What does chlorophyll absorb well?	
What does chlorophyll not absorb well?	
Why are most plants green?	
Where is chlorophyll found?	
What are the light-independent reactions?	
Where do light-dependent reactions occur?	
What is a stack of thylakoids? What are multiple stacks of thylakoids?	
What do light-dependent reactions produce?	
Where do light-independent reactions occur?	
What are stomata?	
What is fixed carbon dioxide + ATP + NADPH?	
What are some adaptations plants make?	

Figure A10. Video (Source: Author's own elaboration)

- List one thing you learned today.

- Do you see value in growing your own plant? Yes No
- Are you motivated to learn more about this unit because of the "growing plants" project? Yes No
- Have you been interested in what you are learning? Yes No

Figure A11. Questions-1 (Source: Author's own elaboration)


1 1 point
What are the products of photosynthesis?
- carbon dioxide and glucose
- oxygen and water
- oxygen and carbon dioxide
- glucose and oxygen

2 1 point
What molecule absorbs sunlight for photosynthesis?
- chlorophyll
- chloroplast
- thykaloid
- stomata

3 1 point
Most plants appear green because chlorophyll...
- does not absorb green light.
- absorbs green light.
- does not absorb violet light.
- absorbs violet light.

4 1 point
The main source of energy for all life comes from ___.
- the moon
- the earth
- the sun
- food we eat

Figure A12. Questions-2 (Source: Author's own elaboration)

