

Content Specific Vignettes as Tools for Research and Teaching

by

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Introduction

Vignettes or cases have been used in methods classes, inservice workshops, and educational psychology courses to bring the 'real' classroom to the 'other' classroom. In many instances the vignette represents an ideal of what is real and creates an opportunity to discuss issues surrounding teaching and learning. Content specific vignettes bring the areas of content and pedagogy together to help inform teachers about the subtleties of teaching specific topics. When used for this purpose, these vignettes capture the context of teaching. This paper provides the background and rationale for developing content specific vignettes, supplies four science specific vignettes, offers examples of open cases or vignettes with tables of issues, and suggests uses for content specific vignettes.

Vignettes

A vignette is a picture or description of a situation which can have a problem scenario or not (Miles, 1987). Vignettes can help capture the essence of a classroom situation. In some cases, vignettes are written, while in others cases, they are audio and/or visual representations of a "live" classroom (Akaishi & Saul, 1991; Smith, 1994). Vignettes have been used for many educational purposes: they have been used to present real life stories about children living in the ghetto, and raise issues about educational policy (Bruckerhoff, 1992); to investigate individual's ethical principles and behavior (Lampe & Walsh, 1992); in the context of teacher in-service workshops for professional development (Lieberman, 1987; Smith, 1994; Whalen & Williams, 1995); in teacher education courses (Hatfield & Frederick, 1991; Stivers, 1987; White & McNergney, 1991); and as tools in qualitative research (Lieberman, 1987; Miles, 1987). Recently, vignettes have been used in the National Science Education Standards to exemplify excellent teaching in content areas relating to specific topics (NRC, 1996). Books have been created that contain open science cases to promote reflective problem solving at the elementary (Tippins, Koballa, & Payne, 2002) and secondary levels (Koballa & Tippins, 2000).

Historically, a vignette has been called many different things; vignette (Shulman & Colbert, 1988), case (Stivers, 1987), case study (Kowalski, Weaver, & Henson, 1990; Silverman, Welty, & Lyon, 1992; Sudzina & Kilbane, 1992), snapshot or mini-case (Miles, 1987), "a pictorial representation" on video (Smith, 1994), and "a carefully constructed description of a particular situation under investigation" (Lanza & Carifio, 1992, p. 82). All of these definitions essentially mean the same. These definitions have similar distinct characteristics that enable the vignette to be an evaluation and discussion tool for monitoring and developing teachers. Some of these characteristics are: 1) simulation of reality (Lanza & Carifio, 1992, p. 82), and 2) stimulation of reflection about classroom practices (Smith, 1994).

Most of the vignettes found in the literature (Greenwood & Parkway, 1989; Kowalski, Weaver, & Henson, 1990; Shulman & Colbert, 1988; Silverman, Welty, & Lyon, 1992; and Walen & Williams, 1995) focus around pedagogical issues, not content. In reality, content drives how many teachers instruct and organize activities, especially in the secondary science classroom. Content needs to be included if students and teachers are to advance their understanding about teaching and learning. Content provides the application and connection to the students' lives and background knowledge.

The vignettes developed in this article involve classroom management, student learning, teaching styles and methods, correct and incorrect science content, and multicultural issues. Several researchers have suggested processes for creating vignettes (Lieberman, 1987; Miles, 1987; Stivers, 1987; and Walen & Williams, 1995). The vignettes developed in this article contain the following components; an introduction of the setting, a description of the participants, an explanation of the problem, a description of the interacting dimensions found in the classroom, the dialogue between participants, and a possible major event worthy of attention by the teacher.

