Student Outcomes from High-Quality Project-Based Learning: A Case Study for PBLWorks

Carla M. Evans, Ph.D.

National Center for the Improvement of Educational Assessment

December 20, 2019

Table of Contents

Executive Summary

This single teacher case study explores the pathway to student outcomes resulting from the design and implementation of one teacher-created project that is aligned to the gold standard project design elements. The teacher-created project was designed based on training received during PBL 101. The sample consists of two sections of high school chemistry taught by one teacher with approximately forty students in early fall 2019. A range of qualitative and quantitative measures were used to collect evidence about one teacher's journey of PBL implementation from PBL 101 training to student outcomes. These measures included classroom observations, student focus groups, teacher interviews, student and teacher survey instruments, and student outcome data. Findings are summarized in the pathway graphic below and show how student outcomes are a direct outflow from the quality of the project design, teaching practices, and student experiences. Overall, students in this single teacher case study had overwhelmingly positive outcomes that promoted their academic success and application of student success skills.

Gold Standard Project Design	Gold Standard Project Design	Teacher Practices	Student Experiences	Student Outcomes
The teacher was confident and ready to implement Gold Standard PBL, based on PBL 101 training.	The project had perfect alignment to the *Gold Standard Design Elements*	The teacher demonstrated use of all *Gold Standard Project Based Teaching Practices*	In general, students reported positive experiences relative to the criteria in the *HQPBL Framework*	62% of students scored proficient or above on the culminating performance task that required students to transfer their understanding of important science practices and chemistry concepts to a novel situation. 83% of students demonstrated proficient or above skills in self-direction and 71% in collaboration based on student reflections and teacher observations throughout the project.

Introduction

PBLWorks contracted with the Center for Assessment to explore student outcomes resulting from the design and implementation of one teacher-created project that is aligned to the gold standard (GS) project design elements. The teacher-created project was designed based on training received during PBL 101. Though there is emerging research that shows high-quality project-based learning (HQPBL) can improve student outcomes, these studies focus on pre-packaged PBL curriculum with some professional development. There is limited evidence about student outcomes resulting from PBL services using teacher-designed projects.

The purpose of this study is to examine one teacher's journey of PBL implementation from PBL 101 training to student outcomes based on the following pathway (Figure 1). The research questions are taken directly from the hypothesized pathway and are used to organize this report.

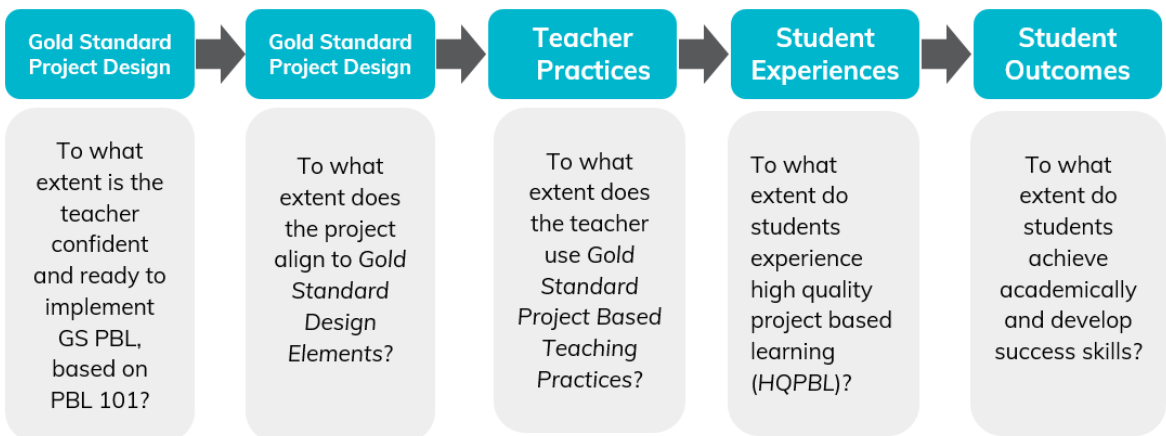

Figure 1. Pathway from PBL 101 Training to Student Outcomes

Methodology

Study Context

This single teacher case study took place in one high school chemistry teacher's classroom in New Hampshire. The high school reports student progress on academic and non-academic competencies (i.e., student success skills) to parents each trimester. As such students are used to being graded on both academic content and use of student success skills.

The teacher, Sheila[i], is in her 25th year of teaching high school chemistry, and has also served as the science department coordinator for the last eight years. Sheila was an atmospheric chemist for eight years prior to teaching and earned both a bachelor's and master's degree in chemistry.

Sheila received PBL 101 professional development during the summer of 2019. Sheila has extensive experience designing and implementing high-quality performance-based instruction and assessment as a result of her experience in New Hampshire's federally-approved innovative assessment system known as PACE (Performance Assessment of Competency Education)[ii]. Sheila has served as one of the high school chemistry content leads for the PACE innovative assessment system over the last five years. Sheila has not previously received training in project-based learning. Sheila was asked and volunteered to take part in this study as a result of her extensive experience.

Project Description

Sheila created a HQPBL unit on Transfer of Energy after receiving PBL 101 training[iii]. Sheila implemented this unit over the course of a few weeks to two sections of high school chemistry students towards the beginning of the school year (mid-September to first week in October 2019). The project planner can be found in Appendix A.

Sheila chose Transfer of Energy because it is an important topic in high school chemistry and is a topic about which many students have misconceptions, even though it is something they experience on a daily basis. The project was specifically designed to elicit the student success skills of self-direction and collaboration, as well as mastery of academic core content and science practices in chemistry. The scoring guide/rubric for the Transfer of Energy project can be found in Appendix B. The teacher-created rubric used to evaluate the student success skills of self-direction and collaboration can be found in Appendix C. The culminating performance-based assessment that Sheila created as an individual measure of students' knowledge and skills of the essential concepts from the unit can be found in Appendix D.

Sample

Two sections of high school chemistry with a total of thirty-seven students participated in this study. The students were predominantly female (62%) and almost 60% were 11th graders (see Figure 2). The class sections were heterogeneous in terms of ability, but had limited demographic diversity[iv]. This is a reflection of the lack of demographic diversity in most New Hampshire high schools, rather than something unique about this grouping of students[v].

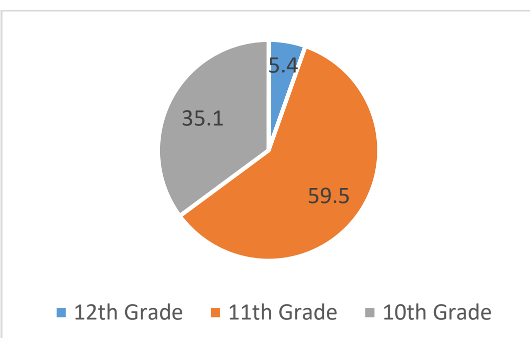

Figure 2. Percent of Students by Grade Level (N = 37)

Measures and Analysis

A range of qualitative and quantitative measures were used to collect evidence about the pathway to student outcomes resulting from the design and implementation of one teacher-created project that is aligned to the gold standard (GS) project design elements. These measures included classroom observations, student focus groups, teacher interviews, student and teacher survey instruments, and student outcome data. Data was collected from mid-September to early October 2019—the student outcome data was collected once grading was complete.

The qualitative measures included classroom observations, student focus groups, teacher interview, and open-ended responses on the student and teacher survey. The interview questions for the teacher interviews and student focus groups can be found in Appendices J and K, respectively. The teacher interview questions were created to probe the extent to which the teacher used gold standard (GS) project-based teaching practices and students experienced HQPBL. The student focus group questions were created using the six criteria in the HQPBL framework discussed in more detail under the quantitative measures below. The open-ended questions and responses for the students and teacher can be found in Appendix I. All qualitative data were analyzed using open theme coding and compared with analysis from quantitative measures to triangulate findings and identify similarities and differences.

The quantitative measures included student and teacher survey data and student outcome data. The student and teacher survey were designed as parallel forms using the HQPBL framework that includes six criteria: (1) intellectual challenge and accomplishment; (2) authenticity; (3) public product; (4) collaboration; (5) project management; and (6) reflection. The student and teacher survey were administered via Qualtrics, an online survey platform—all personally identifiable student information was removed prior to analyses. The construct map for the student and teacher surveys can be found in Appendix E. The student and teacher survey instruments can be found in Appendices F and G, respectively. The student outcome data collected was student performance on the Energy Transfer performance task by rubric dimension and overall, as well as student self-report reflection data on self-direction and collaboration student success skills and teacher grades on the two success skills.

All quantitative measures were analyzed using descriptive statistics such as means and standard deviations for continuous data or frequency counts and percentages for nominal or ordinal data. Appendix H contains item-level descriptive statistics and histograms for the student and teacher survey items. Appendix L contains student outcomes on the Energy Transfer Performance Task rubric and student success skill data on collaboration and self-direction created by the teacher. The final student grade on the performance task was an average across the rubric dimensions. The final self-directed learner and collaborative worker grades were given based on teacher observations and student self-reported reflections with the teacher as the final arbiter of success skill grades.

Key Findings

The key findings are organized according to the pathway (Figure 1) which flows from PBL 101 training to student outcomes.

To what extent is the teacher confident and ready to implement GS PBL, based on PBL 101?

On the exit survey at the end of PBL 101 training, Sheila self-reported that she was confident and ready to implement GS PBL. She said she had been implementing what she thought was PBL in her classroom already, but now realized she "had much to learn." Sheila shared similar reflections during the teacher interview. Specifically, that PBL 101 training was really helpful in terms of understanding how to design engaging and collaborative projects. Sheila used the project planner to design the Energy Transfer unit and thought the planner provided a helpful heuristic and guide.

To what extent does the project align to GS design elements?

There are eight criteria used to evaluate the quality of a project design. These criteria include: (1) key knowledge, understanding and success; (2) challenging problem or question; (3) sustained inquiry; (4) authenticity; (5) student voice and choice; (6) reflection; (7) critique and revision; and (8) public product. A Gold Standard (GS) Project Design Elements Scoring Guide prototype created by PBLWorks was used by the researcher to evaluate the quality of the Energy Transfer project design (Appendix A contains project planner). The scoring guide is in Table 1 below.

Each criteria had multiple indicators that were scored with a "0" if there was insufficient evidence of quality or "1" if there was sufficient evidence of quality. Then a qualitative judgment about each of the eight criteria was made based upon the inclusion of sufficient or insufficient evidence. If there was sufficient evidence, the element was scored "Yes" and if there was insufficient evidence the element was scored "No." Overall, the Energy Transfer unit received a perfect score (8/8)—which means the project does align to the GS Design Elements. This is consistent with the teacher's self-ratings on the PBL 101 exit survey in which she rated the presence of GS Design Elements in this project at the highest level—"to a great extent."

Table 1.

Gold Standard Project Design Elements Scoring Guide Prototype

CRITERIA	Key: 0=insufficient evidence of quality 1=sufficient evidence of quality	
KEY KNOWLEDGE, UNDERSTANDING, AND SUCCESS SKILLS	The project is focused on teaching students' key knowledge and understanding derived from standards and central to academic subject areas.	1
	Success skills are explicitly targeted to be taught and assessed, such as critical thinking, collaboration, creativity, and project management.	1
	Overall Element Y/N	Yes

CHALLENGING PROBLEM OR QUESTION	Open ended; there is more than one possible answer	1
	Engaging for students (Understandable and inspiring to students).	1
	Aligned with learning goals; to answer it, students will need to gain the intended knowledge, understanding, and skills.	1
	Overall Element Y/N	Yes
SUSTAINED INQUIRY	Inquiry is sustained over time.	1
	Inquiry is academically rigorous.	1
	Inquiry is driven by student-generated questions throughout the project.	1
	Overall Element Y/N	Yes
AUTHENTICITY	The project has an authentic context: involves real-world tasks, tools, and quality standards.	1
	The project makes an impact on the world.	1
	The project speaks to students' personal concerns, interests, or identities.	0
	Overall Element Y/N	Yes
STUDENT VOICE & CHOICE	Provides opportunities for students to express their voice and make choices on important matters (topics to investigate, questions asked, texts and resources used, people to work with, products to be created, use of time, organization of tasks)	1
	Students have opportunities to take significant responsibility and work as independently from the teacher as is appropriate, with guidance.	1
	Overall Element Y/N	Yes
REFLECTION	Students and teachers engage in thoughtful and ongoing reflection during the project and after the project related to what and how they learn.	1
	Students and teachers engage in thoughtful and ongoing reflection about the project's design and management.	1
	Overall Element Y/N	Yes
CRITIQUE & REVISION	Includes regular structured opportunities for students to give and receive feedback about the quality of their products and work-in-progress from peers, teachers, and if appropriate, from others beyond the classroom.	1
	Students use feedback about their work to revise and improve it.	1
	Overall Element Y/N	Yes
PUBLIC PRODUCT	Includes opportunities for students to share their work with an audience beyond classmates and teachers.	1
	Students are asked to explain the reasoning behind choices they made, their inquiry process, how they worked, and what they learned.	1
	Overall Element Y/N	Yes
	Gold Standard Design Elements	8

To what extent does the teacher use GS project-based teaching practices?
Multiple sources of evidence were used to explore the extent to which the teacher used GS Project Based Teaching Practices. These sources include multiple classroom observations and teacher interview questions. The classroom observations were spaced out so that the researcher could observe the teacher at the beginning of the project and the end of the project. The teacher interview questions probed the extent to which the teacher used seven practices aligned with the GS Project Based Teaching Practices: (1) design and plan; (2) align to standards; (3) build the culture; (4) manage activities; (5) scaffold student learning; (6) assess student learning; and (7) engage and coach. These same seven elements were also used as the focus for classroom observations.

Table 2 below contains a researcher-designed scoring guide prototype for the GS Project Based Teaching Practices using the language from the GS Project Based Teaching Practices rubric created by PBLWorks. The same processes and procedures used with the GS Project Design Elements Scoring Guide were applied. Overall, the teacher demonstrated GS Project Based Teaching Practices with a perfect score (7/7).

Table 2.
Gold Standard Project Based Teaching Practices Scoring Guide Prototype

	Key: 0=insufficient evidence of quality teaching practice 1=sufficient evidence of quality teaching practice	
DESIGN & PLAN	Project includes all Essential Project Design Elements as described on the Project Design Rubric.	1
	Plans are detailed and include scaffolding and assessing student learning and a project calendar, which remains flexible to meet student needs.	1
	Resources for the project have been anticipated to the fullest extent possible and arranged well in advance.	1
	Overall Element Y/N	Yes
ALIGN TO STANDARDS	Criteria for products are clearly and specifically derived from standards and allows demonstration of mastery.	1
	Scaffolding of student learning, critique and revision protocols, assessments and rubrics consistently refer to and support student achievement of specific standards.	1
	Overall Element Y/N	Yes
BUILD THE CULTURE	Norms to guide the classroom are co-crafted with and self-monitored by students.	0
	Student voice and choice is regularly leveraged and ongoing, including identification of real-world issues and problems students want to address in projects.	0
	Students usually know what they need to do with minimal direction from the teacher.	1

	Students work collaboratively in healthy, high-functioning teams, much like an authentic work environment; the teacher rarely needs to be involved in managing teams.	1
	Students understand there is no single "right answer" or preferred way to do the project, and that it is OK to take risks, make mistakes, and learn from them.	1
	The values of critique and revision, persistence, rigorous thinking, and pride in doing high-quality work are shared, and students hold each other accountable to them.	1
	Overall Element Y/N	Yes
MANAGE ACTIVITIES	The classroom features an appropriate mixture of individual and teamwork time, whole group and small group instruction.	1
	Classroom routines and norms are consistently followed during project work time to maximize productivity.	1
	Project management tools (group calendar, contract, learning log, etc.) are used to support student self-management and independence.	1
	Realistic schedules, checkpoints, and deadlines are set but flexible; no bottlenecks impede workflow.	0
	Well-balanced teams are formed according to the nature of the project and student needs, with appropriate student voice and choice.	1
	Overall Element Y/N	Yes
SCAFFOLD STUDENT LEARNING	Each student receives necessary instructional supports to access content, skills, and resources; these supports are removed when no longer needed.	1
	Scaffolding is guided as much as possible by students' questions and needs; teacher does not "front-load" too much information at the start of the project, but waits until it is needed or requested by students.	1
	Key success skills are taught using a variety of tools and strategies; students are provided with opportunities to practice and apply them, and reflect on progress.	1
	Student inquiry is facilitated and scaffolded, while allowing students to act and think as independently as possible.	1
	Overall Element Y/N	Yes
ASSESS STUDENT LEARNING	Project products and other sources of evidence are used to thoroughly assess subject-area standards as well as success skills.	1
	Individual student learning is adequately assessed, not just team-created products.	1
	Formative assessment is used regularly and frequently, with a variety of tools and processes.	1

	Structured protocols for critique and revision are used regularly at checkpoints; students give and receive effective feedback to inform instructional decisions and students' actions.	1
	Regular, structured opportunities are provided for students to self-assess their progress and, when appropriate, assess peers on their performance.	0
	Standards-aligned rubrics are used by students and the teacher throughout the project to guide both formative and summative assessment.	1
	Overall Element Y/N	Yes
ENGAGE & COACH	The teacher's knowledge of individual student strengths, interests, backgrounds, and lives is used to engage them in the project and inform instructional decision-making.	0
	Students and the teacher use standards to co-define goals and benchmarks for the project (e.g., by co-constructing a rubric) in developmentally appropriate ways.	0
	Students' enthusiasm and sense of ownership of the project is maintained by the shared nature of the work between teachers and students.	1
	Student questions play the central role in driving the inquiry and product development process; the driving question is actively used to sustain inquiry.	1
	Appropriately high expectations for the performance of all students are clearly established, shared, and reinforced by teachers and students.	1
	Individual student needs are identified through close relationships built with the teacher; needs are met not only by the teacher but by students themselves or other students, acting independently.	1
	Students and the teacher reflect regularly and formally throughout the project on what and how students are learning (content and process); they specifically note and celebrate gains and accomplishments.	0
	Overall Element Y/N	Yes
	Gold Standard Teaching Elements	7

To what extent do students experience HQPBL?
Students were asked about their experiences during the project using student focus group questions and survey items designed to probe their perceptions with respect to six criteria in the HQPBL framework: intellectual challenge and accomplishment (Intell), authenticity (Auth), collaboration (Coll), project management (ProjM), reflection (Refl), and public product (Publ).

Results from the student survey shows that in many cases the full range of student responses were present on the 0 to 10 scale (see Appendix H). This suggests that different students experience PBL differently with respect to the criteria found in the HQPBL framework, even though most item means were around 6.0-7.5 out of 10.

Figure 3 below shows student survey item means with 95% confidence interval error bars applied. The items are named according to the HQPBL framework describing student experiences. For example, Refl6.2s in Figure 3 refers to an item about the reflection criteria in the HQPBL framework. The survey questions themselves can be found in Appendix E.

The highest reported item across students was about working with a group or team to complete the majority of the project (Coll4.1s: M = 8.26, SD = 2.53). The lowest reported item across students was about engaging in work that connected to their personal interests or concerns (Auth2.2s: M = 4.29, SD = 2.71). This finding suggests that though students were able to choose the format for their final public product, this was not perceived by students as personalized learning (in general).

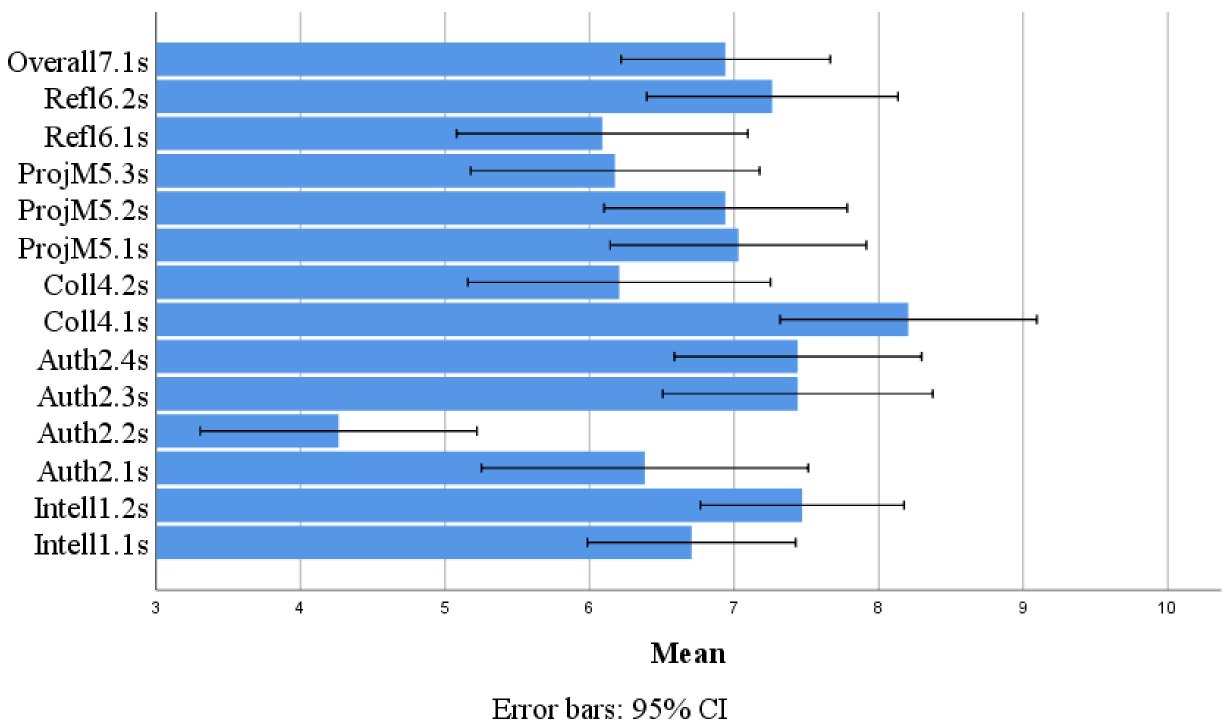

Figure 3. Item Means and 95% Confidence Interval Error Bars on Student Survey Items

Findings from analysis of the open-ended survey items and student focus group data provide support for and nuance to the quantitative results. For example, students explained that they were inspired to work harder and produce better quality final products because they had choice in the public product (Auth2.4s) and the project had an authentic audience with real-world connections beyond school (Auth2.1s & Auth2.3s), but this didn't mean that they found the project itself to be personalized to their interests or concerns (Auth2.2s). These qualitative insights explain differences in the four authenticity item means.

Overall, students reported they found the project "interesting", "challenging", "engaging", and "enjoyable". Many students also reported that the project seemed relevant and meaningful due to the real-world application of skills they thought would be useful beyond school. Negative comments centered on the quick time requirements of the project which made project completion stressful and issues with group members not "pulling their weight".

The teacher also responded to a parallel form of the student survey where she was asked questions about how she perceived students' experiences during the project based on the criteria in the HQPBL framework. For example, Table 3 below shows one of the survey items about the reflection criteria in the HQPBL framework—Refl6.2—and how the teacher was asked to rate the extent to which "my students thought about how they could improve their own and others' work during this project" on a 0-10 agreement scale. The teacher version was designed to mirror the student version in order to examine the extent to which the teacher had similar perceptions of student experiences as the students themselves. The full construct map for the surveys is in Appendix E.

Table 3.
Example of Student and Teacher Version of Survey Item (Refl6.2)

	Student Version	**Teacher Version**	**Item Response**
Refl6.2	I thought about how I could improve my own and others' work during this project.	My students thought about how they could improve their own and others' work during this project.	0-10 agreement scale

Overall, as illustrated in Figure 4 below, the teacher tended to report higher ratings on the 0-10 agreement scale on each item in comparison to the students. The teacher rated student experiences on each item a 7 or above, except for the reflection item just discussed above. In her response to the open-ended survey item Refl6.4, the teacher explained that she thought she "could have done better" designing the project so that students "would need to pause during the project to think about how they could make their final product better." Time was the barrier to providing more opportunities for student reflection as the teacher "did not give them [the students] endless time in the lab so some of them were not able to make their final project better." Appendix H contains a side-to-side comparison of student and teacher responses on the 0-10 agreement scale by item.

Figure 4. Item Reponses on Teacher Survey Items

To what extent do students achieve academically and develop success skills?