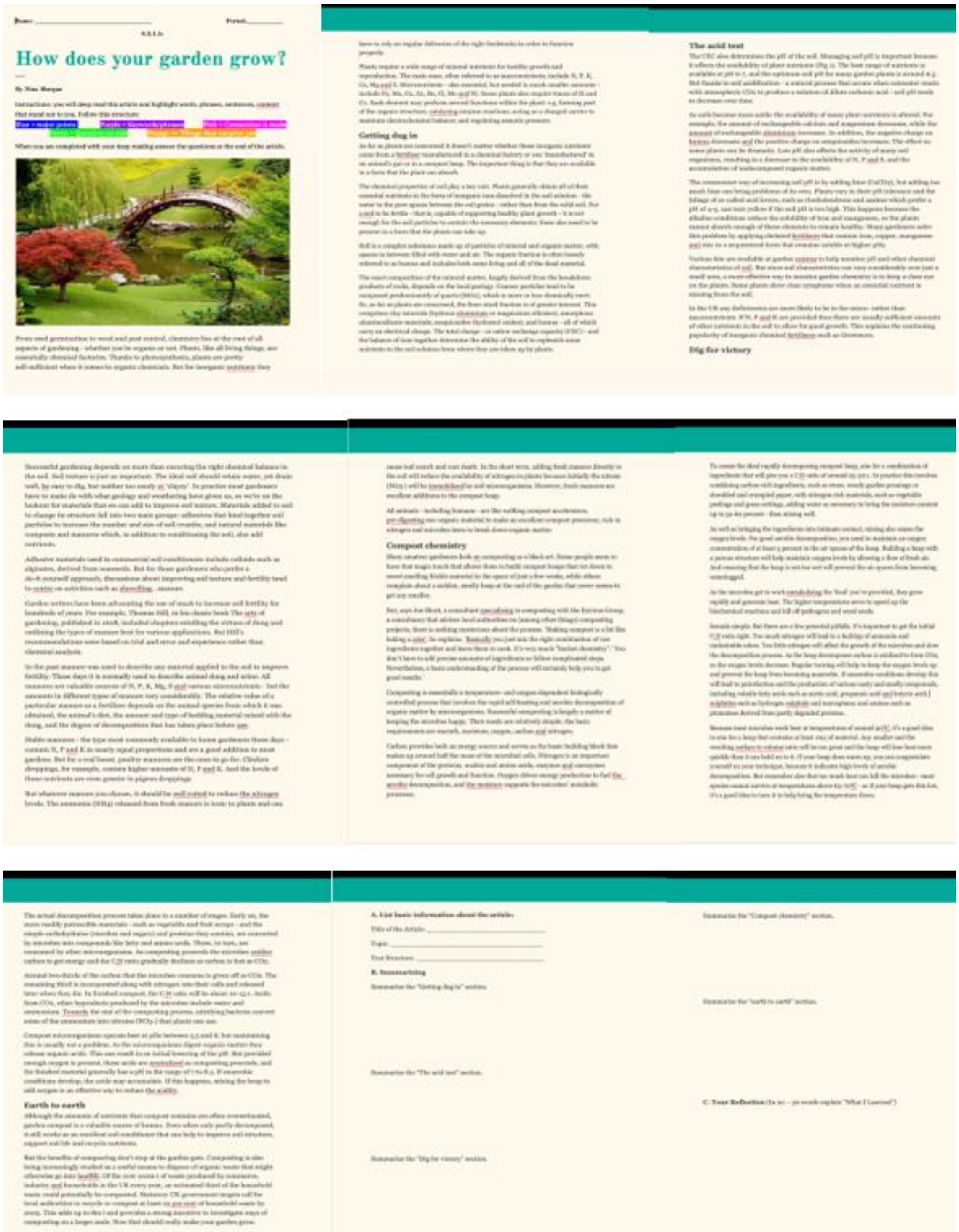
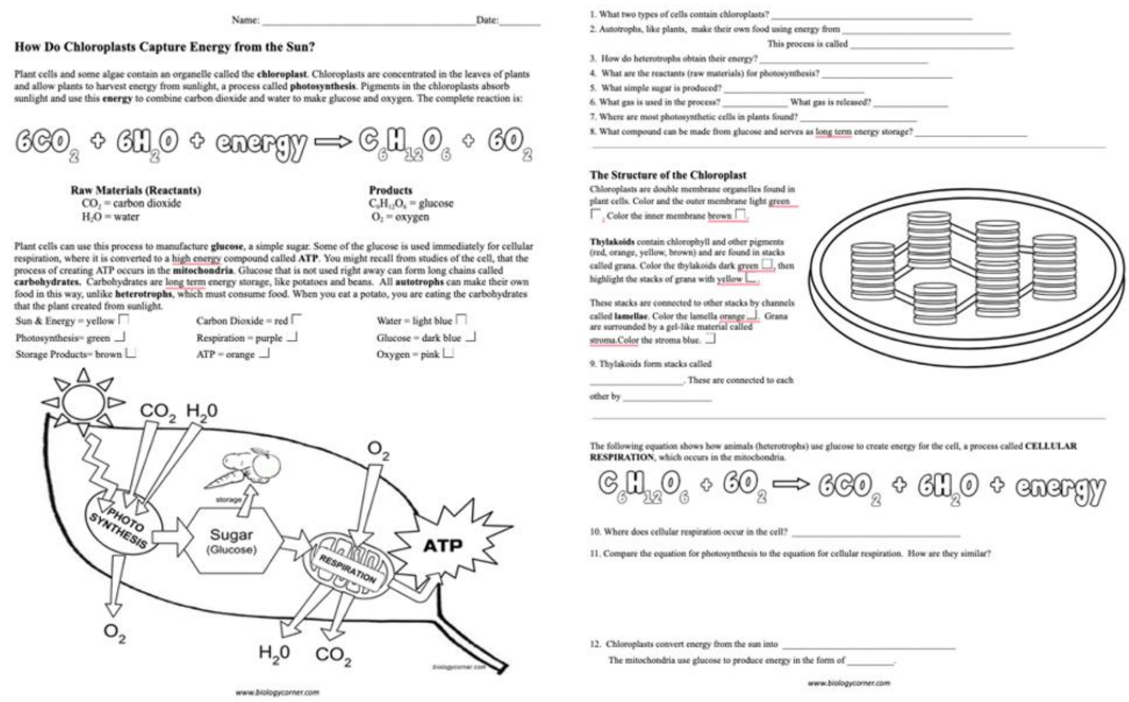


Figure A13. How does your garden grow? (Morgan, 2003)



Name: ______________________ Date: _______

How Do Chloroplasts Capture Energy from the Sun?

Plant cells and some algae contain an organelle called the **chloroplast**. Chloroplasts are concentrated in the leaves of plants and allow plants to harvest energy from sunlight, a process called **photosynthesis**. Pigments in the chloroplasts absorb sunlight and use this **energy** to combine carbon dioxide and water to make glucose and oxygen. The complete reaction is:

$$6CO_2 + 6H_2O + energy \Rightarrow C_6H_{12}O_6 + 6O_2$$

Raw Materials (Reactants)
CO_2 = carbon dioxide
H_2O = water

Products
$C_6H_{12}O_6$ = glucose
O_2 = oxygen

Plant cells can use this process to manufacture **glucose**, a simple sugar. Some of the glucose is used immediately for cellular respiration, where it is converted to a high energy compound called **ATP**. You might recall from studies of the cell, that the process of creating ATP occurs in the **mitochondria**. Glucose that is not used right away can form long chains called **carbohydrates.** Carbohydrates are long term energy storage, like potatoes and beans. All **autotrophs** can make their own food in this way, unlike **heterotrophs**, which must consume food. When you eat a potato, you are eating the carbohydrates that the plant created from sunlight.