Vignette Development

These vignettes in this paper were developed based upon the author's experience teaching physics and chemistry at the high school level. Compared to other published vignettes (e.g., Koballa & Tippins, 2000; Tippins, Koballa, & Payne, 2002), these content specific vignettes contain inaccurate content. The vignettes were purposefully designed in this manner to evaluate content and pedagogical knowledge of preservice secondary teachers. The pedagogical and content issues presented in the vignettes reflect the author's own experiences with students, teaching, lesson planning, discipline, and assessment. The vignettes are open cases and contain many issues that most teachers face in a week, much less a day, and are based upon real situations that occurred in the author's classroom. They were developed so that the author could determine if his preservice secondary teachers could reflect upon content *and* pedagogical issues of teaching. The content of the vignettes came from topics that are found in general chemistry and physics curricula and are taught throughout the year and were of general interest to the author. The content items were drawn from teacher editions of textbooks. University scientists verified the content contained in the vignettes. The pedagogical issues were developed from experience and then corroborated by three other science educators. These vignettes are "tools that can promote discussion, engage diverse perspectives, and explore critical issues of science teaching and learning" (Koballa & Tippins, 2000, p. 8).

Importance of Vignettes

The importance of vignettes is intimately tied to their use in education and research. When used affectively, they can elicit discussion, develop knowledge, foster problem solving, promote decision making, and initiate reflection (e.g., Kagan & Tippins, 1991). Vignettes have been used at the beginning, middle and end of methods courses and education programs. In many instances, the instructor asks for students to find the good and bad events or instances for discussion. This author recommends using the same vignette multiple times to monitor change in understanding

(Veal, in press). In particular for research or training purposes, the microgenetic method (see Sigler & Crowley, 1991) can be used in which the vignette acts as an purposeful intervention or task that is repeated multiple times over a period of time. The value of using the vignettes multiple times over a period of time is that an instructor can see change, preservice teachers can reflect on their own practice and ideas, and preservice teachers can build new conceptions of teaching based upon prior knowledge. The power and applicability of the vignettes is based upon the fact that all of the vignettes in this paper could potentially reflect a real life situation in a secondary chemistry or physics classroom.

Content Specific Vignettes

The first vignette is entitled *Solutions* (Appendix A). In this vignette, the teacher uses the jigsaw method of cooperative learning to teach a chapter on solutions over a seven-day period of time. The jigsaw method involves groups of students becoming experts on certain sections of a chapter or curriculum and then teaching or reporting the content to other groups, either individually or as a class (see Aronson, 1978). The students in the vignette were given individual and group grades for their work. The teacher demonstrated some aspects of the chapter, but left the responsibility for other demonstrations and explanations of concepts up to the students. A sample of pedagogies and content topics included in the vignette is listed in Table 1. The situations embedded within this vignette focused on 1) the incorrect teaching of some concepts of solutions by students, and 2) an angry parent objecting to the group grading system.

Table 1
Pedagogical and Content Items found in the Chemistry Solution Vignette

Pedagogical Items	Content Topics	Misrepresented Concepts	Corrected Concepts
<p>Teacher left the classroom for supplies before the bell rang.</p> <p>Jigsaw method of cooperative learning</p> <p>Group and individual grades were given to the students.</p> <p>Students were given the opportunity to generate their own test items.</p> <p>Teacher grouped the students by academic ability (1 smart, 2 medium, 1 weak).</p> <p>The teacher's classroom management lacked consistency.</p> <p>The students and teacher used a variety of questioning techniques.</p> <p>The teacher's wait time was short, and he answered many of his own questions.</p> <p>The teacher and students used demonstrations.</p> <p>Homework assignments were given for preparation and review of the content.</p> <p>Worksheets were used for evaluation and review purposes.</p> <p>The teacher did not plan his teaching or jigsaw method of cooperative learning well.</p> <p>The students and teacher did grading, assessment, and evaluation.</p> <p>Not every student presentation was monitored for correct content knowledge.</p> <p>The teacher lacked the ability to be flexible in his instructional methods.</p> <p>The teacher did not monitor students' understanding well over the 7-day period.</p>	<p>Percent solutions</p> <p>Dilution</p> <p>Molarity and molality</p> <p>Mixtures</p> <p>Solutions</p> <p>Solutes and solvents</p> <p>Super saturated solution</p> <p>Physical properties of solutions</p> <p>Boiling point elevation</p> <p>Freezing point depression</p> <p>Saturated solution</p>	<ul style="list-style-type: none"> • Amount of solute will change the physical properties of the solutes. • Taking the temperature of a solution improperly with the thermometer bulb touching the bottom of the heated beaker. • Mr. Norton stated that tap water was a mixture or a pure substance. • Objects release heat. • Thermometer reads the heat of kinetic energy. • Raise the freezing point of water. • Solute molecules are no longer solid, but in solution. • Malality • Salt continues to dissolve in a saturated solution. 	<ul style="list-style-type: none"> • Amount of solute will change the physical properties of the solution • Thermometer bulb should not touch the bottom of the heated beaker. • Water can be both a mixture and a pure substance, depending on the context. • Heat is the measure of the transfer of energy between two objects. • Thermometer reads the average of the kinetic energy of the molecules. • Lower the freezing point of water. • The molecules are still solid, just dispersed. • Molality • A saturated solution contains as much solute as it can retain all ready.