Academic Success

The project was designed to teach and elicit student demonstration of science practices through disciplinary core ideas from the Next Generation Science Standards. The science practices emphasized in this project required students to generate testable questions, plan and carry out investigations, analyze and interpret data, communicate findings, and develop arguments using evidence. The disciplinary core ideas included flow of energy, the law of conservation of energy, and specific heat (HS-PS3-4, CE1).

The academic success of students was promoted in this project because the teacher expertly designed the learning experiences in the project to teach important science content through hands-on experimentation and investigation. For example, the teacher designed a collaborative project that required students to demonstrate their understanding of the science content standards and practices, culminating in a final public product of students' choice. In the open response question to the student survey, students explained how the experience challenged them to learn deeply or think critically (see Intell1.3s). Many students indicated that the science practices—such as generating testable questions, designing and carrying out investigations, analyzing and interpreting data—challenged them to apply their learning about transfer of energy in a real-world context.

The teacher-designed project also promoted academic success because students were placed into heterogeneous groups of four students. This allowed students of all abilities to benefit from other students' background knowledge and prior experience. But the project did not end with a collaborative project. Instead, the project ended with a culminating performance task, "Now You're Cooking!" that allowed the teacher to examine the extent to which each student was able to independently transfer their knowledge and skills from one context (beverage stones) to a new context (cookware)(see Appendix D). One student, for example, came up to the teacher while completing the performance task and told her she did not know how to create a data table because her group members had created it in the collaborative project. The teacher would not have known that this student did not know how to create a data table and use it to organize data without the independent measure of student knowledge and skill.[vi]

Table 4 below provides descriptive statistics on student performance on the Energy Transfer Performance Task by rubric dimension. Overall, students tended to score highest on the rubric dimension related to generating testable questions (M = 3.19, SD = 0.61) and the lowest on planning the procedure (M = 2.76, SD = 0.67). The difference between the highest and lowest rubric dimension average is only about ½-point out of a 4-point rubric (M diff = 0.43), which is relatively small. A mean around 3.0 on a 4-point rubric indicates that these students, on average, scored at the proficient level on most rubric dimensions, though there is variability as indicated by the standard deviations.

Table 4.
Descriptive Statistics on Energy Transfer Performance Task Rubric Dimensions (N=37)

	Generating Testable Questions	Planning the Procedure	Analyzing and Interpreting Data	Communicating Findings	Energy & Matter
Mean	3.19	2.76	3.08	2.93	3.07
SD	0.61	0.67	1.04	0.87	0.85
Min	2	2	1	1	1
Max	4	4	4	4	4

When all five rubric dimensions are averaged by student, the distribution of student grades on the culminating performance task ranges from 1.40 to 4.00 (see Figure 5; orange line is the overall mean for all students across rubric dimensions, M = 3.03). This relatively large range on a 1.00 to 4.00 scale shows that the performance task was sensitive enough to pick up differences in student achievement. Given that a 3.0 or higher on a 4-point scale indicates proficiency, 62% (almost two-thirds) of students scored proficient or above on the culminating performance task that required students to transfer their understanding of important science practices and chemistry concepts to a novel situation. This student performance data provides the teacher with real-time, high-quality, actionable information about student academic success in order to target enrichments, supports and interventions to students in the next unit of study and report out to students and parents on student progress towards proficiency in chemistry at this point in the year.

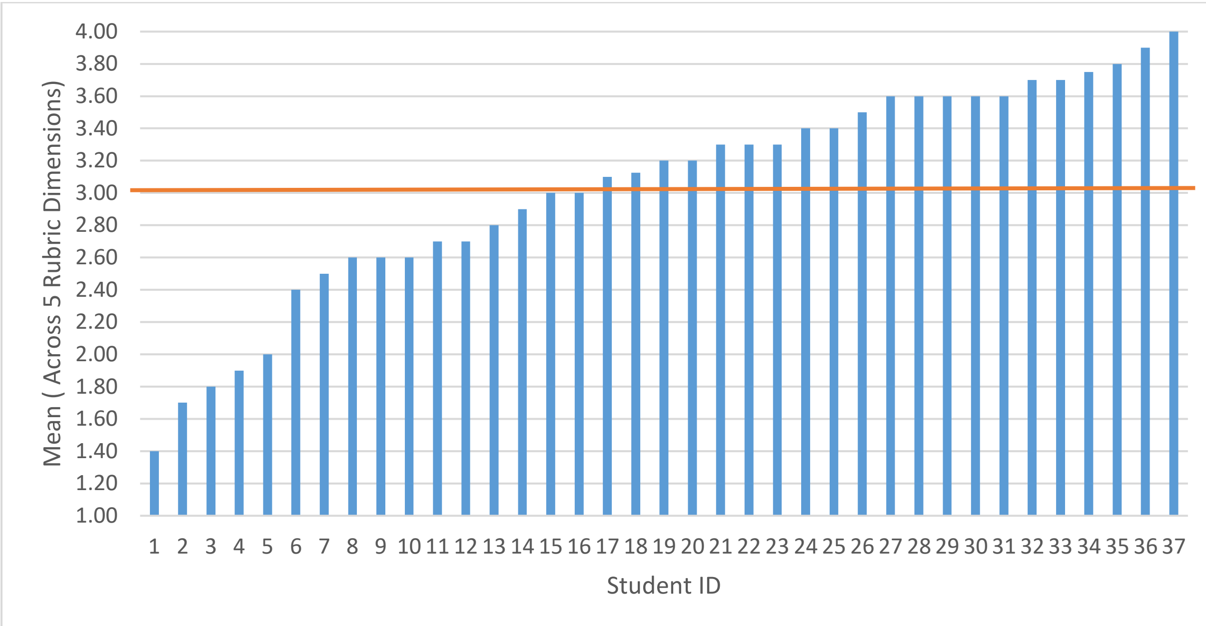

Figure 5. Overall Performance Task Mean by Student ID

Appendix M contains student work generated from the Energy Transfer unit for one group of four students. This includes the final public product created by the group, formative lab reports, and the culminating performance task. The student work products illustrate the level of rigor expected of students in relation to the science practices and disciplinary core ideas emphasized in this project and the ways in which students of various achievement levels completed each aspect of the project.

Success Skill Development

Self-Direction

The teacher designed the project so that it was intentionally open-ended and required student self-direction. When students asked her a question, she would return their question with a question. During student focus groups, many students shared frustration with wanting more teacher direction and scaffolding during the project of what to do and how to do it. One student said: “Freedom was nice, but [I] didn’t always know what to do with that freedom.” Some students expressed that the project was unstructured and open-ended, which was different from prior schooling experiences. Student perceptions about their struggle with the unstructured nature of this project may be amplified because this project was implemented at the start of the school year—though these are high school students who hypothetically would have experienced this type of learning process in prior schooling experiences.

Many students commented on the ways in which the collaborative project required them to employ self-direction and required a level of management that felt difficult for some students. In the open-response section on the student survey related to project management, students explained how they needed to manage themselves and other team members in order to be successful in this project (ProjM5.4s). Specifically, many students talked about setting up a plan or goals, helping keep themselves and/or their teammates on track, monitoring group progress, and time/task management.

In order to assign a grade or score to students on self-direction, the teacher asked students to reflect on their level of self-direction using two questions on a 4-point rubric scale. One question was about the extent to which students engaged and managed their time and work throughout the process. The second question inquired about students' ability to monitor and adapt their course of action based upon what happened during the investigation/experimentation. The majority of students (>75%) placed themselves in Levels 3 or 4 on both questions (see Appendix L). The teacher tended to agree with most students as evidence by the distribution of student scores (green bars) versus teacher scores (yellow bars) on self-direction (see Figure 6). Student scores/grades were computed by taking the average across the two questions. Overall, 83% of students demonstrated proficient or above skills in self-direction according to the teacher score.

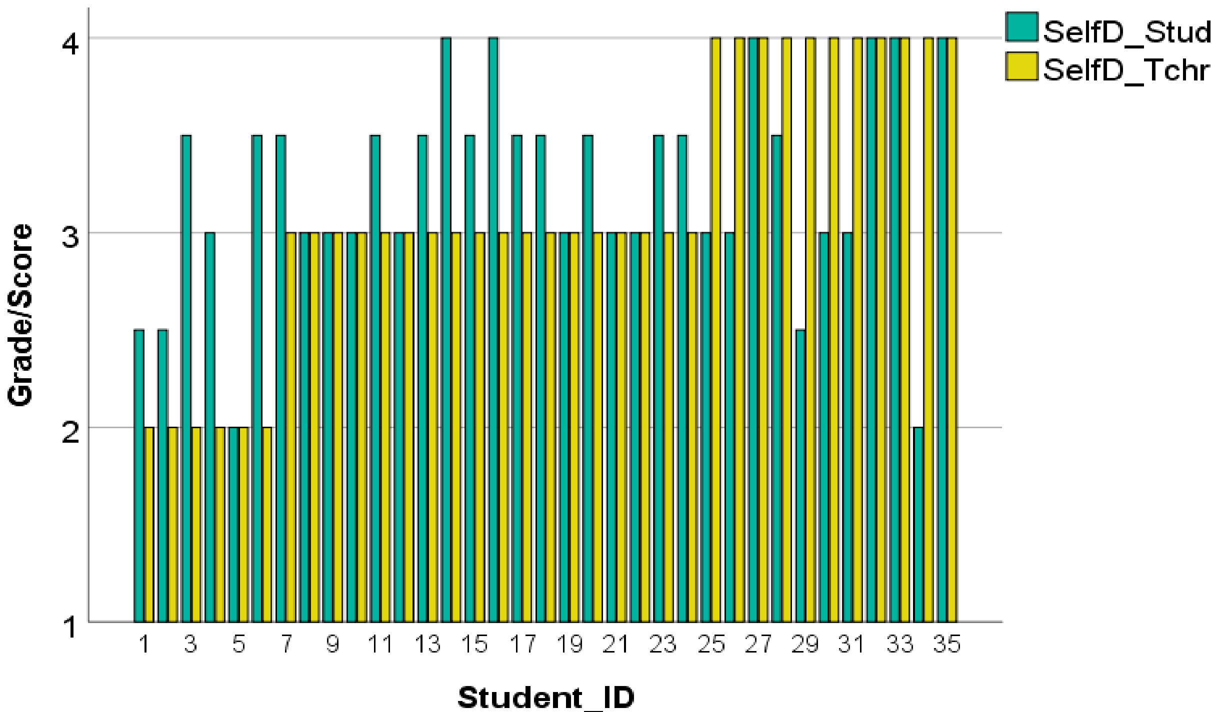

Figure 6. Distribution of Self-Direction Student Scores (Green Bars) versus Teacher Scores (Yellow Bars) by Student ID

Collaboration

All but the final, culminating performance task required collaboration. Students worked in groups of four for both the exploratory phase of the unit and for the final public product. Each group was asked to define and assign roles for facilitator, recorder, task manager, and compiler. The teacher perceived that these roles allowed students to be more successful. Students were instructed to divide up the tasks and work in groups of two to complete the lab investigations.

Students detailed both the positive and negative experiences with peers on the open-response survey item about collaboration (Coll4.3s). Positives included helpful peer feedback and insight, support when they didn't understand a particular concept, and division of responsibilities. Most problems centered on perceptions that not all group members contributed equally during the lab investigations and to creating the final public product. Students detailed the difficulty faced in handling these type of situations.

Student reflections on level of collaboration reveal that 94% of students reported that their group tended to collaborate either 'excellently' or 'good' on the experimenting part of the project. This is in contrast to about 77% of students who responded in a similar way about how well their group did at collaborating about asking questions and contributing to final product (see Appendix L).

Figure 7 below shows the student score (blue bars) versus teacher score (red bars) on collaboration by student ID. Student scores were computed by taking the average across the three collaboration questions. Students tended to over-rate their collaboration skills in comparison to the teacher score. The teacher did not give many students a Level 4 on collaboration—only 4 students out of the 37 (~11%). This is in comparison to 12 out of 37 on self-direction (~32%). Instead, the majority of students were given a Level 3 on collaboration—which is the 'proficient' level.

In general, the teacher tended to score students lower on collaboration than self-direction. For example, 71% of students demonstrated proficient or above skills in collaboration in comparison to 83% of students in self-direction based on the teacher score. This outcome is supported by the many comments from students in the open-response survey items and student focus groups about the difficulties faced collaborating with peers in this project. The teacher also discussed these difficulties she witnessed around collaboration during the teacher interview and realized that part of the difficulty she faced in grouping students at the beginning of the year was that she didn't know the students very well academically yet and so she inadvertently grouped some students together that "might not have been the best fit". She grouped students together, rather than allowing them to group themselves, because she had a few different boyfriend/girlfriend combinations in her classes and some students with identified learning disabilities and so she chose to place students into groups in order to address some of those potential issues. The teacher discussed how she intended to do more explicit teaching about collaboration in a subsequent unit of study and also group students differently to support students' academic success.

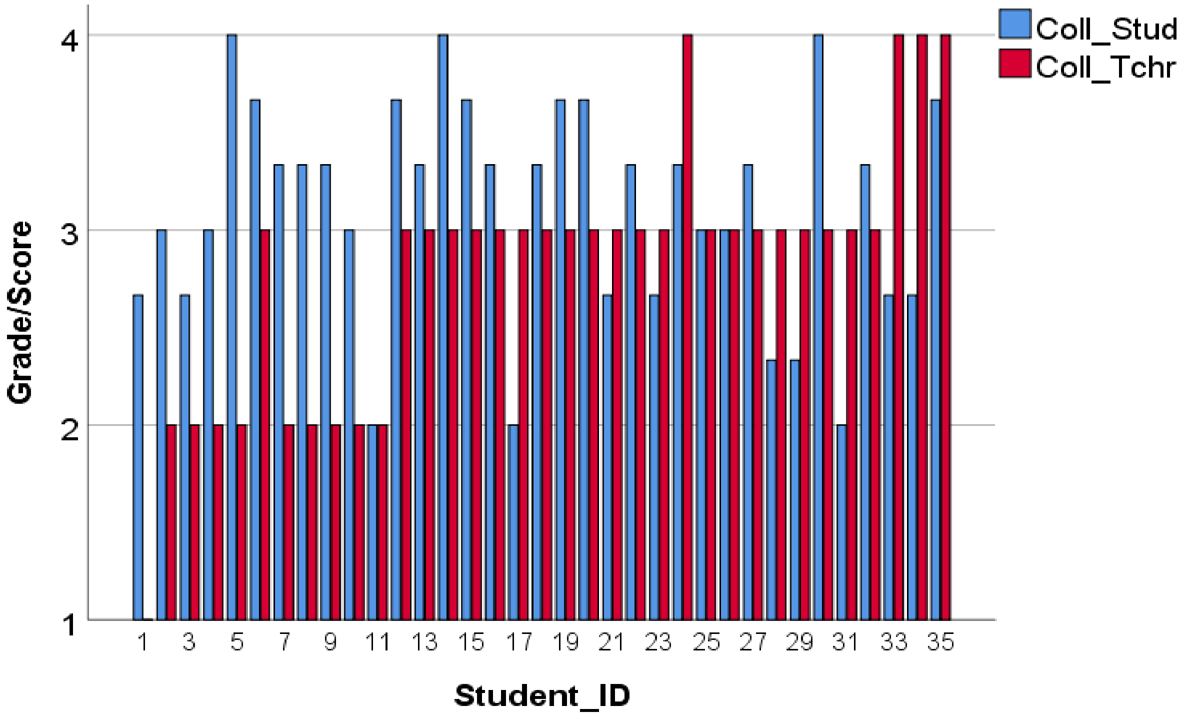

Figure 7. Distribution of Collaboration Student Scores (Blue Bars) versus Teacher Scores (Red Bars) by Student ID

Limitations and Future Research

There are many limitations to this single teacher case study that should be kept in mind when interpreting results and attempting to generalize from findings. These limitations stem from the non-experimental research design and limited sampling. Causal inference requires a counterfactual that shows what would have happened to these students if they had not received the intervention. An effect can then be calculated—or the difference between what did happen and what would have happened. The purpose of this study was exploratory and descriptive rather than causal.

As such, findings from this study are purely descriptive and only tell us about these students' perceptions based on what they or their teacher reported. We don't know if this would be different than what they would have reported or what their teacher would have reported if she had not received PBL 101 professional development. That said, given the limited amount of research in this area to date, this study's findings could be used to point out directions that future research could explore with experimental or quasi-experimental research designs with a larger sample of subjects, students, and teachers.

Endnotes

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[i] Sheila is a pseudonym used to protect the anonymity of the teacher and students.

[ii] For more information about PACE see Marion, S., & Leather, P. (2015). Assessment and accountability to support meaningful learning. *Education Policy Analysis Archives*, *23*(9). Retrieved from http://dx.doi.org/10.14507/epaa.v23.1984

[iii] The Transfer of Energy project discussed in this case study was not the project Sheila created during PBL 101. The project created during PBL 101 will be administered in spring 2020.

[iv] There were no limited English proficiency students in the chemistry sections. Due to the potential student identifiability, the exact percent of students with IEPs or student race/ethnicity were not provided by the school. Almost all of the chemistry students were White/Caucasian and do not have an identified learning disability or IEP.

[v] See https://ireport.education.nh.gov/state/NH/profile.

[vi] One implication of this single teacher case study on PBLWorks professional development is that the teacher mentioned in her interview that PBL 101 training seemed geared to all types of formative learning and assessment experiences and seemed to downplay *summative assessment* (particularly summative performance assessment) experiences. For example, the teacher said that trainers said that teachers didn't even need to look at the final product and give it a grade—instead, it was about the process of completing the project that mattered for student learning. The teacher expressed that the PBL 101 training was really helpful in terms of understanding how to design engaging and collaborative projects, but the summative assessment part of the training/project planner seemed very weak.

Another implication of this single teacher case study on PBLWorks professional development is the importance of collecting evidence about what a student knows and can do *independently* in addition to what a student knows and can do from a collaborative project. The independent assessment can probe the extent to which students are able to *transfer* their learning to new or novel contexts, as well as provide evidence about individual student performance as separate from the group.

PROJECT PLANNER

1. Project Overview

Project Title	Some like it HOT and some like it COLD	**Public Product(s) (Individual and Team)**	Consumer report article. Which product works best? Consumer report article. How to best use the product. Does it work? Write a review of the product for amazon. Make a youtube video to use to either support or discredit claims of product effectiveness. Do a presentation for the school store on to answer the question of whether or not they should carry beverage stones.
Driving Question	How can an educated consumer make decisions about the usefulness of beverage stones?		
Grade Level/ Subject	10,11,12		
Time Frame	2-3 Weeks		
Project Summary	In this project, students will be examining the flow of energy, the law of conservation of energy, and specific heat in order to communicate how materials added to coffee/beverages can be used to keep it warm or cold.		

2. Learning Goals

Standards	***HS***-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal ***energy*** when two components of different temperature are combined within a closed system results in a more uniform ***energy*** distribution among the components in the system (second law of thermodynamics). CE1—Calculate the change in energy of one component in a system when energy changes of the other component(s) and energy flows in and out of the system are known	**Literacy Skills**	SEE SCIENTIFIC EXPLANATION
		Success Skills	Critical thinking, collaboration, self-direction SP1- INVESTIGATION -Students will be able to ask testable questions about natural phenomena to design scientific invesitgations or develop models. Students will be able to plan and conduct inquiry-based investigations. Students will be able to read and interpret scientific text. SP2- ANALYSIS - Students will be able to analyze and interpret data using a variety of tools and reasoning including mathematical thinking and scientific literature to arrive at results or solutions to an engineering problem. SP3- EXPLANATION - Students will be able to construct scientific explanations based on data or natural phenomena. In addition, students will be able to support arguments based on scientific evidence and/or propose potential solutions to given problems. Students will employ reasoning

			and argument to identify the best solution to engineering design problems.
Key Vocabulary	Heat, Temperature, Law of conservation of energy, Endothermic, Exothermic, specific heat,	**Rubric(s)**	Link/name rubric(s) you intend to use; [template for your use]

3. Project Milestones

Directions: Use this section to create a high-level overview of your project. Think of this as the broad outline of the story of your project, with the milestones representing the significant 'moments' or 'stages' within the story. As you develop these, consider how the inquiry process is unfolding and what learning will take place. The Project Calendar (Section 4) will allow you to build out the milestones in greater detail.

Milestone #1 Whole group	Milestone #2	Milestone #3	Milestone #4	Milestone #5	Milestone #6 Public Product
E.g., Entry Event Kickstart video Show shark tank video? What questions do you have for the sharks? Read the science behind joulies? What question do you have now? What science do you need to know something more about.	E..g., Student generated questions; research How does energy flow? What is endo/exothermic mean? Experiment with hot and cold cube and thermometers. Research law of conservation of energy. What is specific heat. What factors effect specific heat.	E..g., Field observation and data collection Choose a focal question to develop an experiment. Conduct the experiment and collect data.	E..g., Feedback from an expert and revision Review experimental design and data.	E..g., Finalization of product and preparation for presentations Prepare product	E.g., Final presentation and reflection Present product
Key Student Question	Key Student Question	Key Student Question	Key Student Question	Key Student Question	Key Student Question
What is the difference between heat and temperature?	What is temperature measure? How is it different from heat. Why do somethings change the temp. a lot and other a little? What are the factors that affect energy transfer.	What should I measure? How much data should I collect?	What does the data tell me? What can make your experiment better?	Are we reaching our audience?	
Formative Assessment(s)	Formative Assessment(s)	Formative Assessment(s)	Formative Assessment(s)	Formative Assessment(s)	Summative Assessment(s)

What do you think the relationship between temperature , heat and thermal energy is?	Diagram where the energy goes in the system! Reflection on what do I now know				

4. Project Calendar

Driving Question: Is beverage stone(whiskey stone) advertising honest, informative and useful? How can it be made better?				
Week: 1	**Project Milestone:** 1 and 2			
Key Student Question(s): How can an educated consumer make decisions about the usefulness of beverage stones.				
Day 1: Black day	**Day 2: White**	**Day 3: Black**	**Day 4: White**	**Day 5: Black Day**
E.g., Entry Event Kickstart video Show shark tank video? What questions do you have for the sharks? Read the science behind joulies? What question do you	How does energy flow? What direction does it go? Based on questions students will do an exploratory experiment.	Continuation of exploratory experiment. Mini lecture Worksheet	Formative quiz	Work teams Selection of topic. Project planning. Whos working on what? Begin work on project
Notes: Include any notes that will help you with the implementation of this project milestone (e.g., resources, notes to self, etc.)				

Driving Question:	
Week:2	**Project Milestone:** Duplicate tables for each milestone as needed.

Key Student Question(s):				
Day 1: White Day	**Day 2: Black Day**	**Day 3: White Day**	**Day 4: Black Day**	**Day 5: Perfomance Assessment?**
Work on experiments.	Analyzing data. Reviewing experimental design and data Experimenting Finalizing data Beginning work on product.	Work on product	Finish Product	
Notes:				

5. Lesson Planner (Supporting Resource)

How to use the document: This planner offers guidance on how you might plan your daily lessons in the project calendar. Pick and choose what feels necessary to achieve the learning outcome and advance product development for all students.

I. **CHECKING PRIOR KNOWLEDGE** Identify how you will inventory student knowledge ahead of the task, lesson, or activity. (e.g., previous day's exit tickets, warm-up activity, need to know list review, quiz, class discussion, etc.)

II. **LEARNING OUTCOME** These can be related to success skills or standards. If your district uses a graduate profile or career pathway outcomes, include relevant outcomes here as well.

III. **KEY VOCABULARY** Note which terms or academic vocabulary will be essential to this lesson. If you serve English language learners, consider what additional vocabulary might be necessary for them to access the content/skills during the instructional activities.

IV. **FORMATIVE ASSESSMENT** For each lesson, consider which assessment type best measures the learning outcome. For example, a quiz may be the best way to check for understanding of key terms while an annotated sketch might be best for determining student understanding of how the key terms fit together. In some cases, your assessment may be informal, such as an exit ticket, or more formal, as in a rough draft. Finally, when planning your formative assessment, diversify who is doing the assessment. Include self, peer, and teacher assessment opportunities, as appropriate for the age group. When possible, have external partners or end users provide feedback to improve or guide the work.