Sun & Energy = yellow
Carbon Dioxide = red
Water = light blue
Photosynthesis= green
Respiration = purple
Glucose = dark blue
Storage Products= brown
ATP = orange
Oxygen = pink

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1. What two types of cells contain chloroplasts? ______________________
2. Autotrophs, like plants, make their own food using energy from ______________________
This process is called ______________________
3. How do heterotrophs obtain their energy? ______________________
4. What are the reactants (raw materials) for photosynthesis? ______________________
5. What simple sugar is produced? ______________________
6. What gas is used in the process? ___________ What gas is released? ___________
7. Where are most photosynthetic cells in plants found? ______________________
8. What compound can be made from glucose and serves as long term energy storage? ______________________

The Structure of the Chloroplast

Chloroplasts are double membrane organelles found in plant cells. Color and the outer membrane light green . Color the inner membrane brown .

Thylakoids contain chlorophyll and other pigments (red, orange, yellow, brown) and are found in stacks called grana. Color the thylakoids dark green , then highlight the stacks of grana with yellow .

These stacks are connected to other stacks by channels called **lamellae**. Color the lamella orange . Grana are surrounded by a gel-like material called stroma.Color the stroma blue.

9. Thylakoids form stacks called ______________. These are connected to each other by ______________

The following equation shows how animals (heterotrophs) use glucose to create energy for the cell, a process called **CELLULAR RESPIRATION**, which occurs in the mitochondria.

$$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6H_2O + energy$$

10. Where does cellular respiration occur in the cell? ______________________

11. Compare the equation for photosynthesis to the equation for cellular respiration. How are they similar?

12. Chloroplasts convert energy from the sun into ______________________
The mitochondria use glucose to produce energy in the form of ________.

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Figure A14. Energy capture (https://www.biologycorner.com/)