<p>The teacher used advanced organizers to help students prepare for their instruction. The teacher revisited the concepts the last day with demonstrations and discussion.</p>			
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The second chemistry vignette is entitled *Heating the Discussion with Thermodynamics* (Appendix B). In this vignette, the teacher used a variety of pedagogical methods to teach the concept of heat, temperature, and other concepts related to thermodynamics. He demonstrated concepts, lectured, lead a discussion, and had the students complete a mini-lab. A sample of pedagogies and content topics included in the vignette is listed in Table 2. The situations embedded within this vignette focused on 1) the use of a teaching method which was not conducive to all types of learners in the class, 2) the teacher paying too much attention and favoring a highly active student, while neglecting the other students' concerns and opportunities to learn, and 3) the teacher's lack of concern about a student dropping out of class because the student's learning style did not match his instructional methods.

Table 2
Pedagogical and Content Items found in the Chemistry Thermodynamics Vignette

Pedagogical Items	Content Topics	Misrepresented Concepts	Corrected Concepts
<p>Teacher and one student demonstrated with a remote controlled car.</p> <p>Two or three large problems were worked out each day.</p> <p>Incorporation of a tardy student into the demonstration.</p> <p>Student helped with working problems during oral review.</p> <p>The teacher lead a discussion on speed vs. velocity.</p> <p>Classroom management was integrated with the teaching methods.</p> <p>The students and teacher used a variety of questioning techniques.</p> <p>The teacher's wait time was long.</p> <p>The teacher used drawings to help explain concepts.</p> <p>Homework assignment was given for review of the content.</p> <p>Classroom atmosphere was relaxed, but focused.</p> <p>The teacher realized a student misconception and altered her questioning to guide students to the correct conclusion.</p> <p>The teacher anticipated a student question.</p> <p>Students worked problems on the chalkboard.</p> <p>The teacher suggested alternative methods for completing a problem.</p> <p>The teacher gave a homework assignment of problems from the end of the chapter.</p> <p>The students did a mini-lab impairs with non-motorized cars.</p> <p>The teacher rushed the last demo.</p>	<p>Speed/Velocity</p> <p>Acceleration</p> <p>Linear Motion</p> <p>Instantaneous Speed</p> <p>Conversion Units</p>	<ul style="list-style-type: none"> • “She electrolyzed some simple electrical motors.” • “Work was being done by the ‘horsepower.’” • “It took the car .476190476 meters per second to get to the other end.” • “1 meter is equal to 3.78 feet.” • “Did the car have the same pace or rate of movement?” • “Speed equals distance divided by time.” • “Distance is the total distance traveled.” 	<ul style="list-style-type: none"> • She supplied energy to simple electrical motors. • The simple motor was doing work. • Significant figures. 0.5 m/s. • 1 m = 3.3 ft • Teacher should have asked, “did the car have the same change in speed.” • Speed is the change in distance divided by the change in time. • Distance is not always the total distance traveled.

The first physics vignette is entitled *Linear Motion* (Appendix C). In this vignette, the teacher used a variety of teaching methods to introduce the concepts of speed, velocity, and acceleration. The teacher instructed using an open demonstration and discussion format. The teacher and students discussed, calculated, and defined linear motion concepts using a remote controlled car in the middle of the classroom. Table 3 lists the pedagogical issues and content topics found within the vignette. The situations embedded within this vignette focused on 1) the incorrect teaching of some concepts of linear motion, and 2) a student who dropped the class, because his learning style did not fit well with the teacher's instructional methods.