V. **MAJOR INSTRUCTIONAL ACTIVITIES** This can include lessons, tasks, activities, or learning experiences. Choose the instructional method that will best help students achieve the learning outcome. For example, a direct instruction lesson may be appropriate for introducing the key players in World War II while an artifact inquiry activity during which students examine primary source documents would be better suited for them to understand the impact of those key players on the pivotal events during the war. This would also be the space to include teaching and learning related to classroom culture, student collaboration, and/or project management tools or skills, as appropriate for students or project milestone needs. Included links show examples of such activities.

VI. **SCAFFOLDS** Scaffolds are intended to be temporary supports that are removed when students no longer need them. These scaffolds can be used to support either content or the project process (e.g., need to know questions). Leverage "checking prior knowledge" to ensure you are offering the right scaffolds to the students who need them. Be sure to consider a wide range of needs, such as literacy skills, language acquisition levels, auditory/visual processing, building schema, learning style preferences, academic performance levels, etc.

VII. **REFLECTION** How will students reflect on their thinking, process, or learning?

VIII. **STUDENT NEED TO KNOW QUESTIONS ADDRESSED** Which student questions will be answered, or are you aiming to answer, during this instructional activity?

IX. **TOOLS/RESOURCES** Student-facing tools, human resources such as experts or community members, teacher tools, equipment, etc.

2019/2020 School Calendar				
September				
Monday	Tuesday	Wednesday	Thursday	Friday
16 White	17 NO CLASS	18 Entry Activity Shark Tank	19 Research/Exploration pHET Answer questions.	20 NO CLASS
23 Research/Exploration Factors that effect heat transfer.	24 Mini lecture Specific Heat	25 NO CLASS	26 Formative Assessment Intro to project. Team formation and planning	27 Planning and designing experiment
Sept. 30 NO CLASS	1 Conduct Investigation. Begin final product	2 Investigation Final Product Work	3 NO CLASS	4 Final Product
7 Final Product Due	8 NO CLASS	9 BACK UP DAY	10 NO CLASS	11 Black

White Block days classes meet Period 4 10:02- 10:50 and Period 7 12:43-1:31
Black Block days classes meet Period 4 9:05- 10:50 and Period 7 12:43-2:23

Appendix B: Transfer of Energy PBL Scoring Guide/Rubric

	Nature of Science:				Scores
	4	**3**	**2**	**1**	
Generating Testable Questions	• I develop a relevant, testable question to investigate or define a problem that includes specific variables or details and makes connections to broad scientific principles and/or theories. *[provide explanation of why to test this question]*	• I develop a relevant, **testable** question to investigate or define a problem that includes specific variables/details. *[should relate to heat transfer]*	• I develop a relevant question to investigate or define a problem.	• I develop a question related to the task.	Planning Docs from Group Project Performance Task
Planning and Carrying out the Procedure	• I communicate a detailed, clear, and replicable scientific procedure including tools /instruments and types of measurements where applicable. • I make adjustments noting the changes and explaining how the changes will improve the	• I communicate a clear and replicable scientific procedure that addresses the question or problem. *[includes steps that are needed to determine heat transfer, controlled variables are evident, but don't need to be stated]*	• I communicate a partially replicable scientific procedure addressing essential steps of the investigation.	• I communicate a scientific procedure.	Formal Lab from Group Project

	investigative process and/or outcome where applicable.				
Analyzing and Interpreting Data	• My data are appropriate to produce the most reliable results possible given the tools available.	• My data are organized and sufficient to produce results. *[includes all data necessary to calculate the specific heat of metals, table(s) are labelled and include units]*	• I collect scientific data relevant to the task.	• I record scientific data.	Planning Docs from Group Project Performance Task
	• I accurately analyze data using appropriate logic and tools. *[needs to specifically reference details in the data]* • My analysis accurately addresses the question or problem.	• I analyze data using appropriate logic and tools. *[must include calculations of specific heat for the metals tested]* • My analysis addresses the question or problem. *[includes a comparison of lab data with other factors such as cost, availability, health, and safety]*	• I analyze data. • My analysis partially addresses the question or problem.	• I analyze my data.	

Communicating Findings	• I produce a defensible scientific explanation, accurately citing scientific ideas and relating to broad scientific principles. *[must discuss heat transfer and specific heat and their relevance to cookware]* • My explanation is supported by all specific and relevant evidence based on my data. • I assess the limitations or sources of error, how they specifically impact the results and relate to the validity of the outcome.	• I produce a defensible scientific explanation, accurately citing scientific ideas. *[need to discuss heat transfer and specific heat]* • My explanation is supported by relevant evidence based on my data. • I assess the limitations and/or sources of error and how they relate to the accuracy of the results.	• I produce a defensible scientific explanation relative to the task. • My explanation references my data/results.) • I identify limitations or possible sources of error.	• I provide a scientific explanation.	Group Project Performance Task

	Energy and Matter				
	4	**3**	**2**	**1**	
Energy and Matter	• When appropriate, I can create a mathematical model to represent the flow of energy and/or mass. • I can manipulate the flow of energy and/or matter to optimize the system for the desired outcome.	• I can generate a model/diagram to explain the flow and conservation of energy and/or matter within a system and/or between systems. • I can use evidence to explain how the flow of energy and/or matter is impacted by changes within a system. • I can describe when appropriate how energy drives the movement of matter.	• I can identify the specific inputs and outputs of energy and/or matter within a system. • I can recognize that matter and/or energy are conserved within physical and chemical processes.	• I can identify the energy and/or matter within a system. • I can identify that energy and/or matter moves within a system and/or between system(s).	Group Project Performance Task

Appendix C: Self-Direction and Collaboration Rubric/Survey

Self-Direction

SELF-DIRECTION	**I have done everything in level 3 +**	**I have done everything in level 2 +**	**I have done everything in level 1 +**	**I have just started**
	Level 4: Extending	*Level 3: Applying*	*Level 2: Developing*	*Level 1: Emerging*
	I Can…	**I Can…**	**I Can…**	**I Can…**
ENGAGING AND MANAGING	Persevere productively, avoiding procrastination and distraction throughout the work process.	Work productively and stays attentive to the task at hand.	Redirect my own efforts when distracted or behind schedule.	Use guidance from others to redirect my efforts and get back on track when I am distracted or behind schedule.
MONITORING AND ADAPTING	Analyze experimental observations to modify the experiment to increase effectiveness.	Select a course of action based on driving questions. Use experimental observations to identify areas for improvement and develop appropriate actions.	Select a course of action. Make some changes based on experimental observations.	Select a course of action with guidance from others.

Collaboration

How well did your group do at collaborating for the following parts of the project?

	Excellent	Good	Not bad but not great either	Could have been more productive
Asking Questions				
Experimenting				

Contributing to Final Product				

Appendix D: Energy Transfer Performance Task

"Now You're Cooking!"

Energy Transfer Performance Task

Generating Testable Questions

Copper cookware has become popular in recent years. But is it really worth all the hype? Determine the best metal for creating cookware from the options given. The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.

In the space below, write 2 testable questions that will help you focus your investigation:

Materials and Methods

Materials List:

Metal samples: • copper \$6.12/kg • aluminum \$2.20/kg • iron \$0.53/kg	safety goggles & standard lab equipment
	Styrofoam cups with covers

A summary of the procedure is as follows:

50 mL of water was added to a styrofoam cup. This was repeated for 3 cups. The cups were then labeled copper, aluminum, and iron. The mass and temperature of the water was determined. Then approximately 25 g of the appropriate metals was added to the styrofoam cup of water. Each of the metals was preheated to 100 C and the actual temperature was recorded. The final temperature of the system (water and metal) was recorded.

Please diagram this experiment and show (using arrow) and annotate where the thermal energy flows from and to.

Data Table

Metal used	*Mass Metal*	*Temp of Metal Initial*	*Mass of Water*	*Temp of Water Initial*	*Final temp of water and metal*
copper $6.12/kg	*25.321 g*	*99.2 C*	*50.1 g*	*21.5 C*	*24.82 C*
aluminum $2.20/kg Specific heat =.92 J/gC	*23.629 g*	*100.1 C*	*50.3 g*	*23.5 C*	*30.67*
iron $0.53/kg	*27.018 g*	*100.8 C*	*49.9 g*	*24.3C*	*28.59*

Analyzing & Interpreting Data

Please calculate the heat (q) transferred by the *aluminum* (Specific Heat = 0.92). Please discuss if the energy transferred was absorbed or lost by the aluminum using evidence from the data.

How much energy was transferred to the *water (Specific Heat = 4.184)* for the iron trial. Please discuss if the energy transferred was absorbed or lost by the water using evidence from the experiment.

Please calculate the specific heat for iron and copper metals.

Please generate a results table to summarize how you processed the data.

Provide and annotation to this table that summarizes your results.

Communicating Findings

Identify what metal is best for making a piece of cookware if you are using the criterion: “The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.” You should relate your knowledge of the flow of energy and temperature to your claim. Support your claim with quantitative and qualitative data from the experiment.

Appendix E: HQPBL Student and Teacher Survey Construct Map

Domain	Item#	Student Question	Teacher Question	Response Options
Intellectual Challenge and Accomplishment (Intell)	1.1	I investigated a challenging problem, question or issue in this project.	My students investigated a challenging problem, question or issue in this project.	0-10 agreement scale
	1.2	I did my highest quality work in this project.	My students did their highest quality work in this project.	0-10 agreement scale
	1.3	In what ways (if any) did this experience challenge you to learn deeply or think critically? Please explain.	In what ways (if any) did you design this experience to challenge your students to learn deeply or think critically? Please explain.	Open ended
	1.4	In what ways (if any) did this experience challenge you to strive for excellence? Please explain.	In what ways (if any) did you design this experience to challenge your students to strive for excellence? Please explain.	Open ended
Authenticity (Auth)	2.1	I engaged in work that makes an impact or connects to the world beyond school.	My students engaged in work that makes an impact or connects to the world beyond school.	0-10 agreement scale
	2.2	I engaged in work that connects to my personal interests or concerns.	My students engaged in work that connects to their personal interests or concerns.	0-10 agreement scale
	2.3	I used tools, techniques, and/or digital technologies that are used in the world beyond school.	My students used tools, techniques, and/or digital technologies that are used in the world beyond school.	0-10 agreement scale
	2.4	I made choices about my topic, activities, and/or products.	My students made choices about their topic, activities, and/or products.	0-10 agreement scale

	2.5	In what ways (if any) did this experience seem authentic or “real”? Please explain.	In what ways (if any) did you design this experience to be authentic or “real”? Please explain.	Open ended
Public Product (Publ)	3.1	I shared my work-in-progress with peers, teacher, or others for feedback during the project.	My students shared their work-in-progress with peers, me, or others for feedback during the project.	Yes/No
	3.2	I shared my final product to an audience outside of my classroom.	My students shared their final product to an audience outside of my classroom.	Yes/No
	3.3	I received feedback about my final product from my teacher, peers, or others.	My students received feedback about their final product from me, peers, or others.	Yes/No
	3.4	In what ways (if any) did you make your work public by sharing it with peers or other people beyond the classroom? Please explain.	In what ways (if any) did you design the project so that students would make their work public by sharing it with peers or other people beyond the classroom? Please explain.	Open ended
Collaboration (Coll)	4.1	I worked with a group or team to complete the majority of this project.	My students worked in a group or team to complete the majority of this project.	0-10 agreement scale
	4.2	I learned how to be a more effective team member or leader during this project.	My students learned how to be more effective team members or leaders during this project.	0-10 agreement scale
	4.3	In what ways (if any) did you collaborate with your peers in this project? Please explain.	In what ways (if any) did you create the project so that students would need to collaborate with their peers in this project? Please explain.	Open ended
Project Management (ProjM)	5.1	I managed myself and other team members in order to be successful in this project.	My students managed themselves and other team members in order to be successful in this project.	0-10 agreement scale

	5.2	I thought through how to manage this project with my team in order to complete the final project effectively and efficiently.	My students thought through how to manage this project with their team in order to complete the final project effectively and efficiently.	0-10 agreement scale
	5.3	I learned to use project management processes, tools, and strategies.	My students learned to use project management processes, tools, and strategies.	0-10 agreement scale
	5.4	In what ways (if any) did you need to manage yourself or other team members in order to be successful in this project? Please explain.	In what ways (if any) did you design this project so students would need to manage themselves or other team members in order to be successful in this project? Please explain.	Open ended
Reflection (Refl)	6.1	I reflected on my work and learning during this project.	My students reflected on their work and learning during this project.	0-10 agreement scale
	6.2	I thought about how I could improve my own and others' work during this project.	My students thought about how they could improve their own and others' work during this project.	0-10 agreement scale
	6.3	In what ways (if any) did you pause during the project to think about what you were doing and learning? Please explain.	In what ways (if any) did you design this project so that students would need to pause during the project to think about what they were doing and learning? Please explain.	Open ended
	6.4	In what ways (if any) did you pause during the project to think about how you could make your final product better? Please explain.	In what ways (if any) did you design this project so that students would need to pause during the project to think about how they could make their final product better? Please explain.	Open ended

Overall (Overall)	7.1	How would you rate your overall experience in this project?	How do you think your students would rate their overall experience in this project?	0-10 rating scale
	7.2	Explain why you gave the rating (0-10) about your overall experience in this project.	Explain why you gave the rating (0-10) about your students' overall experience in this project.	Open ended

Appendix F: HQPBL Student Self-Assessment & Reflection Tool

Directions: You will be asked a series of questions about the *Transfer of Energy* project you completed in your Chemistry class this year. Please answer each question carefully, but do not spend too much time on any one question. Your name and any other personally-identifiable information will not be collected, so please answer every question as honestly as possible.

End of Block: Directions

Start of Block: Intellectual Challenge and Accomplishment

Q3 I investigated a challenging problem, question or issue in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q4 I did my highest quality work in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q5 In what ways (if any) did this experience challenge you to learn deeply or think critically? Please explain.

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Q6 In what ways (if any) did this experience challenge you to strive for excellence? Please explain.

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End of Block: Intellectual Challenge and Accomplishment

Start of Block: Authenticity

Q7 I engaged in work that makes an impact or connects to the world beyond school.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q8 I engaged in work that connects to my personal interests or concerns.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q9 I used tools, techniques, and/or digital technologies that are used in the world beyond school.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q10 I made choices about my topic, activities, and/or products.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q11 In what ways (if any) did this experience seem authentic or “real”? Please explain.

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End of Block: Authenticity

Start of Block: Public Product

Q12 I shared my work-in-progress with peers, teacher, or others for feedback during the project.

○ Yes (1)

○ No (2)

Q13 I shared my final product to an audience outside of my classroom.

○ Yes (1)

○ No (2)

Q14 I received feedback about my final product from my teacher, peers, or others.

- Yes (1)
- No (2)

Q15 In what ways (if any) did you make your work public by sharing it with peers or other people beyond the classroom? Please explain.

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End of Block: Public Product

Start of Block: Collaboration

Q16 I worked with a group or team to complete the majority of this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q17 I learned how to be a more effective team member or leader during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q18 In what ways (if any) did you collaborate with your peers in this project? Please explain.

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End of Block: Collaboration

Start of Block: Project Management

Q19 I managed myself and other team members in order to be successful in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q20 I thought through how to manage this project with my team in order to complete the final project effectively and efficiently.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q21 I learned to use project management processes, tools, and strategies.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q22 In what ways (if any) did you need to manage yourself or other team members in order to be successful in this project? Please explain.

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End of Block: Project Management

Start of Block: Reflection

Q23 I reflected on my work and learning during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q24 I thought about how I could improve my own and others' work during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q25 In what ways (if any) did you pause during the project to think about what you were doing and learning? Please explain.

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Q26 In what ways (if any) did you pause during the project to think about how you could make your final product better? Please explain.

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End of Block: Reflection

Start of Block: Overall

Q27 How would you rate your overall experience in this project?

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q28 Explain why you gave the rating (0-10) about your overall experience in this project.

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End of Block: Overall

Appendix G: HQPBL Teacher Reflection Tool

Directions: You will be asked a series of questions about the *Transfer of Energy* project you created for your Chemistry class this year. Please answer each question carefully, but do not spend too much time on any one question.

End of Block: Directions

Start of Block: Intellectual Challenge and Accomplishment

Q3 My students investigated a challenging problem, question or issue in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q4 My students did their highest quality work in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q5 In what ways (if any) did you design this experience to challenge your students to learn deeply or think critically? Please explain.

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Q6 In what ways (if any) did you design this experience to challenge your students to strive for excellence? Please explain.

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End of Block: Intellectual Challenge and Accomplishment

Start of Block: Authenticity

Q7 My students engaged in work that makes an impact or connects to the world beyond school.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q8 My students engaged in work that connects to their personal interests or concerns.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q9 My students used tools, techniques, and/or digital technologies that are used in the world beyond school.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q10 My students made choices about their topic, activities, and/or products.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q11 In what ways (if any) did you design this experience to be authentic or “real”? Please explain.

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End of Block: Authenticity

Start of Block: Public Product

Q12 My students shared their work-in-progress with peers, me, or others for feedback during the project.

- Yes (1)
- No (2)

Q13 My students shared their final product to an audience outside of my classroom.

- Yes (1)
- No (2)

Q14 My students received feedback about their final product from me, peers, or others.

- Yes (1)
- No (2)

Q15 In what ways (if any) did you design the project so that students would make their work public by sharing it with peers or other people beyond the classroom? Please explain.

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End of Block: Public Product

Start of Block: Collaboration

Q16 My students worked in a group or team to complete the majority of this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q17 My students learned how to be more effective team members or leaders during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q18 In what ways (if any) did you create the project so that students would need to collaborate with their peers in this project? Please explain.

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End of Block: Collaboration

Start of Block: Project Management

Q19 My students managed themselves and other team members in order to be successful in this project.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q20 My students thought through how to manage this project with their team in order to complete the final project effectively and efficiently.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q21 My students learned to use project management processes, tools, and strategies.

	0 1 2 3 4 5 6 7 8 9 10
Move the bar to indicate your choice. ()	

Q22 In what ways (if any) did you design this project so students would need to manage themselves or other team members in order to be successful in this project? Please explain.

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End of Block: Project Management

Start of Block: Reflection

Q23 My students reflected on their work and learning during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q24 My students thought about how they could improve their own and others' work during this project.

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q25 In what ways (if any) did you design this project so that students would need to pause during the project to think about what they were doing and learning? Please explain.

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Q26 In what ways (if any) did you design this project so that students would need to pause during the project to think about how they could make their final product better? Please explain.

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End of Block: Reflection

Start of Block: Overall

Q27 How do you think your students would rate their overall experience in this project?

	0	1	2	3	4	5	6	7	8	9	10
Move the bar to indicate your choice. ()											

Q28 Explain why you gave the rating (0-10) about your students' overall experience in this project.

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End of Block: Overall

Appendix H: HQPBL Student and Teacher Survey Descriptive Statistics by Item Number

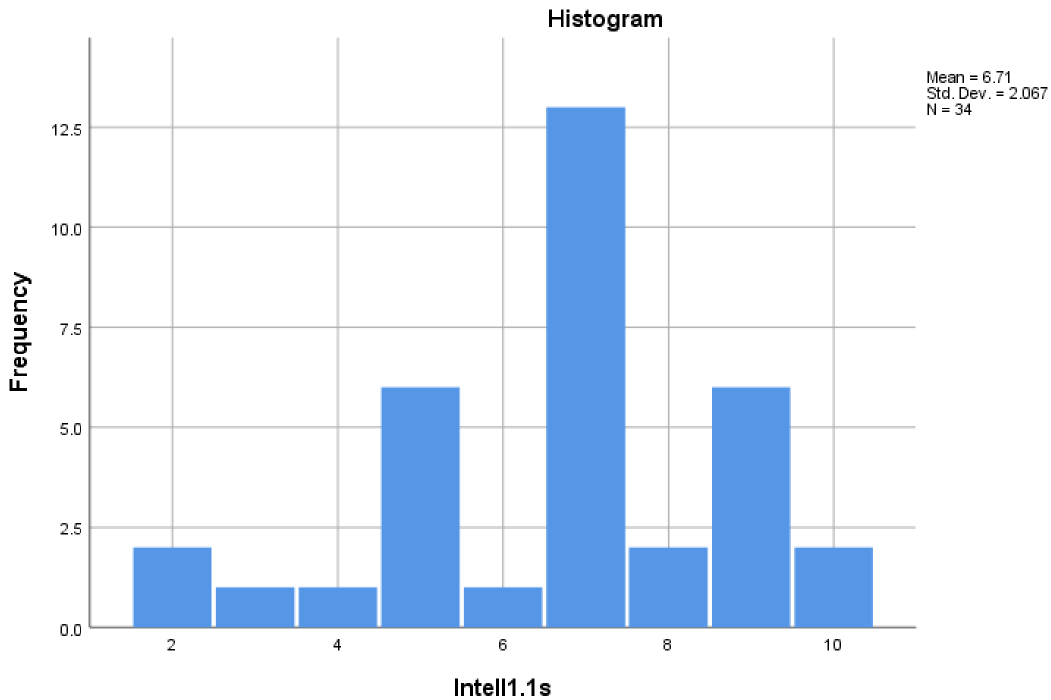
Descriptive Statistics

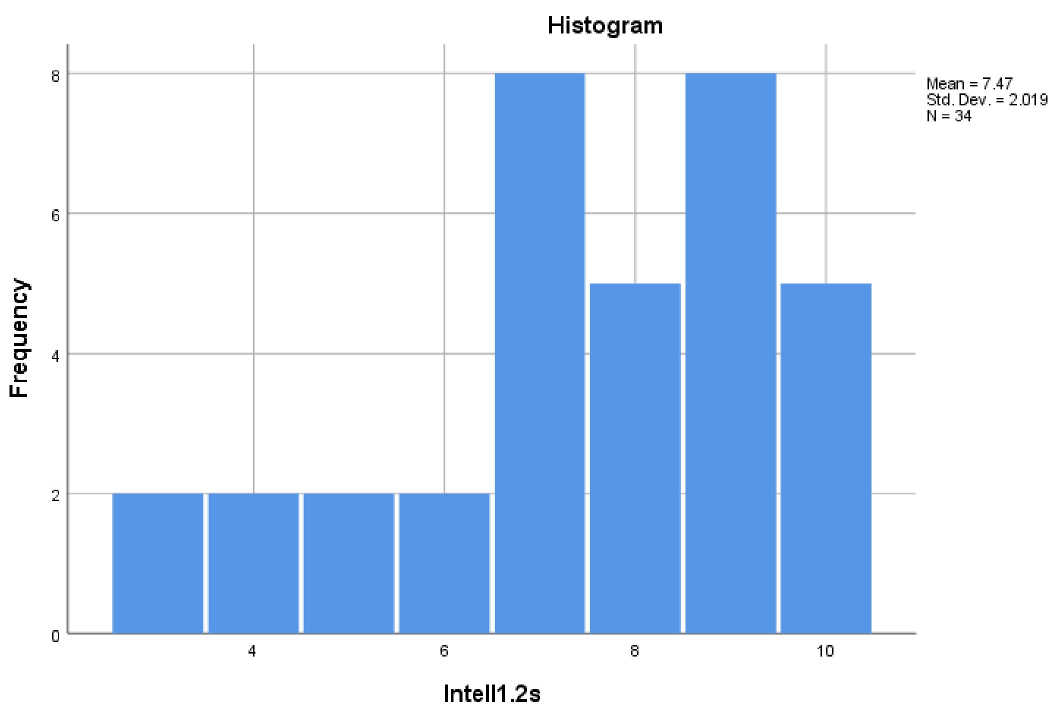
	N	Range	Min	Max	Student Response Mean	Std. Deviation	Teacher Response
Intell1.1s	35	8	2	10	6.66	2.057	9
Intell1.2s	35	7	3	10	7.46	1.990	9
Auth2.1s	35	10	0	10	6.43	3.202	8
Auth2.2s	35	10	0	10	4.29	2.707	9
Auth2.3s	35	9	1	10	7.43	2.638	10
Auth2.4s	35	9	1	10	7.43	2.417	9
Coll4.1s	35	8	2	10	8.26	2.525	10
Coll4.2s	35	9	1	10	6.29	2.996	10
ProjM5.1s	35	9	1	10	7.00	2.509	9
ProjM5.2s	35	9	1	10	6.91	2.381	8
ProjM5.3s	35	9	1	10	6.20	2.826	9
Refl6.1s	34	9	1	10	6.09	2.885	7
Refl6.2s	34	9	1	10	7.26	2.490	3
Overall7.1s	34	7	3	10	6.94	2.074	9