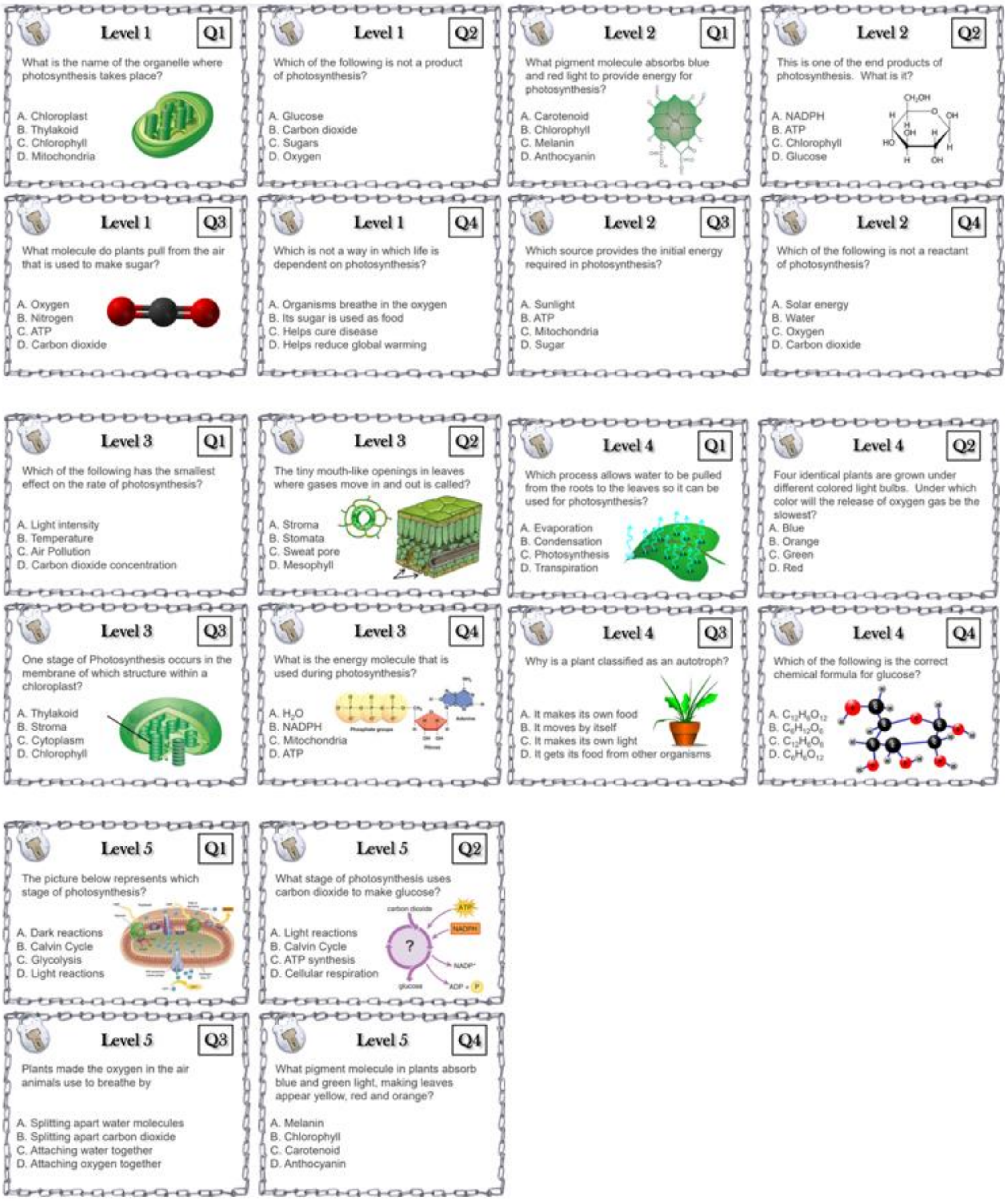
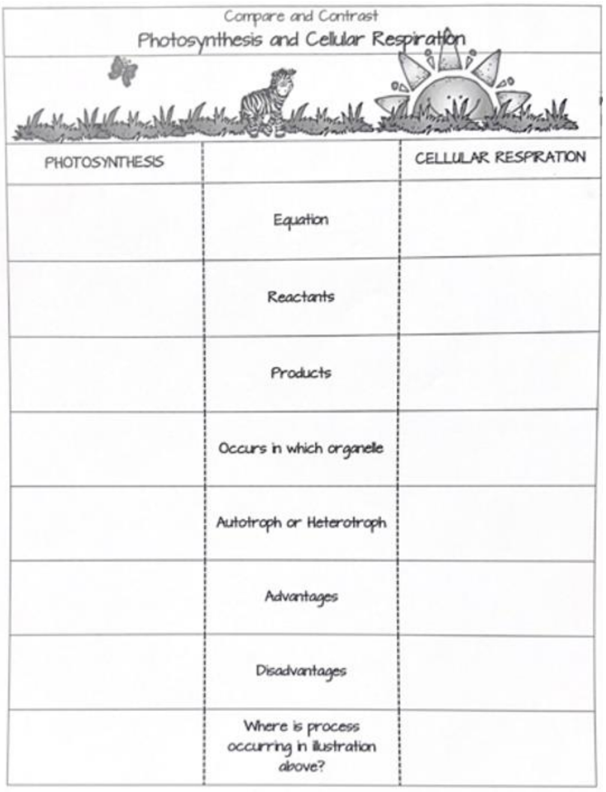


Figure A15. Levels (Source: Escape Room EDU, https://www.teacherspayteachers.com/)



Compare and Contrast
Photosynthesis and Cellular Respiration

PHOTOSYNTHESIS		CELLULAR RESPIRATION
	Equation	
	Reactants	
	Products	
	Occurs in which organelle	
	Autotroph or Heterotroph	
	Advantages	
	Disadvantages	
	Where is process occurring in illustration above?	