Table 3
Pedagogical and Content Items found in the Physics Linear Motion Vignette

Pedagogical Items	Content Topics	Misrepresented Concepts	Corrected Concepts
<p>Grading system used by the teacher was not a standard 90-80-70-60 scale.</p> <p>Classroom management was absent for one student that affected the learning of the other students.</p> <p>The questioning techniques of the teacher were excellent.</p> <p>Homework was not assigned due to the situation at the end of the vignette.</p> <p>The vignette incorporated a 'problem' student who was active, used foul language, and was given extra-ordinary rules for his hyperactive personality.</p> <p>A contract for discipline between the teacher and one student was not enforced.</p> <p>The teacher did not always acknowledge students' answers.</p> <p>The teacher used advance organizers on the side chalkboard.</p> <p>The lecture was a mixture of discussion and demonstrations.</p> <p>The teacher used a plethora of practical examples.</p> <p>The teacher gave a student guided, self-exploratory mini-lab at the end of class.</p> <p>The teacher gave poor instructions for the mini-lab.</p>	<p>Laws of Thermodynamics</p> <p>Temperature</p> <p>Heat Energy</p> <p>Mechanical Energy</p> <p>Heat Content</p> <p>Heat Capacity</p> <p>Specific Heat</p> <p>Calorimetry</p> <p>Absolute Zero</p> <p>Thermochemical Equations</p> <p>Microscopic Kinetic Energy of Molecules</p> <p>Pressure</p> <p>Chemical Reactions</p> <p>Hair Dryer Analogy</p>	<ul style="list-style-type: none"> • Safety- Bunsen burners were lit to warm the classroom, and the teacher left briefly to retrieve some supplies. • We can think of heat as temperature." • "Thermodynamics is the study of heat and its transformation into mechanical energy." • Mechanical stuff. • "Absolute zero represents the coldest temperatures we know. It is the temperature at which no atoms move." • "When you raise the temperature, you also raise the heat." • "The water is being electrolyzed with energy." • "Temperature is the same as energy and how much heat there is." • "Heat is the amount of energy it has." • "As molecules move faster, the heat and temperature rise." • "The heated air does work on the water molecules in your hair." 	<ul style="list-style-type: none"> • Should not do this for safety reasons. • Heat energy is not temperature. Temperature is a measure of heat energy transfer. • Thermodynamics is the study of changes of heat energy into mechanical energy. • Mechanical energy. • Molecules barely move at this temperature, and we have only inferred its existence. • The temperature rises when the transfer of heat occurs from a warm body to a colder body. • Electrolyzed does not have any meaning. • Heat energy is not temperature. Temperature is a measure of heat energy transfer. • An object does not contain heat. Heat is the amount of energy transferred from one body to another. • The temperature may rise due to the increase in kinetic energy of the molecules, but it could stay constant such as during a phase change.

Students were cheating on their mini-laboratories by copying work of another student's lab.			<ul style="list-style-type: none"> • The air does not do work.
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The second physics vignette is entitled *Heating the Discussion with Thermodynamics* (Appendix D). In this vignette, the teacher used a variety of pedagogical methods to teach the concept of heat, temperature, and other concepts related to thermodynamics. He demonstrated concepts, lectured, lead a discussion, and had the students complete a mini-lab. Table 4 lists the pedagogical issues and content topics found within the vignette. The situations embedded within this vignette focused on 1) the use of a teaching method which was not conducive to all types of learners in the class, 2) the teacher paying too much attention and favoring a highly active student, while neglecting other students' concerns and opportunities to learn, and 3) students copying answers from each other on a laboratory write-up.