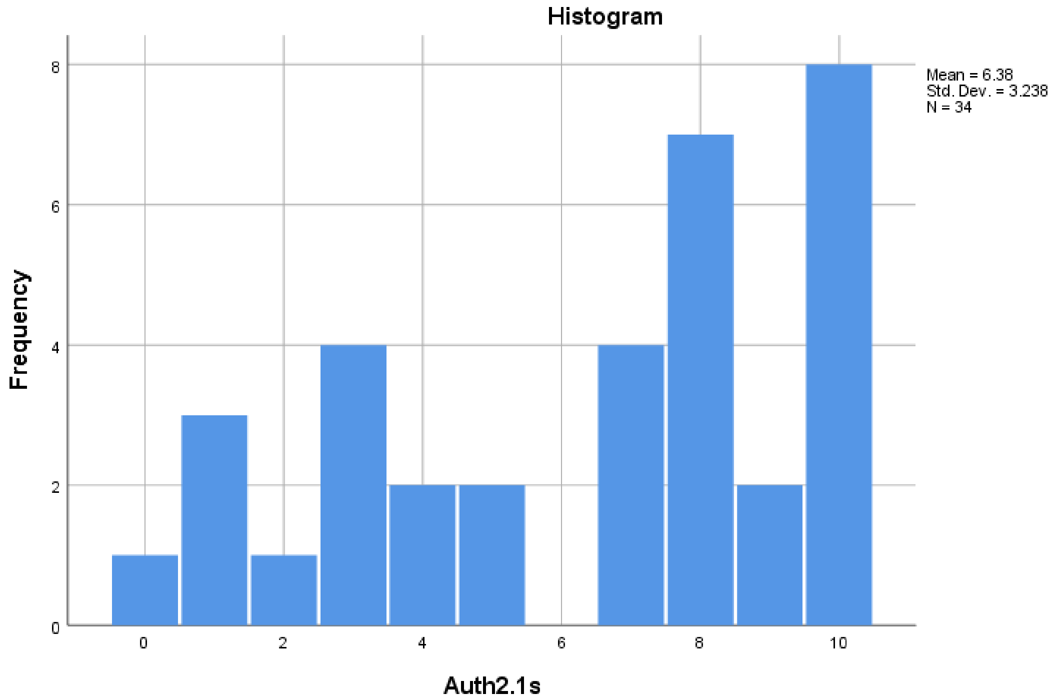
	Publ3.1s		**Publ3.2s**		**Publ3.3s**	
	N	Percent	N	Percent	N	Percent
No	4	11.4	14	40.0	5	14.3
Yes	31	88.6	21	60.0	30	85.7

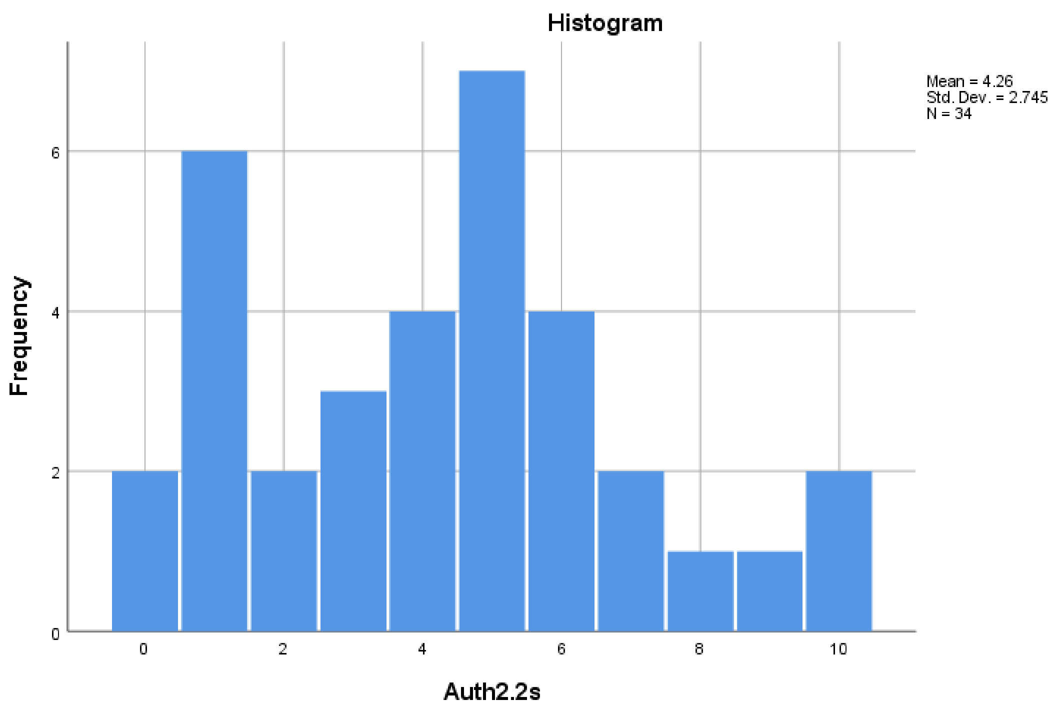
Note. Teacher responded “Yes” to each of these items.

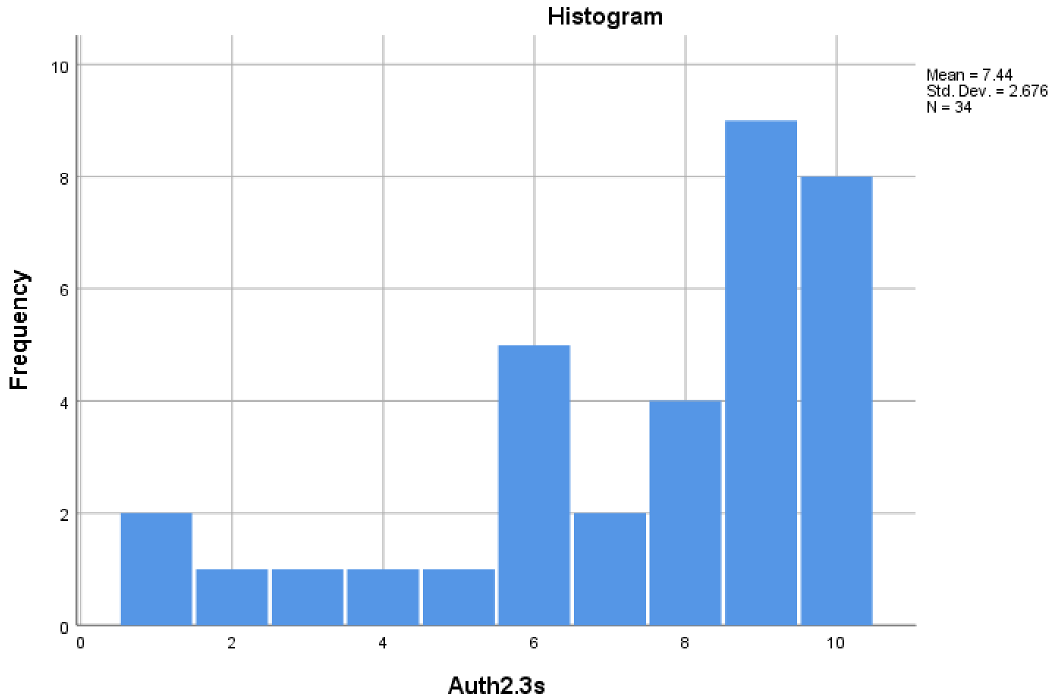
Histograms

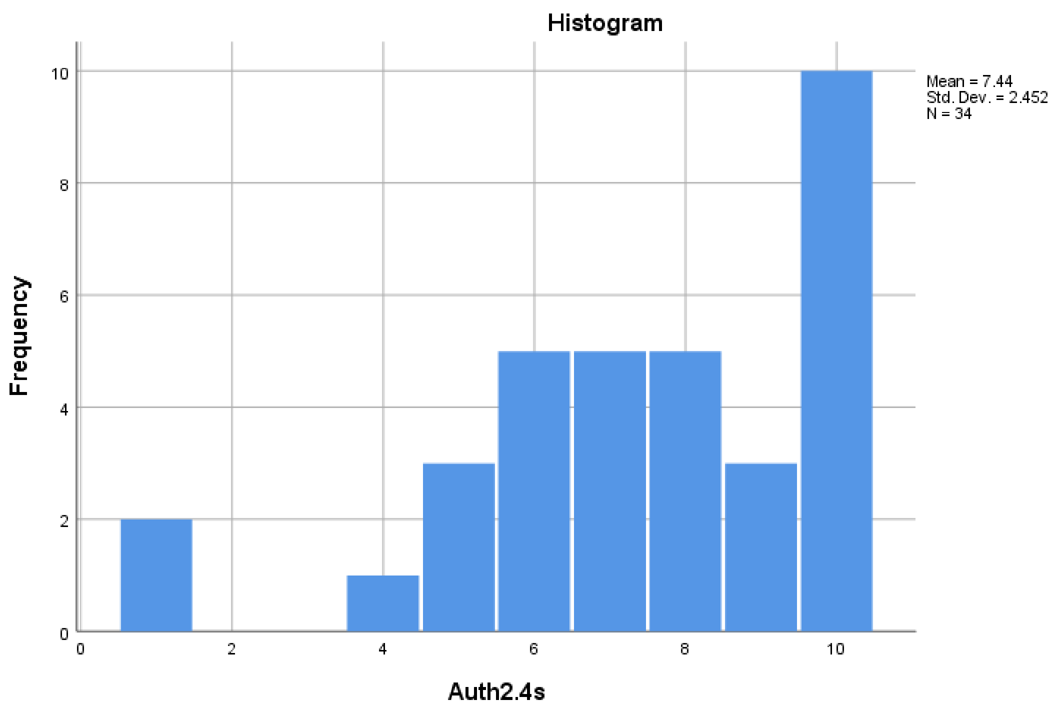

Histogram
Mean = 6.71
Std. Dev. = 2.067
N = 34
Frequency
12.5
10.0
7.5
5.0
2.5
0.0
2
4
6
8
10
Intell1.1s

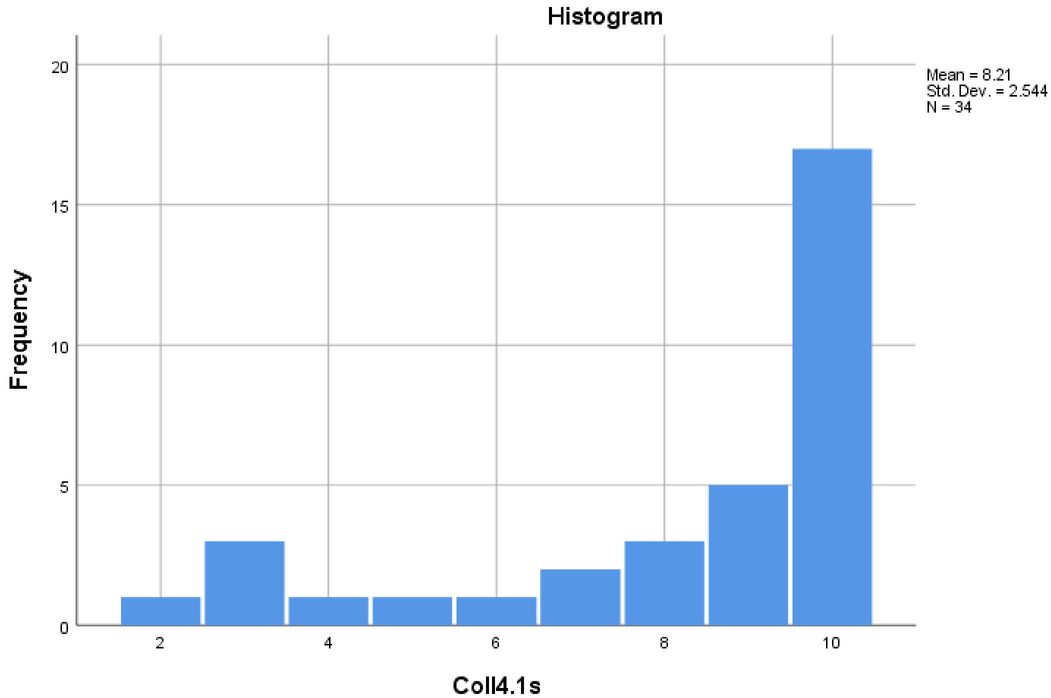

Histogram
Mean = 7.47
Std. Dev. = 2.019
N = 34
Frequency
8
6
4
2
0
4
6
8
10
Intell1.2s

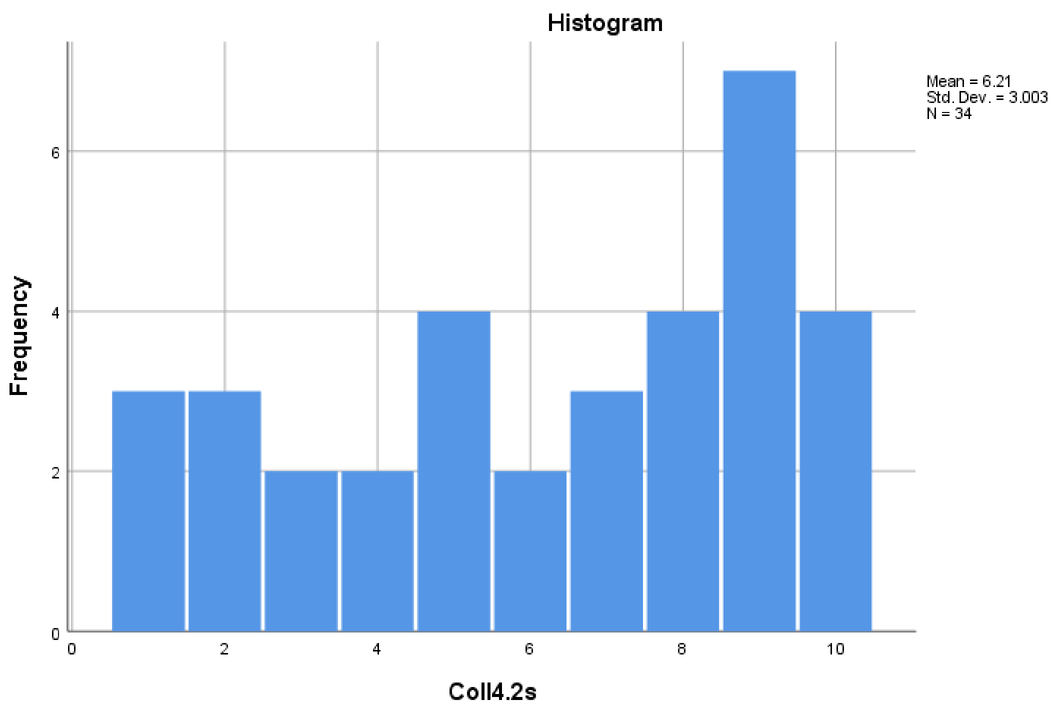

Histogram
Mean = 6.38
Std. Dev. = 3.238
N = 34
Frequency
0
2
4
6
8
10
Auth2.1s

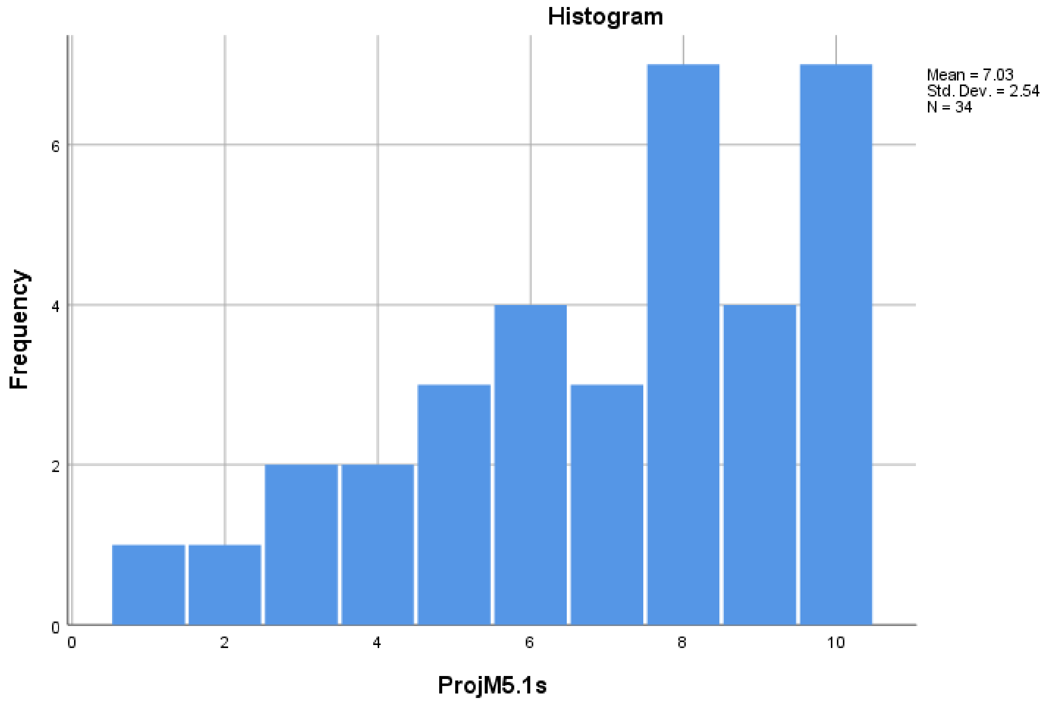

Histogram
Mean = 4.26
Std. Dev. = 2.745
N = 34
Frequency
0
2
4
6
8
10
Auth2.2s

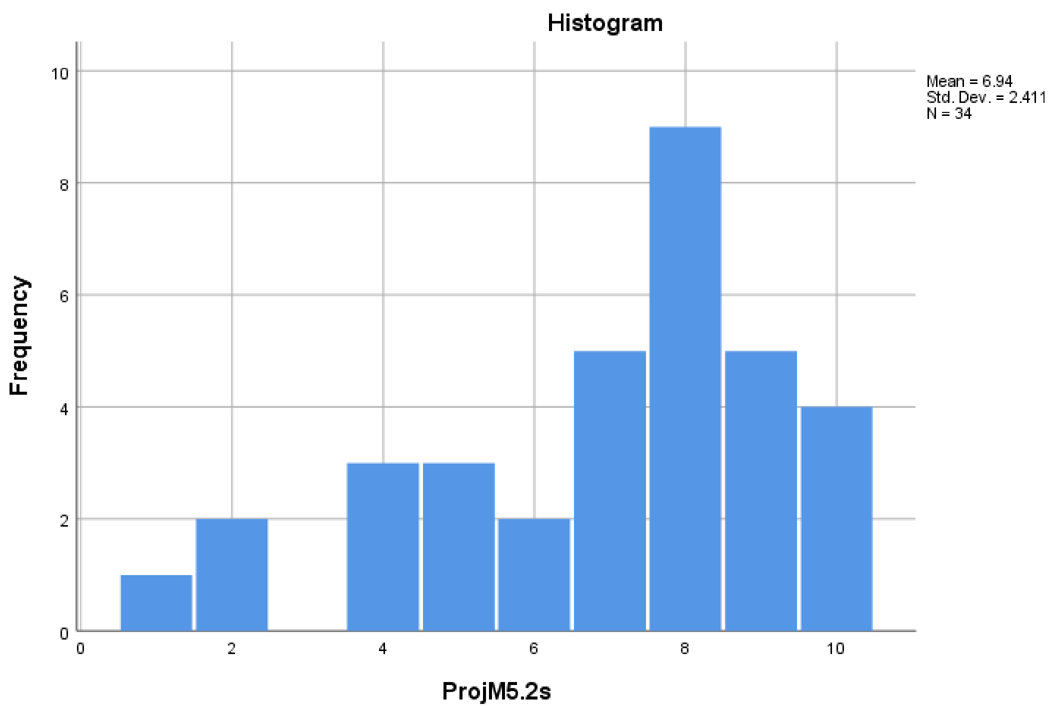

Histogram
Mean = 7.44
Std. Dev. = 2.676
N = 34
Frequency
Auth2.3s

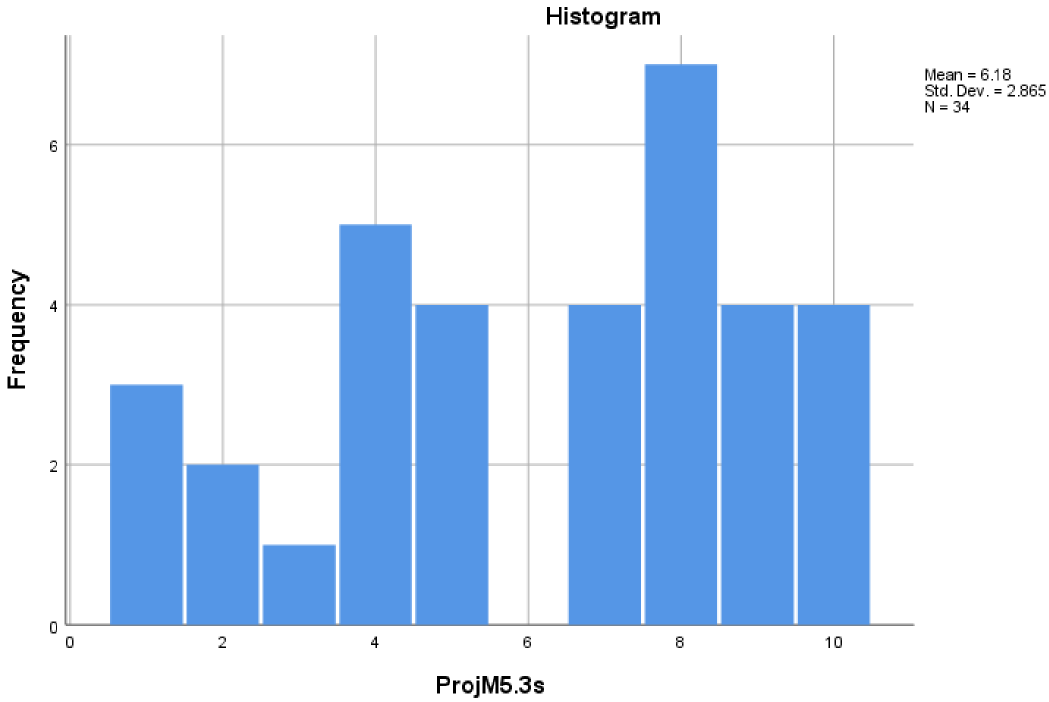

Histogram
Mean = 7.44
Std. Dev. = 2.452
N = 34
Frequency
Auth2.4s

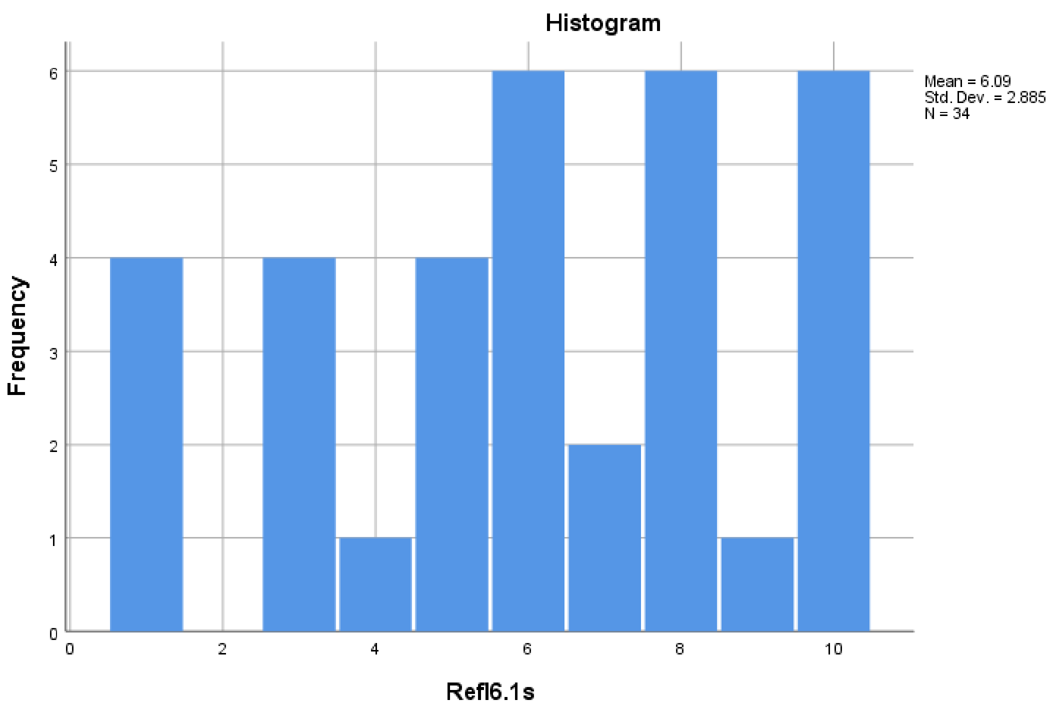

Histogram
Mean = 8.21
Std. Dev. = 2.544
N = 34
Frequency
0
5
10
15
20
2
4
6
8
10
Coll4.1s