Figure A16. Compare & contrast (Source: Author's own elaboration)

- Did you see value in growing your own plant? Yes No
- As the unit progressed were you more interested in learning about photosynthesis and cellular respiration? Yes No
    a. If yes, was this because of our "growing plants" project? Yes No
- Were you excited more than usual to come to class each day because of the project? Yes No
- Do you enjoy projects like these? Yes No

Figure A17. Final questions (Source: Author's own elaboration)

APPENDIX B: LESSON PLANS FOR LEARNING SEGMENT

Lesson Plan 1

Name: Growing Plants Part 1	**Lesson length:** 90 minutes
Grade Level: 8th	**Subject:** Integrated Science

I. Standards	
UT State Standards:	**Standard 8.3.1** Plan and investigate and use the evidence to construct an explanation of how photosynthetic organisms use energy to transform matter. Emphasize molecular and energy transformations during photosynthesis.
Summative (Unit) Assessment:	Completed "Growing Plants Packet" project and presentation
Central Focus:	Students will understand and be able to explain how photosynthetic organisms use energy to transform matter through their investigation.

II. Intended Learning Outcomes	
Learning Objective/Target/Indicator: (Know and Do)	**Know:** Students will explain how photosynthetic organism use energy to transform matter. **Do:** Students will grow their own plants with given materials and record growth and watering data every class period.

III. Academic Language		
Language Function:	Plan, conduct, and explain	
Language Demand		
	Vocabulary:	photosynthesis, matter, mass, chloroplast, chlorophyll, carbon dioxide, glucose, water, energy, cellular respiration
	Syntax:	Presentation slides, videos, games, and worksheets will be used to build vocabulary and background knowledge
	Discourse:	• Providing students, the foundation of photosynthesis • Directing students on what is expected in the packet and presentation

Language Support:	8.3.1 Presentation Slides (figure 4) on vocabulary

IV. Assessment of Student Progress	
Pre-assessment:	Give students an 8.3-unit pre-test (figure 2) on Canvas and record the class average to use for the end-of-unit growth.
Formative assessments:	Students will show their knowledge and understanding through discussion and answers to the daily recap.
Final formative assessment:	Grow a plant through trial and error throughout the 3 weeks. Then, make a final presentation on what was learned, addressing the "Growing Plants" packet's reflection questions, and reverting to the pre-test questions.

V. Preparation	
Students' prior knowledge, skills, and assets:	**Know:** Students know what matter, mass, and energy are from prior units; they understand how they affect one another. I.e., the greater the mass and speed the greater the kinetic energy etc. **Do:** Students will grow their own plants and complete the "growing plants" packet. When students finish the packet, they will then take their outcomes and reflection pieces to create a presentation for the class. **Assets:** Photosynthesis is critical for all living organisms; it is important to make connections of how our ecosystems function.
Student preparation (if applicable):	N/A
Teacher preparation:	• Bean time-lapse video pulled up • Have the pre-test prepared and available on Canvas • Have the 8.3.1-unit slides and notes prepared and printed • Photosynthesis video with guiding question worksheet printed out for students • 38 "Growing Plants" packets printed (in case some get lost) o Materials needed for growing plants project: ▪ Soil ▪ Plastic transparent cups ▪ Small plastic colorful planters ▪ Biodegradable plant pots ▪ Seeds (lima bean, sugar snap peas, and touch-me-not) ▪ Water ▪ Pipettes ▪ Plant name labels and pens
Technology integration:	The pre-test is on Canvas, Google slides are being used for the 8.3.1-unit slides, and use of YouTube for the photosynthesis video, and research will be conducted online.

VI. Addressing Learners' Needs	
Differentiation/Individualization:	• Notes can be completed online or on paper • Packet is on paper, but the project is a mix of hands-on and online
Support for ELLs:	• Para aid support and help • Visual aids • Google translates on Chromebooks • 8.3.1-unit slides linked on Canvas • Pausing throughout YouTube video to go over the guiding questions • Captions on videos for students who are hearing impaired or ELL
Accommodations/Modifications for IEPs/504s:	• Para aid support and help • Pausing throughout YouTube video to go over the guiding questions • Writing the daily agenda on the whiteboard at the front of class • Making every assignment, google slides and worksheet available on Canvas • Extra time to research and create a presentation (monitor student to see an adequate amount of extra time)

VII. Instructional Procedures (including models of instruction, strategies, assessments, differentiation, transitions, etc.)	
Pre-assessment (15 min):	I will give the students 15 minutes to complete the pre-test

Hook (15 min):	• We will watch a timelapse (https://www.youtube.com/watch?v=w77zPAtVTuI) of a bean growing from seed, twice
	  • Prior to watching the video, I will ask the students to observe the plant growth and how they can relate it to energy and matter
	  • After watching the video, we will discuss what observations they made
	    o I will guide them to understand that the plant needed the energy to grow and as the plant grew it also grew its mass
	  • Prior to watching the video, a second time I will ask the students to think of questions that they can relate to energy and matter
	  • After watching the video, we will discuss what questions they made
	    o I will guide them to questions on where did the mass come from? Where is the plant getting energy from? What process is occurring for a plant to grow?