Table 4
Pedagogical and Content Items found in the Physics Thermodynamics Vignette

Pedagogical Items	Content Topics	Misrepresented Concepts	Corrected Concepts
<p>Grading system used by the teacher was not a standard 90-80-70-60 scale.</p> <p>Classroom management was absent for one student which effected the learning of the other students.</p> <p>The questioning techniques of the teacher were excellent.</p> <p>Homework was not assigned due to the situation at the end of the vignette.</p> <p>The vignette incorporated a 'problem' student who was active, used foul language, and was given extra-ordinary rules for his hyperactive personality.</p> <p>A contract for discipline between the teacher and one student was not enforced.</p> <p>The teacher did not always acknowledge students' answers.</p> <p>The teacher used advance organizers on the side chalkboard.</p> <p>The lecture was a mixture of discussion and demonstrations.</p> <p>The teacher used a plethora of practical examples</p> <p>The teacher gave a student guided, self-exploratory mini-lab at the end of class.</p> <p>The teacher gave poor instructions for the lab.</p>	<p>Laws of Thermodynamics</p> <p>Temperature</p> <p>Heat Energy</p> <p>Mechanical Energy</p> <p>Heat Content</p> <p>Heat Capacity</p> <p>Specific Heat</p> <p>Calorimetry</p> <p>Absolute Zero</p> <p>Enthalpy</p> <p>Energy</p> <p>Entropy</p> <p>Conduction</p> <p>Convection</p> <p>Radiation</p> <p>Macroscopic</p> <p>Mechanical Work</p> <p>Pressure</p> <p>Energy</p> <p>Transformation</p> <p>Waterfall</p> <p>Analogy</p>	<ul style="list-style-type: none"> • Safety- Bunsen burners were lit to warm the classroom, and the teacher left briefly to retrieve some supplies. • "We can think of heat as temperature." • "Thermodynamics is the study of heat and its transformation into mechanical energy." • Mechanical stuff. • "Absolute zero represents the coldest temperatures we know. It is the temperature at which no atoms move." • "When you raise the temperature, you also raise the heat." • "The water is being electrolyzed with energy." • "Temperature is the same as energy and how much heat there is." • "Heat is the amount of energy it has." • "As molecules move faster, the heat and temperature rise." • "The heated air does work on the water molecules in your hair." 	<ul style="list-style-type: none"> • Should not do this for safety reasons. • Heat energy is not temperature. Temperature is a measure of heat energy transfer. • Thermodynamics is the study of changes of heat energy into mechanical energy. • Mechanical energy. • Molecules barely move at this temperature, and we have only inferred its existence. • The temperature rises when the transfer of heat occurs from a warm body to a colder body. • Electrolyzed does not have any meaning. • Heat energy is not temperature. Temperature is a measure of heat energy transfer. • An object does not contain heat. Heat is the amount of energy transferred from one body to another. • The temperature may rise due to the increase in kinetic energy of the molecules, but it could stay constant such as during a phase change.

Students were cheating on their mini-laboratories by copying work of another student's lab.			<ul style="list-style-type: none"> • The air does not do work.
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Use of Vignettes in Teacher Education and Research

Vignettes have been used in many instances to improve the knowledge and understanding of preservice and inservice teachers. There are few examples and directions for how to use them. Below, I have outlined several methods for using the vignettes in teacher education and research. The first method is to have preservice and inservice teachers read a vignette, comment in groups on generic issues raised in the vignette, and discuss as a class broad issues of application (e.g., Tippins, Nichols, & Dana, 1999). A second method is to have preservice and inservice teachers read and then comment on the vignettes as homework. A third method is to have teachers reflect on the vignettes by developing a lesson plan around the content presented. This would help the teachers realize the pedagogical and content aspects of the vignettes. A fourth method involves the reading of the vignette at the beginning and end of a semester, reflecting on the vignette each time, and then analyzing the reflections by comparing them. This procedure allows teachers to monitor and see change in their perceptions over time. The same procedure could also be done during student teaching, and this could easily heighten the awareness of the contextual factors presented in the vignettes. These vignettes can readily be placed online to supplement instruction during any part of a certification program. Using asynchronous or synchronous communication methods online, preservice and inservice teachers could discuss the salient aspects of the vignettes over time. The main thrust in content specific use for teacher education is to allow teachers to reflect on the situations embedded in the vignettes over a period of time.