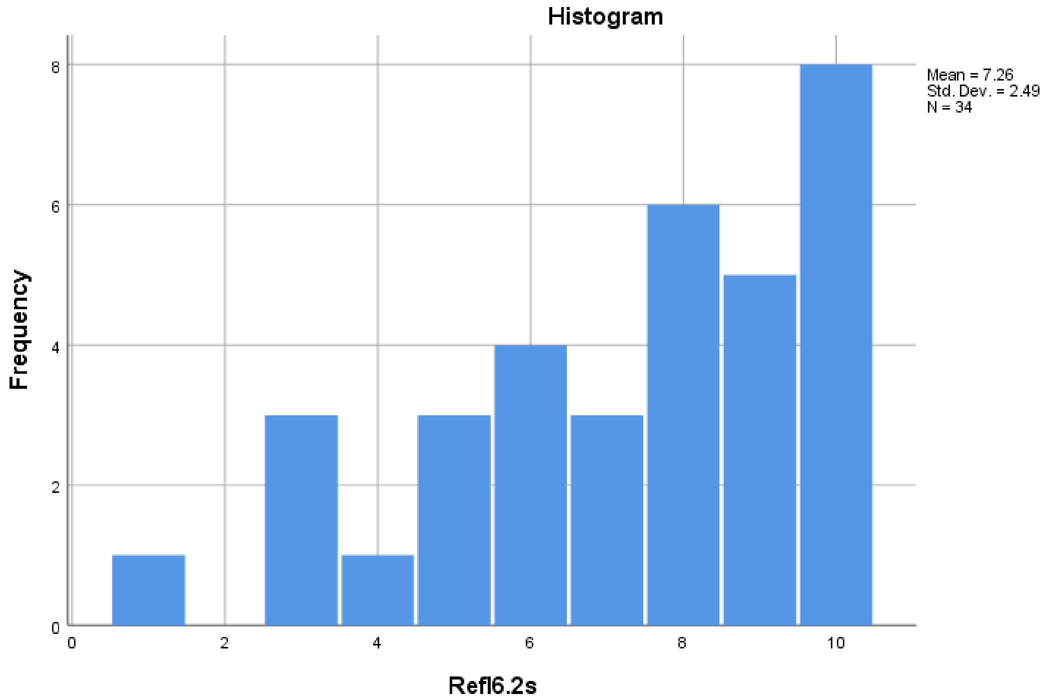

Histogram
Mean = 6.21
Std. Dev. = 3.003
N = 34
Frequency
0
2
4
6
0
2
4
6
8
10
Coll4.2s

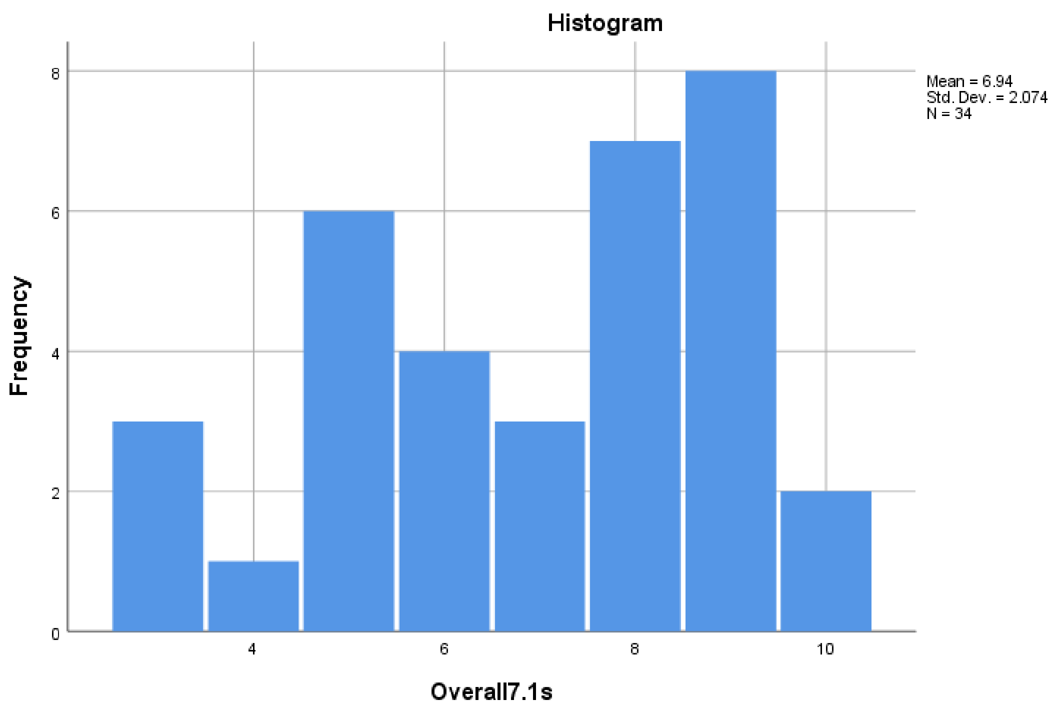

Histogram
Mean = 7.03
Std. Dev. = 2.54
N = 34
Frequency
ProjM5.1s

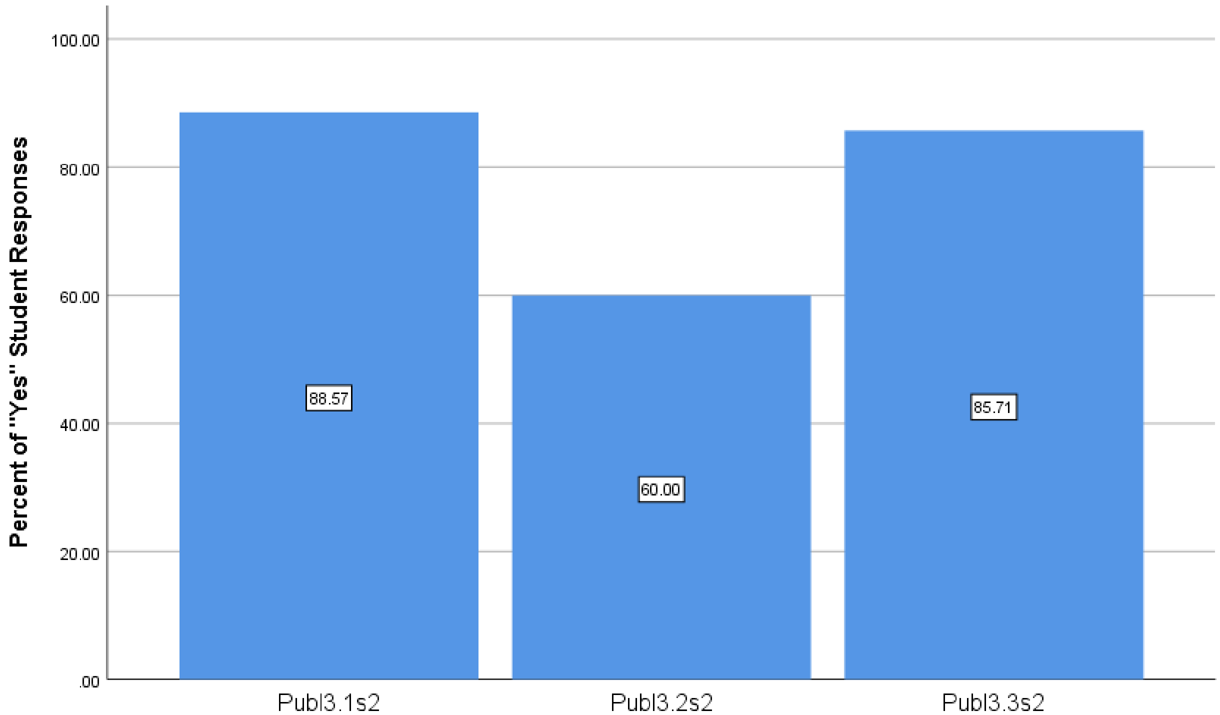

Histogram
Mean = 6.94
Std. Dev. = 2.411
N = 34
Frequency
ProjM5.2s


Histogram
Mean = 6.18
Std. Dev. = 2.865
N = 34
Frequency
0
2
4
6
0
2
4
6
8
10
ProjM5.3s


Histogram
Mean = 6.09
Std. Dev. = 2.885
N = 34
Frequency
0
1
2
3
4
5
6
0
2
4
6
8
10
Refl6.1s


Histogram
Mean = 7.26
Std. Dev. = 2.49
N = 34
Frequency
0
2
4
6
8
0
2
4
6
8
10
Refl6.2s


Histogram
Mean = 6.94
Std. Dev. = 2.074
N = 34
Frequency
0
2
4
6
8
4
6
8
10
Overall7.1s


100.00
80.00
60.00
40.00
20.00
.00
Percent of "Yes" Student Responses
88.57
60.00
85.71
Publ3.1s2
Publ3.2s2
Publ3.3s2

Appendix I: HQPBL Student and Teacher Survey Qualitative Responses by Item Number

Intell1.3s—Student Responses

In what ways (if any) did this experience challenge you to learn deeply or think critically? Please explain.

Coming up with the questions that would push our lab working to the next level was the big critical thinking part. Especially trying to make your labs unique, that was a hard part.
I definitely had to connect lot of things that we learned about over the last months to do this project. I think that I had to think pretty deeply when brainstorming testable questions because I struggle with that.
I don't think this experience challenged me very much and the outcomes of all the data were very predictable. Nothing required deep thought during this experiment and the hardest thing in this experiment was the equations which aren't very difficult. The experiment was just very tedious and got extremely boring really fast.
I feel this experience challenged me to think critically but making me come up with my own testable questions and experiments. As well as, conduct the experiments and analyze the results.
I had to fix my specific heat equation several times since, I kept getting outlandish numbers. I had to reason why my numbers were off from what they should have been. I had to keep everything neat as things changed throughout the lab.
I had to work with little guidance and work quickly
I learned more formating than actual information.
i needed to figure out how to get all of the tests done efficiently and accurately and evaluate if i needed to do a new trail because their was an error.
I think that after we made all of the slides and we needed our conclusion slide, it challenged myself to learn deeply and process all of our data to determine what product worked best and what was the science behind it.
It challenged me to look at science from a perspective I hadn't before. Asking questions and thinking in a scientific manner is much different than your "normal" way of thinking.
it didn't because we were creating an eq we practically already knew the answer too
It forced us to think broadly and then narrow down what we needed to do to answer our questions. There wasn't a lot of structure in this experiment so it made it difficult to know if what you were doing was correct or on track. But having in this way allowed us to really think through what we were doing and why we were doing it.
It made me think about heat and how it was moving, what causes that move and so forth. By doing this project it let you see first hand how the energy was moving rather than just reading about it which for me made it much easier to grasp since I'm not a very amazing analyzer when reading texts.

It made me think of ways that I can apply my learning to the project to make it easier.
It was an interesting problem, with many parts to it. There were so many ways to test and so many questions to ask. I had to think about the problem, and how we would test for each question, to determine which ones we should experiment with.
It was hard to come up with a specific question and match and experiment to it that wasn't just based on opinions of what works best
Not only did this challenge my collaboration skills but it also challenged my ability to make my own questions and be able to come up with experiments to answer said questions: This caused me to find new ways of developing questions, tests, and more in-depth questions after the test was completed.
Some ways it challenged me were to think deeply was when we had to think of our own tstable questions. That really got us thinking about how we wanted to go about experimenting and how we wanted to use the materials.
The biggest challenge with this experiment was mostly forming a procedure that would give us mostly accurate and repeatable results
This experience challenged me because it pushed me to become good with coming up with testable questions that work well to design an experiment. It took a while at first to come up with these questions, but once I figured out what I was going to do the rest of the project went smoothly.
This experience challenged me by making me take and record the data then using that data to get more information. Then it challenged me by making me analyze the data and then connect it bak the essential question we were trying to answer.
This experience challenged me to come up with testable questions that were on topic and moved the experiment forward rather than just do a simple experiment that did not achieve anything other than hit a rubric point.
This experience challenged me to learn deeply and think critically because I did not completely understand the concept at first. I knew the basic information but I did not know exactly what we were supposed to do. My group needed to think critically in order to come up with questions to investigate for our project.
This experience challenged me to learn deeply because we had to come up with our own experiments and questions while making them challenging and doable. Making our own way of presenting the information also challenged us and to find the best way to present our findings.
This experience challenged me to think more critically on energy transfer and how the temperature of different things would affect the outcomes of the questions we made.
This experience challenges allowed me to think deeper and more critically than previous labs. I think this is due to fact that the information I collected from the lab was solely based on how I structured my questions and experiments. I was responsible for my success and therefore was more thorough when it came to planning out what I was going to do and the things I wanted to learn.

This experience made me learn deeply by challenging me to think of questions that fit the essential questions, evaluate if those questions were viable and testable, and test and analyze the results of the questions.
this experiment made me think out of the box in terms of finding scientific questions to answer with an experiment attached to that as well.
We had to think about good scientific, testable questions to use in our work. This made us be more involved with the project.
When doing the lab, there was an opportunity to truly learn deeply and really understand what was being said, but my partner and I went "the easy way out", and chose a question that we already really knew the answer.
when I first started this project I had no idea how to calculate specific heat and in our project we had to use specific heat and I knew I would have to learn how to calculate it eventually so I decided to try to learn it during the project
When writing the analysis, I had to bring all of the facts and information I learned and took notes about in class into the experiment and had to apply that information to explain what was happening. This was challenging because it was important to know what the material meant and how it impacted the experiment.
While collecting data for the experiment and sharing both trials within the group towards the end of the project. During the calculation part of it. Trying to understand where to plug in data into the equations.
Working with an unfamiliar group caused me to have a different role in a group project compared to my normal role. In addition, this experiment wasn't something I was used to doing. (Creating questions for investigations.)
yes when we had to figure ou the procedure without any explination

Intell1.3t—Teacher Response

In what ways (if any) did you design this experience to challenge your students to learn deeply or think critically? Please explain.

The topic of energy transfer is one in which many students have misconceptions about even though it is something that they experience on a daily basis. In designing the unit I want to tap in to ordinary experiences and think about what they really were observing. Critical thinking first requires content knowledge. So I designed the entry activity to not just be engaging but to also start students thinking about how energy was being transfered. I followed this activity up with some exploration of phase changes and energy transfer with the pHET simulations and the exploratory lab. The essential question for this phase of the project was "What factors effect temperature, heat and energy flow. Students had to begin to think critical at this point in the project in order to design some inquiry questions to answer this EQ [essential question]. This part of the project allowed me to coach them on how to think more critically. This allowed the students to explore the content and synthesis their experience with what is temperature, heat and thermal energy flow. Building on that knowledge students where then introduced to the the mathematical relationships involved in energy transfer. Once students then had some solid background knowledge and some formative work in the lab. By design I asked them to transfer this knowledge to "Educate consumers about the use of beverage stones. To do this required critical thinking skills in asking testable questions , lab design, data analysis and synthesizing the information. Since this was a group project I then designed an individual quiz that required that they transferred the same skills.

Intell1.4s—Student Responses

In what ways (if any) did this experience challenge you to strive for excellence? Please explain.

Due to the little to no instructions with regards to what experiments and information we were supposed to be gathering, I had to rely on myself and my knowledge on the topic to make accurate decisions. This caused me to double-check my work and really make sureI was understanding everything correctly and finding accurate information.
During the experiment, I tried to be as precise as I could most of the time while measuring the materials so that I could have the best product of the experiment.
I am already an academically centered and motivated student. This particular problem did not challenge me to strive for excellence, simply because it is in my nature to strive for excellence. This project did nothing to make me less dedicated.
I felt like during this project I felt the need to do good on it because, like in any group project, I wanted to make my group members happy
I knew that since it was a self made experiment I designed it to how I worked so i wanted to do well to prove I could match an experiment to what I came up with
I never felt fully motivated or on the same page as the rest of my team because were never working on the same thing since we were split up. This resulted in me not really being fully committed to the question at hand and not putting 100% into the experiment.
I think because it was in the form of a product review it made me more interested in the topic, and curious to know what the outcome would be.
I think that Chemistry is one of my most important classes just because I am learning so much and this caused me to strive for excellence especially since this was one of the first labs.
I wanted to understand what was going on and why it did what it did

I was challenged because the final project that my group chose to do was sort of unfamiliar to me. Putting all of the pieces of the different experiment onto one final project was hard because some of our data contrasted with the final results of a different experiment.
I was challenged to strive fr excellence because I came up with my own experiments and wanted them to end up working and being effective.
I was working hard with my partner and I really wanted to get all the trials done, even though I already knew the outcome most of the time
It forces you to make connections you might not have otherwise made when just reading through a textbook. Like the idea that heat only flows from hot to cold, before this project I would have just thought that heat goes in both directions in order to hit an equilibrium but because of the nature of the lab of this project, it made it easier and more clear to make that connection.
It gave us more familiarity with the subject we would test by not giving us questions to answer, but by having us make the lab ourselves.
it helped me work as a group
It made me strive for excellence because I care about my grades a lot and I always try my hardest to do the best of my ability.
It really challenged our ability to do this quickly because with it being cold and heating up every wasted second between measuring temperature and carrying the cubes really pushed me to efficient in executing my experiments and redoing them if I noticed I messed something up
Just as a person, I hate not being perfect in every aspect. So even though my partner and I chose an easy question, we strived to get the best data we could and getting the best experiment out of the question we had. Dissapointly, we didn't get the data we wanted due to some of the limitations we hadn't accounted for in the beginning of the lab, but we went back and tried again, added more trials, and kept working to get the data we knew we wanted.
One way this experiment made me strive for excellence was with the individual lab reports. In those, I wanted to show what I understood plus how much I had learned from the project.
The fear of failing. I like this class and want to do well.
The presentation to the class and Brian. We could easlily explain which cube was best and why.
This challenged me to strive for excellence not only because I wanted to produce the best quality of work for my own questions, and tests, but I also wanted to succeed for my partners as well.
This experience caused me to think more deeply about how I can have a mindset that relies on scientific thinking for challenges and projects.
This experience challenged me to strive for excellence because getting an understanding of a topic and really digging into the learning is what motivates me most. During this project, that is what I experienced and is what pushed me to do my best.
This experience challenged me to strive for excellence because I wanted to be able to understand the concepts. I wanted to be able to complete the work and know what I was doing and talking about.
This experience challenged me to strive for excellence because of the actual final project. My group personally made a consumer report, and therefore I had to record and test good questions in order to get valuable data and information to then make a consumer report to prove why one type of beverage stone was better than the others.
This experience challenged me to strive for excellence by putting me in a group with other people where I was held accountable for my own work and relied on by my group mates.

This experience challenged me to strive for excellence by putting me into group, so my work affected my teammates. This made me strive for excellence so I did not bring the group down by doing bad work.
This experience did not challenge me to strive for excellence because I was stressed about completing the project on time and I just wanted to complete and not get behind.
This experience made me strive for excellence by having me do exact calculations on heat transfer and exact measurements.
This experience pushed me to question the way I think about certain things
This project opened my eyes to creating and solving a question which I wasn't able to do before and be successful.
We wanted to do our best so our lab would really stick out and be the best.
yes but we knew the answers already so we didn't have to strive that hard

Intell1.4t—Teacher Response
In what ways (if any) did you design this experience to challenge your students to strive for excellence? Please explain.

In the design process I told students that these products were to be made public. Their work would either be presented to the school store manager, published in the school paper or post on you tube etc.

Auth2.5s—Student Responses
In what ways (if any) did this experience seem authentic or "real"? Please explain.

as a team we did a lot of revision and editing to our work because we knew that it would be presented publicly to an audience outside of school. This then made it feel a lot more real to us because it was more then just a "turn it in" and forget about it project.
Because lots of us drink hot/cold drinks so this was a real experiment that would actually benefit our lives
because we were testing real products
By the fact that we were working with real things that real people use, these beverage stones are things that people really use every day. That really made it more personal and work better for me.
i can use the techniques in real life to evaluate other products for a future job
I guess if a person who was reviewing a product like this and did the procedure to find results for the product then it was probably authentic
In no ways did this project really feel real. It felt very generic to me and seemed like it was just thrown together just to give us more work than we already had.
In real life you have to make educated decisions, and we did experiments so that we can make educated decisions.
In real life, working with other people that you might not know that well is pretty common, so that aspect to the experience seemed "real". Also being able to understand which type of material is best for things as simple as keeping your drink cold seemed authentic.

It didn't seem real really because it just seemed so basic. Like we were testing to see if the certain amount of water depends on how fast the water gets.. yet we already knew the answer
It felt like we were almost testing a knock off joulie which can be interesting because you never see the amount of thought and testing a product goes through to be able to be the best product it can be and the number of times that they might have to completely restart at ground zero, which makes one have a different perspective on that field of jobs, and how much more difficult it is than one looking from a distance would assume.
It seemed real because I worked in a drive thru and dealing with drinks a lot of problems with drinks being to warm or to cold came up a lot.
It seemed real because we were experimenting on real products people use everyday, so it could even help make my decision if I wanted to use them.
One way this experiment felt real was when we presented ur finding to the school store to see if they wanted to put beverage stones or joulies on its shelves. We had to present our information on how long each stone kept your drinks warm or cold and which one was more effective.
Since we got to make our own pitch, it made it feel much more organic and natural. Nobody told us what our question was, we had to determine that ourselves and through the research we conducted. So while one group may wonder what beverage stone works the best for cooling your drink, another could be wondering how many beverage stones you should put in your drink so it will be effective and efficient. This leads to projects going in the direction of student interest in the product and not where the teacher says leading to organic learning, learning happens best when the student is interested.
the experience seemed authentic and real, because we were dealing with everyday items that any person uses. Also for the most part our question/experiments applied to keeping the water cold which is something people do all the time, so our results could maybe even help beyond class because they could be helpful when trying to find the best materials.
The materials we were testing are familiar to me. I definitely thought the aspect of how chemistry and science can play a roll in being an educated consumer and how to get high-quality materials for a reasonable price.
The presentation or pamphlet piece of the experience really added to the realism. I definitively could see this being a legitimate experiment for application in the real world.
The products you would use in everyday life.
This experience did not seem real or like I would do this outside of class because it does not relate to anything I am passionate about and relate to.
This experience felt real because right now, reusable products are extremely popular, and a big choice to be made is "which product should I buy?" So we followed a procedure that is like testing I would do for any other product, if only more formal and thorough.
This experience helped me understand how I can be an educated consumer and ask questions to assure that what I am buying is actually worth it.