Vocabulary and Foundation (25 minutes):	• Students will receive their 8.3 Unit notes can do online or on paper (this packet goes over every subunit within the unit as a whole) • We will go over the 8.3.1 Slides to get the vocabulary and overall concept embedded in their mind • Following the google slides we will watch about an 8-minute YouTube video on photosynthesis (https://www.youtube.com/watch?v=CMiPYHNNg28) while filling out the guiding questions worksheet (figure 7) o Every 3-5 questions I will pause the video and go over the questions with them to make sure everyone is able to understand and have the information written down for future use

Growing Plants Part 1 (30 min):	• Students will collect their "Growing Plants" packet
	• I will explain what this project is by reading the first page of the packet (regarding parts 1-3) and last page of the packet (regarding the presentation)
	• Then I will go over the timeline
	  o Students will have 7 class periods (about 3 weeks) of data observations
	  o They will then have 2 class periods to finish part 3 of the packets and create their presentations that are due on February 9th.
	• Students will begin on part 1 of the "growing plants" packet and answer questions 1-5
	• When finished students will collect the materials that they chose and put together their planned plant pot using the materials provided.

Assessment (5 min):	• Daily until February 9th (between each lesson) I will provide dated exit tickets (figure 8) for students to track their motivation and understanding throughout the unit, by asking:
	  o List one thing you learned today.
	  o Do you see value in growing your own plant?
	  o Are you motivated to learn more about this unit because of the "growing plants" project?
	  o Have you been interested in what you are learning?
	• Students will also have daily recaps (self-starters) that consist of questions regarding key concepts we learned in the previous classes
	  o Following this lesson, the daily recap (figure 9) will have 4 questions

Lesson Plan 2

Name: Growing Plants Part 2	**Lesson length:** 2 days at 90 minutes each
Grade Level: 8th	**Subject:** Integrated Science

I. Standards	
UT State Standards:	**Standard 8.3.1** Plan and investigate and use the evidence to construct an explanation of how photosynthetic organisms use energy to transform matter. Emphasize molecular and energy transformations during photosynthesis.
Summative (Unit) Assessment:	Completed "Growing Plants Packet" project and presentation
Central Focus:	Students will understand and be able to explain how photosynthetic organisms use energy to transform matter through their investigation.

II. Intended Learning Outcomes	
Learning Objective/Target/Indicator: (Know and Do)	**Know:** Students will explain how photosynthetic organism use energy to transform matter. **Do:** Students will grow their own plants with given materials and record growth and watering data every class period.

III. Academic Language		
Language Function:	Plan, conduct, and explain	
Language Demand		
	Vocabulary:	photosynthesis, matter, mass, chloroplast, chlorophyll, carbon dioxide, glucose, water, energy, cellular respiration
	Syntax:	Presentation slides, games, and worksheets will be used to build vocabulary and background knowledge
	Discourse:	• Providing students, the foundation of photosynthesis • Directing students on what is expected in the packet and presentation
Language Support:	8.3.1 Presentation Slides on vocabulary: 8.3 Slides	

IV. Assessment of Student Progress	
Pre-assessment:	Give students an 8.3-unit pre-test on Canvas and record the class average to use for the end-of-unit growth.
Formative assessments:	Students will show their knowledge and understanding through discussion, packet completion, and answers to the daily recap.
Final formative assessment:	Grow a plant through trial and error throughout the 3 weeks. Then, make a final presentation on what was learned, addressing the "Growing Plants" packet's reflection questions, and reverting to the pre-test questions.