This experience seemed authentic because we were asked to complete a few studies, and then compile the data into a final project. The final project needed to be either a consumer report or something presentable to a group of people. The essential question we had also helped make this experience seem authentic. The question was "What does an educated consumer need to know when buying beverage stones?" This question gave us a specific goal and helped us realize that people do this in the "real world." The beverage stones were also an item that could be used in our own lives as well.
This experience seemed real because it related to something that is used by any people everyday. It seemed like it actually would be useful information to have and that it wasn't just a random experiment on something that didn't matter.
This experience seemed real because of the fact that it was based around a problem in the real world. People who drink both hot and cold beverages exist everywhere, and want to be able to drink the liquid at the temperature that is to their liking. Beverage stones are an invention that quite possibly could be the solution for that, which is why it was such a realistic experiment.
This experience seemed real when they said that the stones were actually called whiskey stones because It made me feel like it wasn't just this school's labs because they would edit that.
This experiment seam authentic for many reasons although the reason that made it the most real for me was that I was in control of the questions we were answering and I was in control of what experiments we would do to answer this question and this allowed me to have control over my learning making more like the real world.
This mostly felt real because it is a problem that many people face. I personally do not drink coffee or tea, nor do I plan to drink any beverage that would require these stones. It was still a real experience because in a future job, I may have to test and review a product or material. Many others experience the problem investigated in this project.
This project seemed real because of who and what the information was targetted towards. In the end, we had to express which product we believed would be the most beneficial for a school environment and for students to purchase and that really made everything come full circle in terms of analysis. It forced us to make decisions not solely based on facts, but also based on how it would affect the student body as a whole and look at things from a perspective other than mathematical calculations.
This seemed real because we had to create a final product that was informational, to explain why one beverage stone was the best. We also had to explain in scientific terms why it worked better than the others. It was real because it forced us to find real data to back up and support our claims
This was a good experiment for the real world because it is using ever day items and comparing the quality and how good the items work when used.
we used the cubes to cool a drink
We were pretty much left to ourselves to figure out what aspect of the lab we wanted to test and how to compare and present data, so it wasn't structured toward any particular goal, just to further understanding for us.
We were testing cubes that made liquid colder, people can use these in the real world and now we have the knowledge if we want to buy any of the cubes.

Well everything we used in the experiment was real stuff that relates to things we do every day. we drink water we put ice in our water so It showed us some new options and we actually got to test those options to actually prove what was better.

Auth2.5t—Teacher Response
In what ways (if any) did you design this experience to be authentic or "real"? Please explain.

I designed this lab from the beginning to be "real" for students. Beginning with the entry activity of kickstarter and shark tank right through to the end when the group project was to produce something similar to what they they may see outside the walls of a classroom. For example ratings from consumer reports or amazon review etc.

Publ3.4s—Student Responses
In what ways (if any) did you make your work public by sharing it with peers or other people beyond the classroom? Please explain.

Brian who runs the school store. we made a pitch to which beverage stone works best
For my group we wrote an Amazon review and turned it in to the teacher.
For my project, our main goal was to present our findings to members of a group running the school store. We wanted to persuade them into letting beverage cubes to be sold to students. This motive helped us be more thorough and strive to be more accurate when it came to expressing and showing our found information.
I did not
I did not make my work public. That was mostly a personal choice. I prefer not to share my work with others, but the project was designed in a way that if I had wanted to share my work, it would have been possible.
I didn't show anyone outside of my peers and teacher what my experiment held, mostly due to the lack of depth in my partner and I's question, as well as our data being inconclusive.
i dont think the work was publasized
I made my work public by sharing it with the class, and my teacher. Originally I was supposed to present with my group to the school store, but the person that was coming was unable to make it. Instead I just presented to the class. The presentation was filmed so it will soon be sent to those who work at the school store.
I presented my project to the class, while my teacher recorded it after getting our group's permission. She then shared it with the school store board
i shared my video on youtube
I showed my parents the final powerpoint becuase they were interested, but that was it.
I tried to post my final project on different social media sites but I don't really use social media much or know how to.
I wrote down my final specific heat of the granite cube on my hand so I had it during presentations, so I was explaining what we were doing in chem to my dad and what the numbers on my hand were .

In class, we had a peer editing day where we engaged with other groups to reflect and explain what we did for our experiments and present our final projects. This allowed us to get feedback as well as ensure that we had all of the criteria that we needed for this project.
In theory, I made my work public beyond the classroom because I pitched to the school store, meaning that now there is the opportunity for beverage stones to be sold in the school and reach out to a much wider range of people besides my immediate chemistry class. Other groups probably have a further reach, however, groups that wrote a consumer report are posting their report online to reach the millions of people that use the internet, even though they may never see any results of their work being public.
Me and my group made our final project public, by posting it on youtube and sharing it with some of our peers in our class for feedback.
My group and I shared it using a article.
My group made a video for our final project. We shared our video by posting it on YouTube so that others can see it.
My group presented the project in front of the class
My group presented to another classroom,and my teacher presented to a group of other teachers about our projects.
Once I was outside of the classroom I was excited about what I was learning, the questions I had, and the answers that I did not yet have. This caused me to talk to other people about it as I wanted to continue to learn about the subject outside of the classroom.
One of my group members posted our info graphic on Pinterest and on her Facebook page.
Our group posted our project on Pinterest, where users could see the results on our project and cause them to receive the knowledge from the foundings we had.
Our presentation was shared with the head of the school store for them to put the stones that we were recommending into their store for students to buy.
We created an article to possibly get published on The Claw which is our schools online new paper
We had to explain our lab to the head of the school store because the we had to explain which beverage stone was the best to be sold in the school store. Other than that though no one else outside of the classroom saw or heard our experiment.
We made a consumer report that we put on Consumer Reports.
We made our work public by sharing it online. Other people outside of the classroom can view it and see our experiment.
We shared it with the school store owner who is evaluating to see if the school store should have beverage stones
We shared our work with a school store member to see if they wanted joulies or beverage stones in on their shelves.
We showed our final product to another group in the classroom, and they read it over and gave us some feedback. A couple of us also checked in with each other to make sure we were on the same page with the final product.
We showed our presentation to the teacher who runs the school store at our school to maybe introduce the idea of buying and selling the item we were experimenting on.
We were going to share our product with another faculty member at our school but they were not available so we shared it with our class as an in-class presentation.

Well we condensed our findings into a youtube video with a little clever acting so it is public and anyone can see it

Publ3.4t—Teacher Response
In what ways (if any) did you design the project so that students would make their work public by sharing it with peers or other people beyond the classroom? Please explain.

Prior to turning in their final project each group had another group peer review their work. Since I did not have a good protocol for this I am not sure that students got much out of this. In the future I will probably put together a more formal peer review process. I too reviewed students work before it was shared publicly and again I think I could formalize this a little better

Coll4.3s—Student Responses
In what ways (if any) did you collaborate with your peers in this project? Please explain.

Another group mate and I were basically doing most of the whole thing so we asked the other group mates to help out more and we told them what they could do so it is more of a group effort
As a group we divided and conquered our experiments. I worked with a partner for all aspects of the project, and we wrote the Amazon review as a whole.
At the beginning and end of the project, there was too much work to not split up all the members.
Doing the experiment together and sharing data.
During this project collaboration was the key to success as you needed other people to help conduct an experiment with you, to help draw conclusions, to conduct more tests, to create more questions, to receive feedback, etc.
Honestly, this is probably the part of the project I am the most down on and I understand that this isn't an issue of the project itself. In my group, I felt as if I had to do all of the work. My team members did not really do a whole lot in the ways of suggesting ideas, asking questions or help out with the science behind the project. Then when it came time to put together the presentation, out of fear of my bad partners hurting my grade I essentially built the entire presentation myself, exception to one or two slides. Overall I was kind of bummed because it made me take on a lot of extra stress I didn't really need to take on, however, I do know that with a better group that wouldn't be an issue and don't necessarily think it a fault of the project but the people.
I collaborated with my peers by engaging in this project through checking in with each other on how our experiments were going, what questions we were testing, and the data or results that we were finding throughout the entire project.
I collaborated with my peers during the entire project. Talking within the classroom we discussed the layout of the project, steps and the best way to go about working on the project.
I collaborated with my peers for almost the entire project. Together, we wrote testable questions, planned experiments, performed experiments and procedures, and put together a presentation for an audience.
I collaborated with my peers on this project, by sharing ideas in group work time and doing the experiments in partnerships. We also worked with other groups in order to get feedback on what we could improve on an what we were doing well

I collaborated withmy peers when it came to creating our powerpoint. We all got together and planned out a storyboard and divided up the work on the slides.
I felt like two of the five members in my group became the leaders. I was one of those people. I don't usually pursue a leadership role but most of my group members were hard-working and got their work done but were shy and not quick to start a conversation. I think I and my co-leader worked well together and got the others to participate more verbally
I had to work with others in creating questions and deciding which ones to use, experimentation, and writing the final piece to present our research. We worked together to decide which questions we would research, and then we broke into pairs to test questions. I did much of the work, because my group was easily distracted. When we were working with the whole group, it was harder to stay on task. We did get all the work done on time.
I helped create the scientific questions, i also helped conduct the experiments.
I made sure to have good communication skills with my group members when we were outside of school and we had individual work to complete. In addition, I made sure to give feedback on their work and receive feedback from my group members on my work.
i worked primarily with one other group member to complete the trails needed to draw conclusions
I worked with another team member on an experiment on specific heat. Once we completed the experiment, the whole group worked together to create our final project video.
I worked with my whole team on the outline and general project, but I worked with only one peer for the experiment phase.
In this project we collaborated well with each other. we split up to do different experiments and then reported back to the other members. Over the weekend we talked to each other on a group chat that was made
Most of the project was done with peers. Our testing with experiments and the overall final piece was done with peers. Throughout the process we had to collaborate with each other.
My partner and I did our lab together, then when looking at our whole group's lab, we broke our final project up into sections for each person, then stayed relatively independent outside of adding comments to other people's sections to help me in the best situation grading wise.
The entire process was as a group. We were either working in groups of 4 for the project or splitting into groups of 2 for the labs. It was all in a group.
The main way that my group and I collaborated during this project was when we had to divide and conquer in hopes of getting all of or experiments done. We split up and then had to accurately communicate back to each other our findings and how they could benefit and relate to the other group members tests'. We also collaborated when it came to presenting our information the Brian. We split up our topics and since we all communicated our findings so well to each other, we were all able to talk and build of the information being talked about even it is wasn't our experiment.
The peers that I worked with didn't really care about working collaboratively we took the data together then didn't really work with each other.
This entire project was centered around dividing work equally between group members, and we had to collaborate to make sure that work was presentable and accurate.

We all had to work together to get the experiments done, and we had to communicate our results to one another to draw conclusions that make sense and that we have data to support these claims.
we all worked together on the eq
We collaborated throughout nearly the entire project from writing our questions to creating our procedures and collecting our results however during the final stages with our video there was a little less team work just because we all can't be talking or working at once in one scene
We did most of the work together, assigning jobs and designating time to specific resources.
We didn't really collaborate during the project because we were split up in the beginning and then were not given much time to execute our lab making it difficult to find time to talk and collaborate with our peers.
We divided the work and did different aspects of the experiment so that we could get it done in time. Then we came together and explained the conclusions of all of our experiments. Then we decided how the final project should look, and talked a little bit about it.
we had a google powerpoint that we shared with each other so we could collaborate on the project in real time as we added results and conclusions of our experiments
We were a 4 person group who worked together to create 2 EQ's, then we split into pairs to do our separate experiments however when it came to the end our whole group game together to create the article but we only used one of the EQ's so it made it very hard
We worked together in a group

Coll4.3t—Teacher Response
In what ways (if any) did you create the project so that students would need to collaborate with their peers in this project? Please explain.

Students worked in groups of 4 for both the exploratory phase of the unit and for the final project. The students were then instructed to break down the tasks and work in groups of 2's to complete the lab investigations.

ProjM5.4s—Student Responses
In what ways (if any) did you need to manage yourself or other team members in order to be successful in this project? Please explain.

For the most part, my team was mostly on task. The only times when we weren't and the conversation drifted away from the project was when we had no more tests to run or gather any more information.
I feel like I could have been more involved. Personally I could have done a better job then I did.
I had to leave early on one day of the project but I communicated with y group members after school to retrieve all information to complete the project.

I had to manage myself by being aware of time. I play soccer, so away games can sometimes conflict with study and homework time. Though this is true, I am very good about time management, which was a savior for me during this project. I made a shared Google Slides document and a iMessage group chat with my teammates to communicate. I had to manage my teammates by reminding them to work on the project. Unfortunately, some of my teammates did not pitch in in the final product.
i had to stay on task
I kept asking questions and trying to work through some of the math with my teammates, and helped set up the power point with one of my other teammates.
I made goals for myself when to have things done by like the experiment and article as well as my group did for themselves individually since they were not given a deadline
I made sure that I always came to class prepared with an idea of what I had to get done in class that day. I also made sure that we were engaged in the project all throughout class and not getting distracted or talking to other groups. I also managed the time very well and made sure to continually let everyone know how much time we had left in the class period
I managed my team members by telling them they have to do work, managed myself by realizing they weren't going to do it, and then I picked up some of the slack. I did not do all of their work for them though because I can't be a free ride I managed myself by holding back and potentially hurting my grade.
I managed myself and group members during this project by keeping us on task and focused, as well as contributing ideas for the experiment and sharing a large portion of the presentation.
I missed the first day of work because I had to leave early and it got we behind by a lot and I had to do a lot to understand what we were doing
I myself, really on making sure that I had my own part done and on time, of course, if there was a situation where someone was behind in their work, one would inform them to try to catch up and offer to help if they didn't have time, but luckily every one had their work finished at roughly the same time.
I need to give myself a set schedule in order to complete work or projects without having to scramble to finish. I learned that if I use my class time wisely, then I will not have to do any work outside of school.
i needed to remind myself to stay focused while i was completing the trails and i worked hard to effectively complete the project
I tried to keep everyone on track and engaged in some helpful part of the experiment so that we would finish on time. Something I didn't do, was make a plan for over the weekend, or gather contact information, so I was unable to contact some of the group members over the weekend.
I tried to make sure everyone knew what they were supposed to do and always asked questions if I was confused about what I was doing. Over the weekend I sent an email to one of my group members to remind them of the part of the project they hadn't finished on the shared document yet.
I tried to make sure we looked at the rubric but otherwise, we just went along with whatever was next for that day
It was mostly independent work, so there was not any real managing.
Making sure i had all the data i needed and collaberating together to find specific heat

My team and I managed the project by starting off with a plan. This way we could follow it and stay on task. This resulted in us being successful and completing the project effectively and efficiently.
Our team was very good at talking things over
Some group members may not have been very good at doing calculations and I had to help them out. At other times, it was just figuring out who says what in the presentation or other very small things.
Some of my team members didn't want to contribute much. So in order to get things done, I would have to assign roles to certain members or continually check up on those who were slacking off.
Some of our group members lacked good communication skills, so we had to adjust the workload for our group. We split the work of what he didn't do amongst each other.
There were no ways that I had to manage my team members because one person had the papers and that didn't allow for us to have our own papers for writing procedures to the experiments later on in the project.
We all gave each other tasks to do inside and outside of school, holding each other accountable.
We definitely could have planned better there was a lot of retakes a lot of redos and a lot of adjustments just because of simple mistakes but overall we managed our time pretty well aswell as our resourses
We didn’t all get a long and so we had to make sure everyone was on the same page and working together
We made plans about how to execute the experiments and how to present our findings. we also planned accordingly for any bumps in the road and made sure we were being realistic and were finding effective results.
We made sure everyone carried their own weight during the lab and pushed them to do their work if they didn't.
We managed our times, the roles we played (such as collecting all the papers, materials, etc.), and we managed how we would go about the experiment.
We needed to make sure we were efficient and fast. There was a limited number of cubes, so we had to work effectively to get all of our testing done. We had to manage our time and our tests so we had enough cubes. We also had to make sure our final written piece was completed on time.
we needed to time manage ourselves
When something needed to be done I told my group it needed to be done so I can put it on the info graphic, and when someone didn't do their job, some other group members and I compensated by doing the best we could in that section until that person had it done.
When we split up into groups, I was a designator of tasks to people who weren't already doing anything. so I had to do some management.

ProjM5.4t—Teacher Response

In what ways (if any) did you design this project so students would need to manage themselves or other team members in order to be successful in this project? Please explain.

When beginning the group work I had students define roles for themselves, Each group defined a Facilitator, Recorder, Task Manager and Compiler. I think this help everyone feel somewhat responsible for there part in the project. I think these roles allowed students to be more successful.

Refl6.3s—Student Responses

In what ways (if any) did you pause during the project to think about what you were doing and learning? Please explain.

A few times I would have to stop and rejog my memory, but I could always tie pieces back in together.
About halfway through the project, we decided to scrap one of the ideas we were working on. and focus on another because the first one wasn't going anywhere.
During the equations
During the project I often thought about how the project connected with what we were learning. We were learning about specific heat and heat transfer, and during the experiment I connected it to science and the essential question of the project.
I constantly am second-guessing myself so pause a lot during labs and such to think about if im really doing it correctly and efficiently.
I did not pause during the project to think about what I was learning because the project at hand did not have any real connection to energy transfer and I just wanted to complete the project.
I didn't really have any moments like that. It was fairly straight-forward.
I didn't really pause to think about it but I feel like I had a pretty good grip on what I was learning and doing.
I do not reflect. I do not like reflecting. I sitting and thinking about mistakes and how we can fix problems doesn't actually fix the problem. I notice when I make a mistake, and try to not make the same mistake. I try to be more proactive, and I personally find that reflecting makes me dwell on the past and the mistakes I have made. I let the past stay in the past, and work towards the future.
i needed to think about the time that i would need to use to complete the project and needed to understand what was going on in order to accurately write the formal lab report
I paused during this project to think about what I was doing and learning in order to create real-world connections and to further fulfill my curiosity.
I paused to review my notes and check in with my peers to ensure I was doing everything correctly.
I paused to think about what I was doing and what I was learning by taking a step back after write out the white experiment planning papers, and reading through them one more time. I did this to check my understanding of the topics, but also to make sure my group wasn't leaving anything out for the final product. Stopping and reviewing the project papers was a good decision, for I picked up some things to add and fix for the final project product.
I paused when I had to think about how the experiment was working and what was causing the outcome.
I paused when I wasn't understanding, then when i understood, I picked up.

I stopped in the projected and thought to myself, "what the heck are we even doing" then another person who was gone on the first work day told me about how he had no idea what was going on either
I thought about what I was doing and learning during this project multiple times. I thought about what I was doing when I realized that I conducted my experiment wrong, when I thought my data didn't make sense, and when I needed to summarize my information for the video.
I would stop and think about it when we were measuring the temperature of the water and items we were using and thought about the transfer of energy throughout the whole process.
In the beginning when we were first deciding how we wanted to answer our experiment questions we had to think through how to perform a lab for them . For example "how long does the drink keep optimal temperature before it reaches thermal equilibrium?" were one of the few questions we had to think through collectively to create a lab that answers it. This part probably took the longest because we had to make sure it solved it and connected back to our other questions to find out if the stones were effective or not effective.
In the end, when we were writing the conclusion slide, I really started to process what was going on and what we were learning with heat transfer
Multiple times throughout the project I paused and carefully considered if what our group was doing was productive and connected back to the essential question and sub essential questions.
No because we were so busy working on the project in a short amount of time that it felt like there was no time to think about what we were learning.
Once we had finished the experiments and were starting to compile all our conclusions into one final conclusion, I paused to take in all the information we were gathering.
Personally, there really wasn't much time to "Pause" during the project since everything was really fast-paced. We only had a little bit of time to get everything done and put together a presentation so there really wasn't much downtime to think about what we were doing.
We paused a lot to talk about the thermodynamics and the math behind specific heat to make sure we had all the data we needed.
We paused and thought "how does this help us answer the essential question?" and we paused to analyse the data to see what connections we can make.
we paused during the project when we were having any problems with the experiment and then we talked it over with each other in order to find a good solution.
We stopped to make sure we were on track before getting too far into the experiment
when i was confused i n eeded help so i asked for help
When I was doing the individual part of the project I could see how everything from the last unit was appearing again in this unit and how all of the rules of energy and heat transfer appears in everyday life.
When my partner and I realized we had messed up our experiment piece and possibly had to redo it
When we had to understand what high and low specific heat means for the product.
Whenever I had any form of confusion I would stop and take a couple of minutes to really process what was truly going on.

Refl6.3t—Teacher Response
In what ways (if any) did you design this project so that students would need to pause during the project to think about what they were doing and learning? Please explain.

After reaching the content knowledge milestone (after the exploratory lab) I had students reflect back on what they knew. I then shared their responses anonymously with the class. I do think that this help students recognize their level of understanding.

Refl6.4s—Student Responses
In what ways (if any) did you pause during the project to think about how you could make your final product better? Please explain.

After we filmed our video, I thought of a few ways I could have made the final product better. My group and I thought we would not have enough time to finish, so we filmed our video in one take and did not prepare a complete script. If we had realized that we had more time, we could have created a script and had more structure to our video so that it was more concrete.
collaberating with my group more
During our project, I had a realization that we could add a second comparison experiment that would make a nice contrast to the data we had already collected and would help us in our pitch to consumers, so we stopped and did that experiment quickly.
During the end of the project we were focused on making sure that everyone's data was the same and made sense.
During the entire process of building our presentation I was thinking about that. How could we change the wording here, what picture could we add here, things like that. And how long should our presentation be, how much time should we spend on this, where should this table go, etc.
During the final project I looked at what we were learning and tried to make sure the project had elements of all the stuff we learned. This way I could better understand the material we were learning.
I could've produced a better question, lessened the amount and the severity of the limitations, tried getting rid of extra independent variables, worked better with my group, written my part stronger, added more info, create a better applicable lab for the situation, tried harder, and overall just have a stronger lab, for myself.
I did not pause that often to do this
I did not reflect.
I didn't really have a huge amount of time to go back over my final project, but I did change a few of the data tables.
I paused during this project to think about how I could make it better by doing the same thing I wrote above. I reviewed my papers, just to check if anything was left out before continuing on.
I thought that we could add more info to the info graphic by adding charts and tables and graphs without adding an unnecessary amount of wordage.
I was constantly thinking of more ways to include more data and analysis in the project. I wasn't sure what an infographic was supposed to look like and if it was supposed to be more pictures than words

I would only pause during writing to think about what I was typing into the powerpoint presentation.
In the project, the group took time to see how we were contributing to the final result and what we need to further contribute to it in order to make it better.
Instead of just typing out our powerpoint, I tried to add some circles and pictures to make it more fun and interesting so that we were not just reading off the slides
looking for the problem areas
Many times my group would talk a lot about the delivery of our presentation and how we should convey our words and messages to the audience. We could have made our information a little bit more clear and concise but overall we still got all of the information we need out.
No because I thought our project was solid in all aspects.
Some of the time I had ideas and shared them to the group. Like not doing a video because of the time.
There were some times at home when I was awa from the class when I could think of how I could make my slides better or my lab report better. Not really anytime in class.
Throughout the project I thought about how our group could cater the experiments and results towards the audience that would be seeing it: the school board.
To make my final product better, I paused to review what I had learned, my notes and analyze all of the data that we had collected throughout the project.
we decided mid-way through one of the experiments that it was unnecessary and would be too time consuming, which is a factor because this project had a time constraint.
We didn't really pause during the tasks to specifically see how t make the project better, but we did collaborate through most of it.
We didn’t really other then thinking about the power point
We kinda just through all of the final stuff together and nobody wanted to touch it after everything was together
We paused to adjust our final product in order for it to fit the requirements.
We were limited on the amount of granite stones we had. During the entire process we talked about how much easier and how much more information we could draw from our experiments if we had more granite cubes.
Well after our first round of tests we realized we forgot to measure the temp of the cubes before inserting them into water so we missed some critical data and had to redo half our tests good thing we reflected before we were totally complete
when creating the slides I felt like I could have been doing more because the information that we had to present was not a lot
When we thought that we any be running short on time we would take a pause to assign everyone roles to make sure our project would be done on time and we wouldn't have to stress about it.
when we wanted to redo our project but couldn't cause we wouldn't of had enough time

Refl6.4t—Teacher Response
In what ways (if any) did you design this project so that students would need to pause during the project to think about how they could make their final product better? Please explain.

This is an area that I think I could have done better at. Students did have to brainstorm before they began the final product and after their experiments. I think that they realized what they might have had to do to get better results but I did not give them endless time in the lab so some of them were not able to make their final project better

Overall7.2s—Student Responses
Explain why you gave the rating (0-10) about your overall experience in this project.

i gave a 5 bc it wasnt well put togtehr and my group didnt work well together
I gave a 9 rating, because I really enjoyed the project and I thought it was very helpful when learning about specific heat. how ever I always think there is room for improvement and it could be better if we had a little more time to experiment.
I gave an 8 as it was a good idea for the lab and I could've made it more interesting if I had decided to push myself, but I decided to be lazy and made a poor lab and poor question hindering the experience of the lab as I felt like it was almost too easy for me. So it is an 8 because the idea is a 10, but I made it worse for myself by not caring enough to push myself past the level of an 8 year old.
I gave it a 6 because I think that working with a group made it difficult for everyone to put in the same amount of effort
I gave it a 6 because it was challenging and slightly stressful from the amount of time we had. One of my group members didn't do as much as they said they would over the weekend even after I offered to help. That group member and another group member kind of butt heads a lot. I enjoyed analysing of the results though and I like working other people.
I gave it an 8 because although it was stressful with finishing the final project on time, the experimenting was fun and interesting.
I gave it this because I enjoyed the project, however there were some bumps in the road along the way, but we eventually got it together.
I gave my experience in this project a 5 because there were some parts that were interesting but after that I was stressed about completing the project and making sure that we had everything we needed to meet the expectations.
I gave the rating of a 7.5 because this project was a little hard at times and time was not always our friend because of the experiments we chose, but it helped me learn a lot about energy transfer.
I gave this an 8 because I overall thought it was a good experience, although I wish that we had more time to work together in class on solely the final project because I felt like one girl did the majority of it outside of class because we all have different schedules and she got to it first since we had to do it over the weekend, instead of work collaboratively on the report together.

I gave this project a 9 because I really enjoyed this experiment, and learned a lot. I would have given it a 10 if my group dynamics were a little different, and everyone had help to put together the Google Slide. If everyone had done a fair share of their work, the project would have definitely been more enjoyable. In saying this, I still did have a great time doing this project.
I gave this project an 8/10 because it was an engaging, hands-on project that challenged us as students to have more individuality when performing labs and generating our own questions.
I gave those experience a 7 because really liked how I could be in control of the situation but I didn't really like how I was doing a lot of the work when some of my group memebres would slack off.
I give it a 5 because it could've been fun if it was more organized and planned out but it wasn't so that made it difficult as well as it was a basic experiment
I liked the experience I had with the group and I felt like a lot of the time was collecting data and analyzing it which I've done so many times in school I've gotten sick of it
I mostly enjoyed this project. The materials and questions were engaging and interesting, and the project was managed well. I have a personal issue with group work, and that was where I struggled most. Otherwise, this project was a success.
I think there's a lot of good things happening in this project that work really well. However, the thing that confused me the most was the fact that our target audience was the consumer. During the making of my presentation I constantly faced the issue of; If I'm selling to the consumer they don't care about the science behind our experiments and just want to see the results, however, the rubric states that the science must be mentioned. In order to show my understanding of the science, I had to put in the science stuff making a weird disconnect between the consumer side of the presentation and the science side. Also the group work was not very great for me specifically.
i thought the project was a very good representation of the energy transfer process and it helped me understand the concept better. it was also a fun and easier lab which will help me understand how chemistry labs work so i can be more successful in this class
I wish we had more time in class to create the final project.
I would say that in the end, this was a very fun project and a super cool idea that I actually learned a lot about while still have fun and getting plenty of work done. My experience was very pleasant and I would not mind doing again with a different group.
It was a fun project I understand energy, heat, and temperature better now however it was a little scuffed
It was a good project and I think I would have enjoyed it more with different teammates
It was difficult because of how little structure we had with this project. But I would say that it probably helped In the end because it forced us to think through our choices.
It was good but also a little too opened ended so we didn’t quite know where to go work it at first
It was very stressful because we didn't have a lot of time and the experiments took a long time. We also had to crunch in all of our research into a conjoined document within a single block because we ran out of time. There was so much paper work and so much to do without enough time. There was also no guidance whatsoever and questions were met with other questions
My overall experience was very good. I could see how the knowledge used during the project could be useful outside of school. I also got a better understanding of the material we were learning. I also worked with a group which made me better at collaboration.

Not a lot of group work, didn't learn a lot and I just wasn't very interested in this.
The project idea itself was fun. it wasnt very organized and the group didn't feel like a group due to splitting up in 2 teams
The project was better than most other labs I have done. It was a little tedious though.
This experience was good overall. I enjoyed conducting my own experiment and creating a final project to compile all my data. I would like to continue doing projects like this but with a little more guidelines.
This project not only allowed me to have control over my learning and how I learned but it taught me how to collaborate and it taught me how to have fun and enjoyment in my learning again.
This project was a fun project which I felt was very relevant and meaningful in the real world, which is why I rated it highly. I would recommend in future classes.
While this lab was generally fairly straight-forward, it gave lots of room for open thinking and deeper learning. We were able to ask whatever we wanted as long as it fit within the boundaries, so it gave us a lot of room to work with. I had a good experience, because I really enjoy that open-ended nature of projects of this sort.

Overall7.2t—Teacher Response

Explain why you gave the rating (0-10) about your students' overall experience in this project.

Students were engaged and were striving for a quality project. However most importantly I feel that students have a much deeper understanding of this concept. I don't feel that they are just meeting the standard by superficially being able to calculate the flow of energy from one object to another. I think that they now truly understand what the factor that affect energy flow are and can use this information in their own lives.

Appendix J: Teacher Interview Questions

Domain	Item #	Interview Question
Align to Standards	TI.1	How do the products allow students to demonstrate mastery on the standards?
Build the Culture	TI.2	Did you use norms to guide the classroom during the project? Were those norms co-crafted with and self-monitored by students? Explain.
	TI.3	In what ways (if any) did you consider student voice and choice in the design and implementation of this project?
	TI.4	Did students usually know what they needed to do during the project (minimal direction), or did you find students needed more direction? Explain.
	TI.5	Tell me about how students worked collaboratively in teams? Did you need to get involved in managing the teams? Explain.
Manage Activities	TI.6	When you designed the project, how did you consider including (or not including) individual and team work time, whole group and small group instruction? Explain
	TI.7	Did you use any project management tools such as a group calendar, contract, learning log, etc. to support student self-management and independence during the project? Explain.
	TI.8	How did you form teams—did you form them? Did students have voice and choice over who would be in their groups? What were the various factors you considered as you formed teams?
	TI.9	Did you have checkpoints and deadlines during the project? If so, were those checkpoints and deadlines fixed or flexible? Did students need to wait to get feedback before moving on at certain points in the project (or not)? Explain.
Scaffold Student Learning	TI.10	To what extent did you scaffold student learning to provide instructional supports for all students to access content, skills and resources? What scaffolds were in place and when did you remove them? Explain.
	TI.11	To what extent did students have opportunities to apply student success skills (WSPs) in this project? Were those opportunities explicit or implicit? Explain.
	TI.12	Did students have an opportunity to reflect on their progress on work study practices and in general during the course of this project? How did you collect this information? How did you solicit student reflections?

Assess Student Learning	TI.13	What formative assessments did you use throughout the project and what was their purpose. What feedback did students receive?
		What summative assessments did you use throughout the project and what was their purpose. What feedback did students receive?
	TI.14	How did you design the project to assess individual student learning and team-centered products?
	TI.15	How did you think about assessing student success skills or WSPs in this project?
	TI.16	Did students have an opportunity (or opportunities) to self-assess their progress during the project? Did students have an opportunity to peer-assess?
	TI.17	What rubrics did you use in this project and how did you use them?
Engage & Coach	TI.18	Did you think about student engagement in designing this project? If so, what information did you use about the students or about teaching strategies in general to try to engage students?
	TI.19	How did you adjust the project design as you went given individual student needs, classroom dynamics, or reflection? Explain.
Other	O.20	In your opinion, what elements were missing from the PBL planner or training that you added in order to design this project?
	O.21	If you were to re-design this project, what would you do differently next time?
	O.22	How would you teach this project differently next time?

Appendix K: Student Focus Group Questions

Domain	Item#	Question
Intellectual Challenge and Accomplishment	S.1	Did this project challenge you academically? Why or why not?
Authenticity	S.2	Did this project seem authentic—like something you might do if you as a job in the future? Explain.
Public Product	S.3	Are you proud of your final product? Explain.
Collaboration	S.4	What is your perspective on working in teams to complete projects? What do you like about it and what do you not like about it?
	S.5	In your opinion, what does it mean to collaborate? What are the features or characteristics of an effective collaboration?
Project Management	S.6	In your opinion, what types of project management skills did you need to employ in order to successfully complete this project?
Reflection	S.7	As you reflect back on your work in this project, what would you do differently? The same?
Overall	S.8	How does project-based learning compare (in your opinion) to the learning that takes place in other ways in your high school classes?
	S.9	What do you like about project-based learning? What do you not like about project-based learning?
	S.10	What was your experience like in completing this project? What did you like/not like about it?

Appendix L: Student Self-Report Data on Success Skills

Collaboration Student Self-Report Survey Items

How well did your group do at collaborating for the following parts of the project? [Asking Questions]

	N	Percent
Excellent	10	28.6
Good	17	48.6
Not bad but not great either	8	22.9
Could have been more productive	0	0.0
Total	35	100.0

How well did your group do at collaborating for the following parts of the project? [Experimenting]

	N	Percent
Excellent	15	42.9
Good	18	51.4
Not bad but not great either	2	5.7
Could have been more productive	0	0.0
Total	35	100.0

How well did your group do at collaborating for the following parts of the project? [Contributing to Final Product]

	N	Percent
Excellent	9	25.7
Good	18	51.4
Not bad but not great either	4	11.4
Could have been more productive	4	11.4
Total	35	100.0

Self-Direction Student Self-Report Survey Items

Engaging and Managing: Please choose where your place yourself. Each level includes the level above it.

	N	Percent
Level 1: I can use guidance from others to redirect my efforts and get back on track when I am districted or behind schedule.	0	0.0
Level 2: I can redirect my own efforts when distracted or behind schedule.	2	5.7
Level 3: Work productively and stays attentive to the task at hand.	21	60.0
Level 4: Persevere productively, avoiding procrastination and distraction throughout the work process.	12	34.3
Total	35	100.0

Monitoring and Adapting: Please choose where your place yourself. Each level includes the level above it.

	N	Percent
Level 1: I can select a course of action with guidance from others.	0	0.0
Level 2: I can select a course of action. Make some changes based on experimental observations	6	17.1
Level 3: I can select a course of action based on driving questions. Use experimental observations to identify areas for improvement and develop appropriate actions	16	45.7
Level 4: I can analyze experimental observations to modify the experiment to increase effectiveness.	13	37.1
Total	35	100.0

Appendix M: One Group’s Student Work Samples from the Energy Transfer Unit

Joulies vs.
Beverage Stones

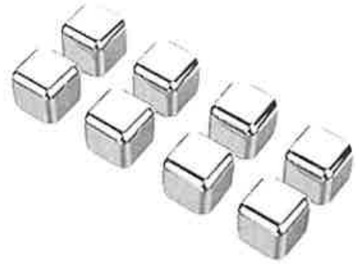
[redacted]

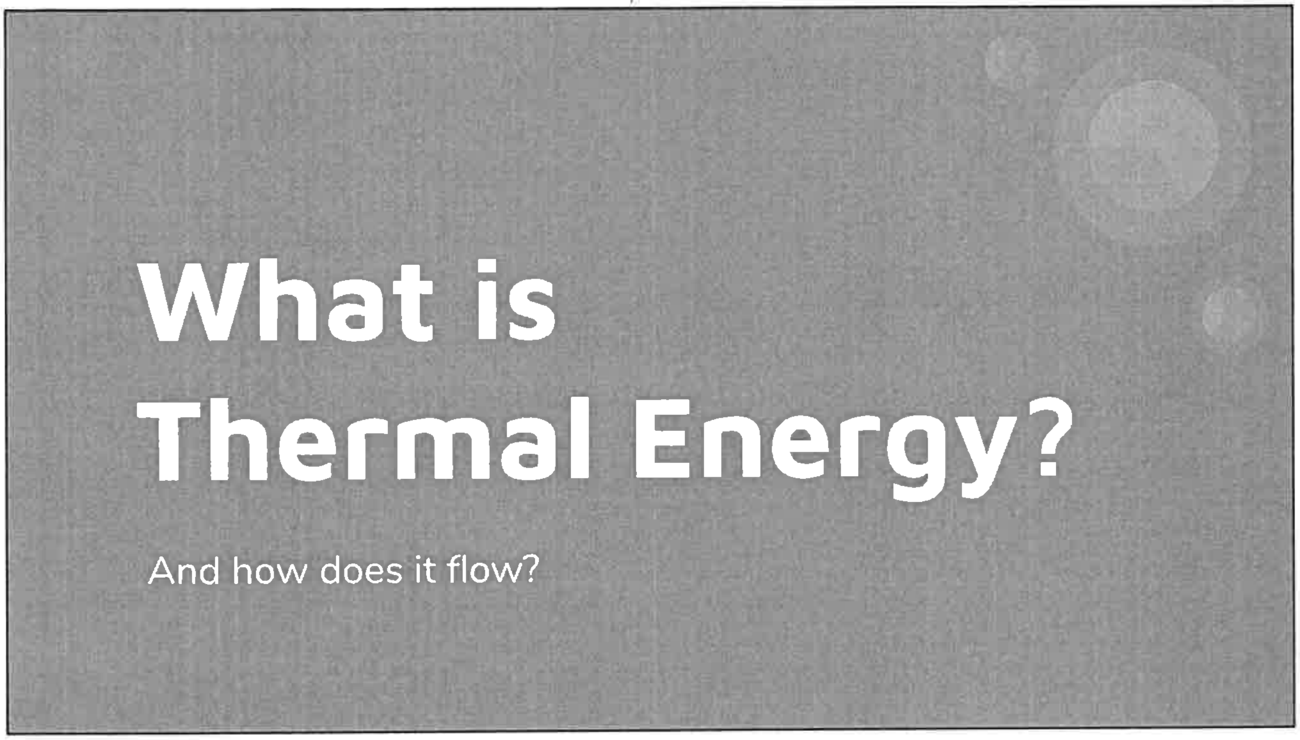
Background - Joulies

- Coffee Joulies absorb heat from your coffee or tea, quickly cooling it to the perfect temperature.
- Joulies will effectively heat your beverage for an all around perfect temperature

Background - Beverage Stones

- Beverage stones are stainless steel cubes with an internal proprietary material that keep your drinks cold without diluting the drink, they are also odorless and tasteless





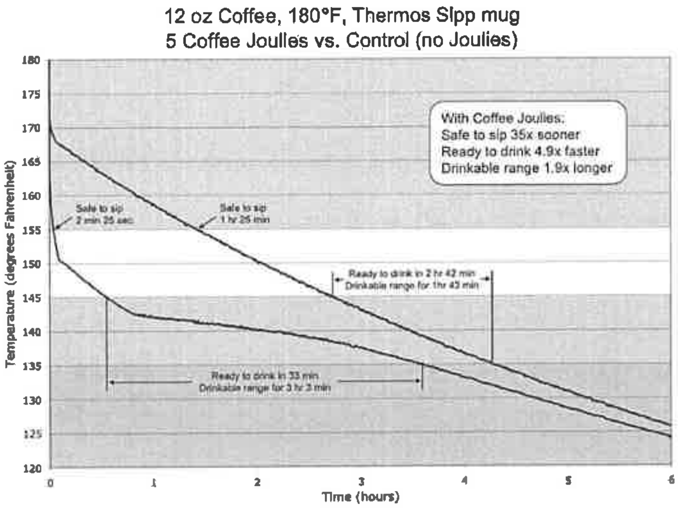
Thermal Energy is heat
Energy transfer always moves from the hot object to the cold object
Exothermic
    Energy flows from the surroundings into the system
        Coffee to the Julies
Endothermic
    Energy flows from the system to the surroundings
        Julies to the Coffee

Specific Heat - What is it?

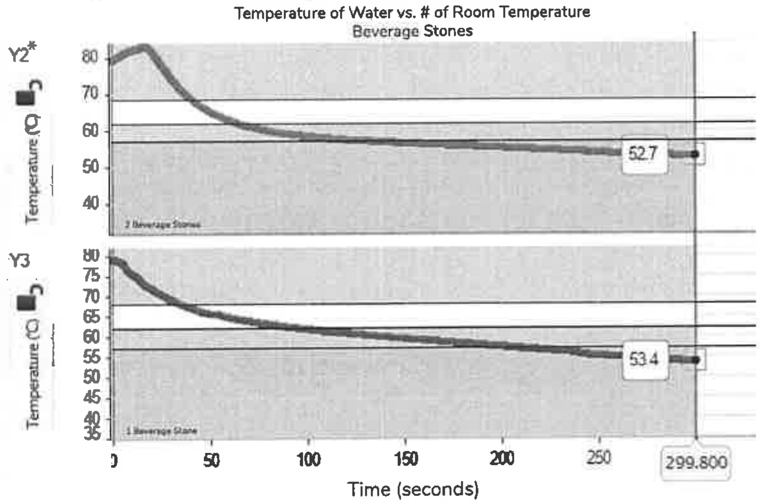
Specific Heat

Specific Heat - What is it?
Specific heat is the measure of how much energy an object can take in per gram before changing 1°C
Higher specific heat means it takes more thermal energy to raise its temperature
Lower specific heat means it takes less thermal energy to raise its temperature

Heating Joulies - Data

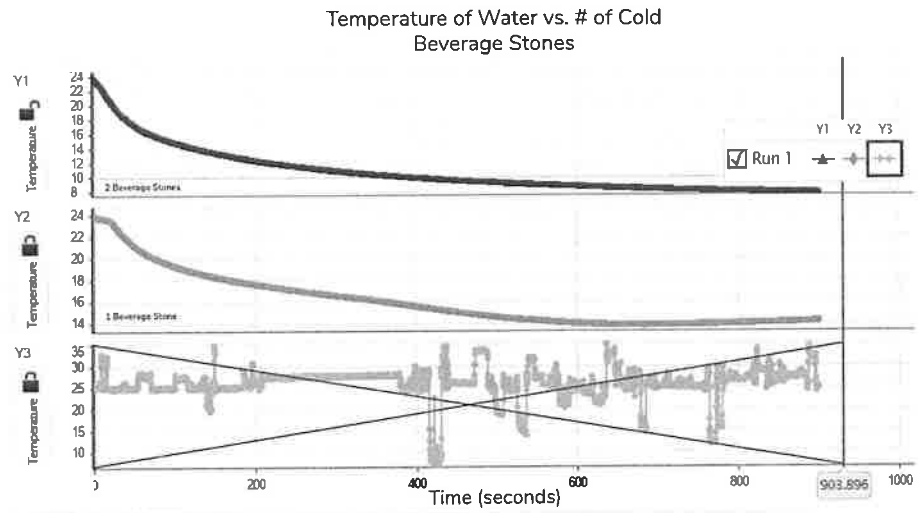


Heating Beverage Stones - Data



*Cubes placed in water 15 seconds after starting timer

Freezing Beverage Stones - Data



Freezing Joulies - Data

# of Joulies	Time to Reach Stable Temp	Holding a Stable Temp	New Temp of Water (celcius)
1	6:03.3s	4:49.3s	21.2
2	6:04.4s	2:00.8s	18.0
3	5:54.6s	3:40.8s	16.2

How do you Calculate Specific Heat?

$-((\Delta T)(\text{mass})(\text{Specific Heat})) = (\Delta T)(\text{mass})(\text{Specific Heat})$

Hot Object — Cold Object

$-((-27.8°C)(75g)(4.184J/g°C))=(40.7°C)(30.97g)(x)$

Water — Beverage Stones

$8723.64=1260.48x$

$6.92=x$

Specific Heat Equals 6.92J/g°C

Are these products useful? Are they multipurpose?

Are these products useful?
Yes our data shows that the products do what they are advertised to do. Joulies keep the drink hot, and the Kollea Stainless Steel "Beverage" keep your drink cool
Are they multipurpose?
Short answer, no
The beverage stones were shown to cool a drink far past what is considered the optimal temperature according to Joulies. The amount of time you have to drink your coffee with Joulies is about 3 hours long whereas with the beverage stones the range is only just over 2 minutes long.

The Specific Heat of the 2 objects tells a similar story as well.
It makes sense to have a higher specific heat for an object meant to cool something and keep it cold because it takes more energy to warm it back up, but when you want your hot object to keep your coffee warm you want energy to be able to move into the coffee easier and so a lower specific heat is better.
The same thing can be found with chilling as well

Both products are very functional for what they claim to do, so what should you spend your money on?
If you drink lots of hot coffee then buying Joulies just makes sense, but if you're not an enthusiast it might not be your smartest purchase considering their stiff price being $40 for just 5 Joulies. Not to say they don't work, they are just expensive.

It is much easier to recommend the chilling stones because they also work just as well as advertised, but the price is much lower being just $15 for 8 stones!

Keep it Hot/Keep it Cold Planning Sheet

Group Members and roles

Date 9-26-19

Facillitator [redacted]

Recorder [redacted]

Task Manager [redacted]

Compiler [redacted]

Decide on what product/products the group is going to study?

Julies

Are you going to study keeping it warm or cold?

~~Warm~~ Cold

Choose a method to educate consumers or propose your own method. Look at the list below as a guide. Look at the list below as a guide. It might be wise to look at some examples of these types of communication. I have included some quality examples on google classroom. Just a heads up that you will need to show evidence from a scientific study which should include multiple trials, graphical analysis, limitations and sources of error for you experiment as well as answer your focal question.

Consumer report and/or Claw article. Which product works best and why?
Design a web page to share the science behind beverage stones.
Design an infographic to explain how best to use the product.
Does it work? Write a scientific review of the product for amazon.
Make a youtube video to use to either support or discredit claims of product effectiveness.
Prepare a presentation(power point) for thc school store to answer the question of whether or not they should carry beverage stones.

Summarize what you are going to study and how you will communicate your results.

We're going to study Julies and whether or not they can keep a drink cool, we will present our information through an infografhic

As a group brainstorm the testable questions you will need to research in order to produce your communication.

How ~~does the starting temp of water affect the julies.~~

How fast does the temperature change with different #'s of julies + Whiskey Stones

Whiskey Stones
× [redacted] that has been frozen vs hasn't been frozen

~~What is the difference~~ between whiskey stones

Specific heat of whiskey stones + julies

How long does julie hold a stable temperature vs Whiskey stones

Divide and conquer. Who is working on what?

[redacted]s testing julies

[redacted] testing whisky stones

Testable Question How fast / how long does the temp change with hot water with a different # of whiskey

Investigators [redacted] [redacted]

Outline a plan for your investigation. Design a data table. Test your plan. Refine your plan/data table until you get the quality of results that you are happy with. Then record your procedure as a series of steps and conduct your experiment for real. When you are finished with this task go to google classroom and enter your final draft procedure, data, example calculations and conclusion for this task.

Plan

1. fill two beaker with 75 ml of hot water.

2. Place two beakers on hot plate and make temp 81°C for both beakers

3. Starting temp 21.1°C of cubes

optimal temp

#	Time s	New Temp	Left OT s
1 plue	1.33.0	62.°C - 57°c	3.48
@ 15s 2 Red	1.03.0	62.°c - 57°c	2.11

2:15 min to drink

1:08 min to drink

Draft of your Procedure(final version will be entered in google classroom)

Data Collected (you will clean this up when you enter it in to google classroom)

Calculations and/or analysis of what you learned from this study question.

NOW GO TO GOOGLE CLASSROOM AND ENTER YOUR FINAL DRAFT OF THE ABOVE INFO.

5.54.6

Testable Question How Fast/how long does the temp change with a different # of Julies?

Investigators [redacted] [redacted]

Outline a plan for your investigation. Design a data table. Test your plan. Refine your plan/data table until you get the quality of results that you are happy with. Then record your procedure as a series of steps and conduct your experiment for real. When you are finished with this task go to google classroom and enter your final draft procedure, data, example calculations and conclusion for this task.

Sub question: What are effects of julie that has been frozen vs hasn't been frozen?

Sub question: How long does a julie hold a stable temp?

	Time	Temp
F	6:21.8	22.7°C
NF	2:28.7	23.8°C

Plan

- put ~~150 ml~~ 75 of water each in of the two styrofoam cups
- in one of the cups put two frozen julies and in the other put one, starting temp of water for both 23.6°C

# of Julies	Time	New Temp
1	6:03.3	21.2°C
2	6:04.4	18.0°C
3	5:54.6	16.2°C

Mass of julie: 32.354g

How long stable temp?

# of	time	New temp
1	4:49.3	21.5°C
2	2:00.8	18.8°C
~~3~~	~~34.80~~	~~16.3°C~~

Draft of your Procedure(final version will be entered in google classroom)

Data Collected (you will clean this up when you enter it in to google classroom)

Calculations and/or analysis of what you learned from this study question.