V. Preparation	
Students' prior knowledge, skills, and assets:	**Know:** Students know what matter, mass, and energy are from prior units; they understand how they affect one another. i.e., the greater the mass and speed the greater the kinetic energy etc. Students now know what photosynthesis is, requires, and produces. They understand that carbon and water are huge proponents of plant growth and mass. **Do:** Students will grow their own plants and complete the "growing plants" packet. When students finish the packet, they will then take their outcomes and reflection pieces to create a presentation for the class. **Assets:** Photosynthesis is critical for all living organisms; it is important to make connections of how our ecosystems function.
Student preparation (if applicable):	Students have their "growing plants" packet in class and part 2 completed.
Teacher preparation:	• Chromebooks charged and ready for student use • Extra packets for any students who lost or forgot theirs
Technology integration:	Using Google Slides

VI. Addressing Learners' Needs	
Differentiation/Individualization:	• Using technology and paper packets • Visual aids • Individual work • Can work with a partner on the presentation if the same exact methods were used throughout the whole project
Support for ELLs:	• Para aid support and help • Visual aids • Google translate on Chromebooks • 8.3.1-unit slides linked on Canvas • Reiterating assignment if needed
Accommodations/Modifications for IEPs/504s:	• Para aid support and help • Writing the daily agenda on the whiteboard at the front of class • Making every assignment, google slides and worksheet available on Canvas • Extra time to research and create a presentation (monitor student to see an adequate amount of extra time) • Allow presenting to me during advisory instead of in front of class • Cut down on required pieces of the presentation rubric (dependent on the severity of learning disability)

VII. Instructional Procedures (including models of instruction, strategies, assessments, differentiation, transitions, etc.)	
Prior to lesson plan 2 class time:	In the span of three weeks from lesson plan 1 to now lesson plan 2, we have had 6 classes. During those classes, we: • Have completed the exit tickets mentioned at the end of the prior lesson plan • Saw in real time how aquatic plants produce oxygen bubbles by splitting into groups and collecting an elodea aquatic plant and a test tube that is filled with 3/4 of water. We turned off the lights in the classroom and placed the aquatic plant in the test tube and recorded how many bubbles were produced within the span of 5 minutes. We then discussed our results as a class. Then we took the aquatic plant out of the test tube and refilled 3/4 of the test tube with water. We then went outside and recorded how many bubbles were produced for another 5 minutes. We went inside and discussed our findings as a class. After our discussion I had the students fill in a text box entry on Canvas with the prompt: "write a conclusion for how light and photosynthesis are connected by using the evidence from their experiment. What can you see being produced?" • Students completed a daily recap asking, "where does the mass of a plant come from?" and "List 3 necessary things for a plant to grow." • I had students read an article titled, "How does your garden grow?" (figure 10) and make extensive annotations throughout it with reflection questions at the end - this took 1.5 classes. • Completed a handout on how chloroplasts capture their energy (figure 11) • Completed a photosynthesis escape room (figure 12) • Went over 8.3 Unit Slides and had students complete their 8.3 Unit Slide Notes o Following these slides, they completed a handout (figure 13) comparing photosynthesis and cellular respiration
Hook (10 min):	Students will take 5 minutes to look at the progress of other students' plants and see their methods • I will ask students to think critically while observing others' plants and see if the plants with the most growth and least growth had similar methods individually
Growing Plants Part 2 (80 min):	• Students will get their "Growing Plants" packet out • I will explain that they have one week to complete the presentation but only 2 class periods (this class day and the next class day) but after those days they will need to work on it on their own time • I will go over the part 3 reflection questions with the students and then the part 4 presentation rubric.
	• Following my initial instructions and rubric, students will have full creativity for their presentation. Students will have the rest of this class and the following class to work on their reflection questions and presentation. o During this time, I will be actively monitoring students and checking in on how they are doing and keeping myself available for assisting and answering their questions.

Assessment (5 min):	• Daily until February 21st (between each lesson) I will provide dated exit tickets for students to track their motivation and understanding throughout the unit, by asking:
	    o List one thing you learned today.
	    o Do you see value in growing your own plant?
	    o Are you motivated to learn more about this unit because of the "growing plants" project?
	    o Have you been interested in what you are learning?
	• Students will also have daily recaps (self-starters) that consist of questions regarding key concepts we learned in the previous classes.

Lesson Plan 3

Name: Growing Plants Part 3	**Lesson length:** 90 minutes (approximately 1.5 class periods)
Grade Level: 8th	**Subject:** Integrated Science

I. Standards	
UT State Standards:	**Standard 8.3.1** Plan and investigate and use the evidence to construct an explanation of how photosynthetic organisms use energy to transform matter. Emphasize molecular and energy transformations during photosynthesis.
Summative (Unit) Assessment:	Completed "Growing Plants Packet" project
Central Focus:	Students will understand and be able to explain how photosynthetic organisms use energy to transform matter through their investigation.

II. Intended Learning Outcomes	
Learning Objective/Target/Indicator: (Know and Do)	**Know:** Students will explain how photosynthetic organism use energy to transform matter. **Do:** Students will grow their own plants with given materials and record growth and watering data every class period.

III. Academic Language		
Language Function:	Plan, conduct, and explain	
Language Demand		
	Vocabulary:	photosynthesis, matter, mass, chloroplast, chlorophyll, carbon dioxide, glucose, water, energy, cellular respiration
	Syntax:	Presentation slides, videos, games, and worksheets will be used to build vocabulary and background knowledge
	Discourse:	• Providing students, the foundation of photosynthesis • Directing students on what is expected in the packet and presentation
Language Support:	8.3.1 Presentation Slides on vocabulary: 8.3 Slides	

IV. Assessment of Student Progress	
Pre-assessment:	Give students an 8.3-unit pre-test on Canvas and record the class average to use for the end-of-unit growth.
Formative assessments:	Students will show their knowledge and understanding through discussion and answers to the daily recap.
Final formative assessment:	Grow a plant through trial and error throughout the 3 weeks. Then, make a final presentation on what was learned, addressing the "Growing Plants" packet's reflection questions, and reverting to the pre-test questions.

V. Preparation	
Students' prior knowledge, skills, and assets:	**Know:** Students know what matter, mass, and energy are from prior units; they understand how they affect one another. i.e., the greater the mass and speed the greater the kinetic energy etc. Students now know what photosynthesis is, requires, and produces. They understand that carbon and water are huge proponents of plant growth and mass. Students know the difference and correlation between photosynthesis and cellular respiration. **Do:** Students will grow their own plants and complete the "growing plants" packet. When students finish the packet, they will then take their outcomes and reflection pieces to create a presentation for the class. **Assets:** Photosynthesis is critical for all living organisms; it is important to make connections of how our ecosystems function.
Student preparation (if applicable):	Students will have parts 3 and 4 completed and ready to present.
Teacher preparation:	• Make sure the Canvas assignment for the presentation is published and gives a 'submit assignment' option for students to turn in their presentation slides so I can project them on the board
Technology integration:	Using Google Slides, Canvas, and projection.

VI. Addressing Learners' Needs	
Differentiation/Individualization:	• Packet is on paper, but the project is a mix of hands-on and online
Support for ELLs:	• Para aid support and help • Visual aids • Google translate on Chromebooks • 8.3.1-unit slides linked on Canvas
Accommodations/Modifications for IEPs/504s:	• Para aid support and help • Writing the daily agenda on the whiteboard at the front of class • Making every assignment, google slides and worksheet available on Canvas • Extra time to research and create a presentation (monitor student to see an adequate amount of extra time) • Allow presenting to me during advisory instead of in front of class • Cut down on required pieces of the presentation rubric (dependent on the severity of learning disability)

<table>
<tr><th colspan="2">VII. Instructional Procedures (including models of instruction, strategies, assessments, differentiation, transitions, etc.)</th></tr>
<tr><td>Preparation (10 min):</td><td>I will give the students 10 minutes to submit their slides to Canvas and get ready to present.</td></tr>
<tr><td>Presentation Day (rest of class time + approx. 30 min next class period):</td><td>• Students will be required to submit their presentation on Canvas, but it will take 2 class periods to present
• Going alphabetically by last names students will present their project (required time 5-7 minutes)
    o B1 has 18 students (at most 126 min)
    o B2 has 15 students (at most 105 minutes)
• As students present, I will be grading them on Canvas based off the rubric</td></tr>
<tr><td>After Presentations:</td><td>• After the presentations are completed, we will go full circle and address their understandings now. I will ask them to talk to their elbow partners first, answering this question, “how do photosynthetic organisms use energy to transform matter?” Then, I will facilitate a class discussion by asking what each partner group said. I will make sure emphasis is put on molecular and energy transformations during photosynthesis.
• I will have the students fill out one last exit ticket (figure 14) addressing the following:
    o Did you see value in growing your own plant?
    o As the unit progressed were you more interested in learning about photosynthesis and cellular respiration?
        ▪ If yes, was this because of our “growing plants” project?
    o Were you excited more than usual to come to class each day because of the project?
    o Do you enjoy projects like these?</td></tr>
</table>