NOW GO TO GOOGLE CLASSROOM AND ENTER YOUR FINAL DRAFT OF THE ABOVE INFO.

Testable Question What is the specific heat of joulies

Investigators [redacted] [redacted]

Outline a plan for your investigation. Design a data table. Test your plan. Refine your plan/data table until you get the quality of results that you are happy with. Then record your procedure as a series of steps and conduct your experiment for real. When you are finished with this task go to google classroom and enter your final draft procedure, data, example calculations and conclusion for this task.

mass of julie: 32.354 g

starting temp of water: 23.6 °C

Amount of water 75 ml

1_j = New 21.2°C

(x) (32.

2_j = 18.0°C

3_j = 16.2°C

W

$$\overset{J}{(\text{mass})}\,(T - T)_{H_2O}\,(x) = (\text{mass})(T - T)\,(4.184)$$

$$(32.354g)\,(23.6°C - \underset{15°}{\overset{8.6°}{\cancel{15}}}°C)\,\overset{J}{(x)} = (75 ml \text{ or } g)\,(\overset{2.4°C}{23.6°C - 21.2°C})\,(4.184)$$

$$\underline{278.2444}x = \overline{753.12}$$

$x = 2.71$

Draft of your Procedure(final version will be entered in google classroom)

Data Collected (you will clean this up when you enter it in to google classroom)

Calculations and/or analysis of what you learned from this study question.

NOW GO TO GOOGLE CLASSROOM AND ENTER YOUR FINAL DRAFT OF THE ABOVE INFO.

Testable Question How fast + how long does the temperature change with a different # of whiskey stones

Investigators [redacted] [redacted]

Outline a plan for your investigation. Design a data table. Test your plan. Refine your plan/data table until you get the quality of results that you are happy with. Then record your procedure as a series of steps and conduct your experiment for real. When you are finished with this task go to google classroom and enter your final draft procedure, data, example calculations and conclusion for this task.

Sub Questions

1) How long does a whiskey stone hold a stable temperature?

2) How do frozen whiskey stones change the speed and duration of cooling?

4 cups

How many ✓
How fast ✓
How long ✓
2
1ws 1ws
1 2

How many ✓
How fast ✓
How long ✓
2
1Cws 1Cws
1 2

Cold WS 15:00

	Starting °C	ST W °C	FT °C	table ST °C	STD M.ss
1cws	-.1°C	23.8°C	14.1°C		
2cws	0°C	23.8°C	7.8°C		

WS 3:50

1ws	25.1°C	22.9°C	23.5		3:50
2ws	26.2°C	23.2°C	24.1°C		3:50

DO THE COLD WS

Draft of your Procedure(final version will be entered in google classroom)

Data Collected (you will clean this up when you enter it in to google classroom)

Calculations and/or analysis of what you learned from this study question.

NOW GO TO GOOGLE CLASSROOM AND ENTER YOUR FINAL DRAFT OF THE ABOVE INFO.

Testable Question What is the specific heat of a Whiskey Stone

Investigators [redacted] [redacted]

Outline a plan for your investigation. Design a data table. Test your plan. Refine your plan/data table until you get the quality of results that you are happy with. Then record your procedure as a series of steps and conduct your experiment for real. When you are finished with this task go to google classroom and enter your final draft procedure, data, example calculations and conclusion for this task.

weigh 1ws = 30.970 g

ΔT w/1 ws

61.323

~~weigh 75 ml water~~

$(7.8)(61.323)(x) = (-16)(75)(4.184)$

m = 75 for water

$478.3194x = +5020.8$

$x = 10.4967517521$

ΔT w/water

$\frac{1}{2}x = 5.24837587605$

4.184 = sh for water

2 cubes

Never hit lowest temp

$(\cancel{14.2}\ 13.8)(30.97)(x) = -(-9.7)(75)(4.184)$

$439.774x = 3043.86$

$x = 6.92141872871$ 1 cube

$x = 7.12203956143$

Draft of your Procedure(final version will be entered in google classroom)

Data Collected (you will clean this up when you enter it in to google classroom)

Calculations and/or analysis of what you learned from this study question.

NOW GO TO GOOGLE CLASSROOM AND ENTER YOUR FINAL DRAFT OF THE ABOVE INFO.

Name: [redacted] Class Period: ___________

"Now You're Cooking!"

Energy Transfer Quiz

heat = mass · time · SH

Generating Testable Questions

Copper cookware has become popular in recent years. But is it really worth all the hype? Determine the best metal for creating cookware from the options given. The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.

In the space below, write 2 testable questions that will help you focus your investigation:

What metal can hold the longest specific heat time?

what metal can withstand the vast temp changes of the beverage

Materials and Methods

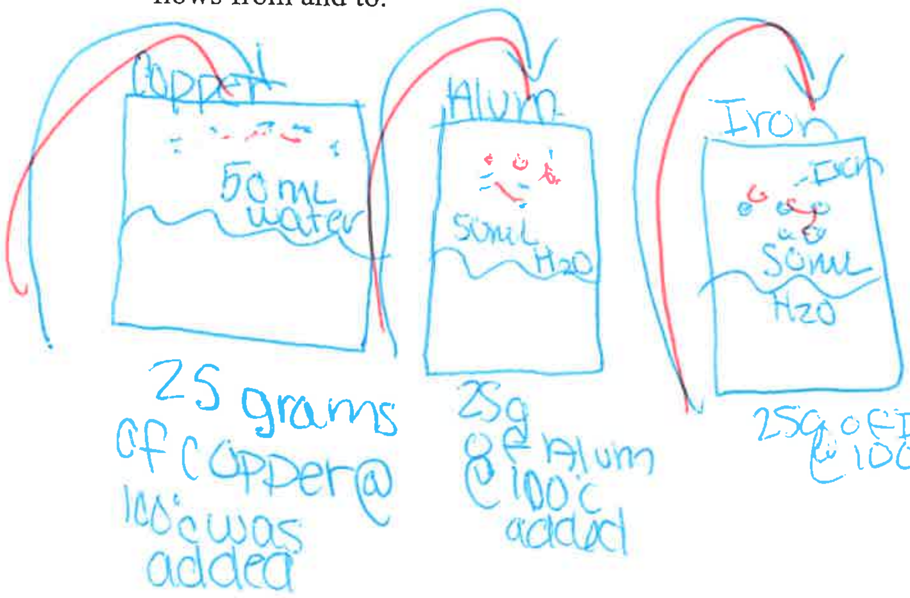
Materials List:

metal samples: • copper $6.12/kg • aluminum $2.20/kg • iron $0.53/kg	safety goggles & standard lab equipment
	Styrofoam cups with covers

A summary of the procedure is as follows:
50 mL of water was added to a styrofoam cup. This was repeated for 3 cups. The cups were then labeled copper, aluminum, and iron. The mass and temperature of the water was determined. Then approximately 25 g of the appropriate metals was added to the styrofoam cup of water. Each of the metals was preheated to 100 C and the actual temperature was recorded. The final temperature of the system(water and metal) was recorded.

heat = mass · + ΔT (SH)

Please diagram this experiment and show (using arrow) and annotate where the thermal energy flows from and to.



The thermal energy was passed from the 100°c metal than was trapped by the lid storing all thermal energy

Data Table

Metal used	*Mass Metal*	*Temp of Metal Initial*	*Mass of Water*	*Temp of Water Initial*	*Final temp of water and metal*
copper $6.12/kg	*25.321 g*	*99.2 C*	*50.1 g*	*21.5 C*	*24.82 C*
aluminum $2.20/kg Specific heat =.92 J/gC	*23.629 g*	*100.1 C*	*50.3 g*	*23.5 C*	*30.67*
iron $0.53/kg	*27.018 g*	*100.8 C*	*49.9 g*	*24.3C*	*28.59*

Analyzing & Interpreting Data (Individual)

Please calculate the heat (q) transferred by the *aluminum* (Specific Heat = 0.92). Please discuss if the energy transferred was absorbed or lost by the aluminum using evidence from the data.

~~100.1c = (23.629g)(~~

x = 0.06046203... 23.629g (69.43) (0.92)

~~q = (23.629g) (100.1c)~~ C, .92 J/g°C

1640.56(x)

1640.56x = 991.916 / 1640.56

23.629 g (100.1 - 30.67) (x) = 50.39 (30.67 - 23.5)

Answer ✓

How much energy was transferred to the *water(Specific Heat = 4.184)* for the iron trial. Please discuss if the energy transferred was absorbed or lost by the water using evidence from the experiment.

27.018g(100.8c - 24.3c)(4.184) ~~(1088.44)~~ = 419.99 (828.59 - 24.3) ~~(24.3c)~~ - 2 (+)

40.396 J/gc

(76.5c) (113.043)

113.043 * (76.5c)

8647.7895 = ~~419.99~~ (221.99)

8647.7895 = 214.071x

214.071 / 214.071

214.071x

40.396 J/gc

Please calculate the specific heat for iron and copper metals.

Iron - 100.8 c = 27.018(100-28.3)(x)

100.8 = 72.21(27.018)(x)

100.8 = 1950.96978x

1950.96978

= 0.0516 J/gc Iron

Copper - 99.2 = 25.321g(99.2c - 24.82)x

(25.321) 74.38x

Copper = 0.052937 J/gc

99.2 = 1883.37x

1883.37 / 1883.37

Please generate a results table to summarize how you processed the data.

name	SH	energy tran		
Copper	0.052937	74.38		
Iron	0.0516	40.396J/gc		
Alu	0.92	0.6641620371		

Provide and annotation to this table that summarizes your results.

Communicating Findings

- Identify what metal is best for making a piece of cookware if you are using "The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied. " You should relate your knowledge of the flow of energy and temperature to your claim. Support your claim with quantitative and qualitative data from the experiment.

The copper would be the best metal to use because it had the smallest "SH" @ 0.052937J/gc but had the largest temp change @ 74.38. Therefore the copper would be the best because the alum. had a "SH" of 0.92 and a energy transfer at about 0.604 and the Iron had a SH of 0.057 but and energy transfer of 40.39J/gc So the copper will hold the heat for a longer time but really be able to change the temp of a substance

Name: [redacted] **Class Period:** 4

"Now You're Cooking!"
Energy Transfer Quiz

F-I

Generating Testable Questions

Copper cookware has become popular in recent years. But is it really worth all the hype? Determine the best metal for creating cookware from the options given. The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.

In the space below, write 2 testable questions that will help you focus your investigation:

Which metal can heat a substance faster?

How long can each metal hold a stable temperature for after energy is taken away?

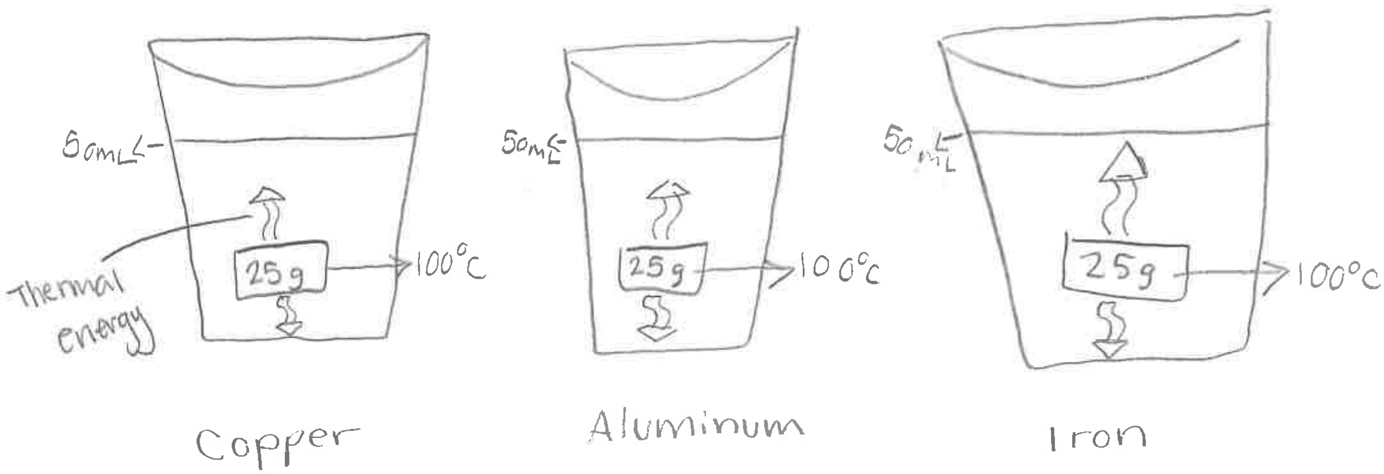
Materials and Methods

Materials List:

metal samples: • copper \$6.12/kg • aluminum \$2.20/kg • iron \$0.53/kg	safety goggles & standard lab equipment
	Styrofoam cups with covers

A summary of the procedure is as follows:
50 mL of water was added to a styrofoam cup. This was repeated for 3 cups. The cups were then labeled copper, aluminum, and iron. The mass and temperature of the water was determined. Then approximately 25 g of the appropriate metals was added to the styrofoam cup of water. Each of the metals was preheated to 100 C and the actual temperature was recorded. The final temperature of the system(water and metal) was recorded.

Please diagram this experiment and show (using arrow) and annotate where the thermal energy flows from and to.



Data Table

Metal used	*Mass Metal*	*Temp of Metal Initial*	*Mass of Water*	*Temp of Water Initial*	*Final temp of water and metal*
copper $6.12/kg	*25.321 g*	*99.2 C*	*50.1 g*	*21.5 C*	*24.82 C*
aluminum $2.20/kg Specific heat =.92 J/gC	*23.629 g*	*100.1 C*	*50.3 g*	*23.5 C*	*30.67*
iron $0.53/kg	*27.018 g*	*100.8 C*	*49.9 g*	*24.3C*	*28.59*

Analyzing & Interpreting Data (Individual)

Please calculate the heat (q) transferred by the *aluminum* (Specific Heat = 0.92). Please discuss if the energy transferred was absorbed or lost by the aluminum using evidence from the data.

$(0.92\ J/g°C)(23.629g)(30.67°C - 100.1°C) = q$

$21.73868°C \times -69.43 = q$

$q = -1509.32\ J$

The aluminum lost it's energy when added to the water becaused the initial temp of the aluminum was 100.1°C but became 30.67°C

How much energy was transferred to the <u>*water(Specific Heat = 4.184)*</u> for the iron trial. Please discuss if the energy transferred was absorbed or lost by the water using evidence from the experiment.

The water absorbed the energy from the iron because the initial temp of the water was 24.3°c before iron the was added became 28.59°c

208.7816 × 4.29

$(4.184\,j/gc)(49.9g)(28.59°c - 24.3°c) = q$

q = 895.67j amount of energ transfered

Please calculate the specific heat for iron and copper metals.

-74.38

$(x)(25.321g)(24.82°c - 99.2°c) = (50.1g)(4.184\,j/gc)(24.82 - 21.5°c)$

3.32

$-1883.37598x = 695.933088j$

$x = .37\,j/gc$

Iron

-72.21

$(x)(27.018g)(28.59 - 100°c) = (4.184\,j/gc)(49.9g)(28.59°c - 24.3°c)$

$-1950.96978x = 895.67j$

$x = .46\,j/gc$

Please generate a results table to summarize how you processed the data.

Metal use	specific heat of metal	Heat of metal	Specific heat of water	Heat of water
Copper	.37 j/gc	695.93j	4.184	695.93j
aluminum	.92 j/gc	1,509.32 j	4.184	1,509.32 j
Iron	.46 j/gc	895.67 j	4.184	895.67j

Provide and annotation to this table that summarizes your results.

In summary, aluminum had the greatest temperature change in amount of time

Communicating Findings

- Identify what metal is best for making a piece of cookware if you are using "The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied. " You should relate your knowledge of the flow of energy and temperature to your claim. Support your claim with quantitative and qualitative data from the experiment.

The best metal for cookware is aluminum. I know this because the water before the aluminum was added was 23.5°C, but once the aluminum was added to the water, the final temp became 30.67°C. Out of all the metals the greatest temperature change was between the metal and the water.

Name: [redacted] Class Period: 4

"Now You're Cooking!"

Energy Transfer Quiz

Generating Testable Questions

Copper cookware has become popular in recent years. But is it really worth all the hype? Determine the best metal for creating cookware from the options given. The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.

In the space below, write 2 testable questions that will help you focus your investigation:

What are the specific heats of the metals

What metal heats up the fastest

What metal gets the hottest

Materials and Methods

Materials List:

metal samples: • copper \$6.12/kg • aluminum \$2.20/kg • iron \$0.53/kg	safety goggles & standard lab equipment
	Styrofoam cups with covers

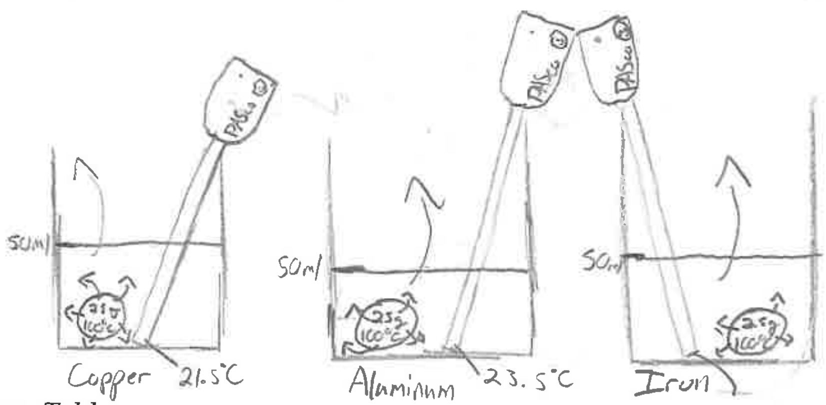
A summary of the procedure is as follows:

50 mL of water was added to a styrofoam cup. This was repeated for 3 cups. The cups were then labeled copper, aluminum, and iron. The mass and temperature of the water was determined. Then approximately 25 g of the appropriate metals was added to the styrofoam cup of water. Each of the metals was preheated to 100 C and the actual temperature was recorded. The final temperature of the system(water and metal) was recorded.

Please diagram this experiment and show (using arrow) and annotate where the thermal energy flows from and to.

Hot → Cold = Flow of thermal energy

The thermal energy will flow from the hot metal object to the cold water. When the water starts to heat above room temperature some energy will flow from the water into the room.



Data Table

Metal used	*Mass Metal*	*Temp of Metal Initial*	*Mass of Water*	*Temp of Water Initial*	*Final temp of water and metal*
copper $6.12/kg	*25.321 g*	*99.2 C*	*50.1 g*	*21.5 C*	*24.82 C*
aluminum $2.20/kg Specific heat =.92 J/gC	*23.629 g*	*100.1 C*	*50.3 g*	*23.5 C*	*30.67*
iron $0.53/kg	*27.018 g*	*100.8 C*	*49.9 g*	*24.3C*	*28.59*

Analyzing & Interpreting Data (Individual)

Please calculate the heat (q) transferred by the *aluminum* (Specific Heat = 0.92). Please discuss if the energy transferred was absorbed or lost by the aluminum using evidence from the data.

The aluminum lost 1509.317 J of energy we know it lost it because of the negative we get from the decrease in temperature from initial to final.

$(-69.43°)(23.629g)(.92\ J/g°C) = q$

$q = -1509.317J$

How much energy was transferred to the _water(Specific Heat = 4.184)_ for the iron trial. Please discuss if the energy transferred was absorbed or lost by the water using evidence from the experiment.

$(4.29^\circ)(49.9g)(4.184 J/g^\circ c) = q$

$895.673J = q$

In the case of water 895.673J of energy were absorbed. We know this because the final output is positive but also because the water's temperature increased from the initial giving as a positive ΔT meaning it took in energy

Please calculate the specific heat for iron and copper metals.

Iron: $-((28.59^\circ c - 100.8^\circ c)(27.018g)(x)) = (4.29^\circ c)(49.9g)(4.184 J/g^\circ c)$

$\frac{1950.97x}{1950} = \frac{895.673}{1950}$

$x = .459 J/g^\circ c$

Copper: $-((24.82^\circ c - 99.2^\circ c)(25.321g)(x)) = (3.32^\circ c)(50.1g)(4.184 J/g^\circ c)$

$1883.376x = 695.933$

$x = .37$

Please generate a results table to summarize how you processed the data.

	ΔT °C	Mass g	Specific Heat J/g°c	
Copper	−74.38°C	25.321g	.37J/g°c	
Aluminium	−69.43	23.629g	.92J/g°c	
Iron	−72.21	27.018g	.459 J/g°c	

Provide and annotation to this table that summarizes your results.

By looking at the table we find that copper has the lowest Csp followed by iron the by Aluminium.

Communicating Findings

- Identify what metal is best for making a piece of cookware if you are using "The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied. " You should relate your knowledge of the flow of energy and temperature to your claim. Support your claim with quantitative and qualitative data from the experiment.

The best metal to meet this condition is copper. We know this because of its specific heat value. Having the lowest C_p of the 3 tested metals means it requires the least amount of Joules per gram per °C. Meaning that a smaller amount of thermal energy will heat up copper more then the same amount of energy would to iron or aluminum. This means copper fits the condition of greatest temperature change for the least amount of energy perfectly because of its lowest Csp.

Name: [redacted] Class Period: 4

"Now You're Cooking!"
Energy Transfer Quiz

Generating Testable Questions

Copper cookware has become popular in recent years. But is it really worth all the hype? Determine the best metal for creating cookware from the options given. The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied.

In the space below, write 2 testable questions that will help you focus your investigation:

- what is the strongest metal that can with-stand high amounts of heat?

- What type of metal can hold heat the longest amant of time?

Materials and Methods

Materials List:

metal samples: • copper \$6.12/kg • aluminum \$2.20/kg • iron \$0.53/kg	safety goggles & standard lab equipment
	Styrofoam cups with covers
	didgital thermometer

A summary of the procedure is as follows:
50 mL of water was added to a styrofoam cup. This was repeated for 3 cups. The cups were then labeled copper, aluminum, and iron. The mass and temperature of the water was determined. Then approximately 25 g of the appropriate metals was added to the styrofoam cup of water. Each of the metals was preheated to 100 C and the actual temperature was recorded. The final temperature of the system(water and metal) was recorded.

Please diagram this experiment and show (using arrow) and annotate where the thermal energy flows from and to.

hot metal -> water

Steam ↗ out of cup

Steam = heat

heat = energy

Data Table

Metal used	*Mass Metal*	*Temp of Metal Initial*	*Mass of Water*	*Temp of Water Initial*	*Final temp of water and metal*
copper $6.12/kg	*25.321 g*	*99.2 C*	*50.1 g*	*21.5 C*	*24.82 C*
aluminum $2.20/kg Specific heat =.92 J/gC	*23.629 g*	*100.1 C*	*50.3 g*	*23.5 C*	*30.67*
iron $0.53/kg	*27.018 g*	*100.8 C*	*49.9 g*	*24.3C*	*28.59*

Analyzing & Interpreting Data (Individual)

Please calculate the heat (q) transferred by the *aluminum* (Specific Heat = 0.92). Please discuss if the energy transferred was absorbed or lost by the aluminum using evidence from the data.

(23.629)(100.1)(0.92) = 2173.868

How much energy was transferred to the ~~water~~*(Specific Heat = 4.184)* for the iron trial. Please discuss if the energy transferred was absorbed or lost by the water using evidence from the experiment.

energy was absorbed
and it was also released.

The heat from the metal going into water that is a cooler temperature is a transfer of heat.
The heat of the steam that is released when hot hits cold is also another transfer of heat.

Please calculate the specific heat for iron and copper metals.

(27.018)(100.8)(q) =

(25.321)(99.2)(q) =

Please generate a results table to summarize how you processed the data.

Metals				
Allumnium				
Iron				
copper				

Provide and annotation to this table that summarizes your results.

Communicating Findings

- Identify what metal is best for making a piece of cookware if you are using "The best metal will be defined by its ability to have the greatest temperature change for the least amount of energy applied. " You should relate your knowledge of the flow of energy and temperature to your claim. Support your claim with quantitative and qualitative data from the experiment.

aluminum seems to hold the most heat and keep something warmer for longer. The ending temp between both the water and aluminum was the highest agains the copper and iron. Also its specific heat was fairly high, So that helps it heat up much more and stay longer then other metals.

hot