In research, content specific vignettes can be used to monitor teachers' development of content, pedagogy, or pedagogical content knowledge over time based upon a specific intervention. For example, if a specific intervention or activity in a methods course or program needs to be evaluated for its impact on students understanding of teaching and learning, then a content specific vignette could help determine if pedagogical content knowledge attributes were being learned. Another method is to use the vignette multiple times over the methods class (microgenetic method), and have preservice and inservice teachers continuously reflect on all of the aspects of teaching and learning (e.g., Veal, in press). Another use is to have inservice and inservice teachers discuss the vignettes online. The inservice teachers could act as mentors and clarify or add to the issues presented in the vignettes. The researcher could then study the sociocultural communities of practice surrounding the content specific implementation of the curriculum (e.g., Hepburn & Gaskell, 1998; Veal & Kubasko, in press).

The development and use of vignettes for research and teacher training is well documented. What has lacked in many of the published vignettes and studies is an integration of pedagogical and content items that makes the reader purposefully evaluate the situation and context. The inclusion of incorrect pedagogy or content forces people to reflect and evaluate the content specific vignette on a different level.

When the pedagogy and content items are used synergistically in preservice classes, beginning teachers will be more readily able to develop characteristics of teaching necessary for pedagogical content knowledge development (Veal & MaKinster, 1999). The vignettes in the Appendix and their descriptions in the preceding tables offer teacher educators a tool for helping preservice and inservice teachers develop some of the appropriate skills and dispositions necessary for teaching. In addition, researchers can implement these vignettes over time in studies focused on learning to teach science. These vignettes represent one tool in the 'bag of tricks' for teacher educators, professional development people, and researchers. The value of these content specific vignettes is that they focus on specific content topics and varying methods of teaching the topics. Thus the instrument focuses on the narrow aspects of teaching science, while students can apply their new knowledge to the broad field of science education.

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Appendix A

Solutions

Charlene, a typical high school junior with long brown hair and conservative dress, entered the classroom looking forward to a good day with her favorite teacher, Mr. Hammond. She was looking forward to the first really big lab that her chemistry class would conduct today. Mr. Hammond had demonstrated the day before how the lab was to proceed with a demonstration of the equipment and the safety procedures for handling corrosive chemicals and lighting a Bunsen burner. Last night, Charlene worked on her pre-lab assignment so that she would be ready for class. The questions for the prelab were from the back of the chapter on chemical formulas, so they were fairly easy.

As Bob, one of her lab partners, began to sit down next to her, she asked him, “Bob did you do the prelab that was assigned to us?” Bob had spent late last night working at the local ice cream store and had not had time to do the prelab. “I didn’t have time to do it. My boss made me close the shop last night, and I didn’t get to sleep until 2:00 am. Could I have your paper so that I can copy the answers,” replied Bob. Charlene was hesitant to do this, but Bob was such a fun loving and jovial person that she rationalized that he was not taking advantage of her.

“Sure, here you go. But I had problems with number 46a. Maybe you could do it right now and let me know what the answer should be?”

“I don’t know whether there is time for me to do it, but I will give it a try,” replied Bob.

While the two students were busy finishing their prelab, the bell rang for class to begin. Mr. Hammond had to quiet the class several times while he took roll. Four people were absent. He knew that Teresa was gone on a school-related trip with the choir, but he wasn’t sure why the other students were absent. “This is the last time I’m going to say this, be quiet,” roared Mr. Hammond.

Several students were still talking, but not as loudly as before. Mr. Hammond began class with a brief review of what they had done yesterday, and what was expected of the students today. “As you all recall from yesterday, I introduced to you the idea of a compound having water attached to it. Jerry, do you know what that type of compound is called?”

Jerry replied, “a hydrate.”

“Good. A hydrate is a compound that has water as part of it. This molecule is actually part of the larger compound. You can’t really see it, but there are certain characteristics that you will explore today that will help you distinguish a hydrate. You will also be determining the empirical formula of an unknown hydrate...”

At that moment Stony, a street kid walked in late to the class with a big grin on his face.

“Howdy Mr. Hammond.”

“Good morning Stony. We have just begun the review of the hydrate lab, and will shortly start the lab. You will have one known hydrate and one unknown.” Mr. Hammond continued with the review and preview without skipping a beat, and not letting the tardy student distract from the other students and the lesson. After Mr. Hammond had finished his brief review and preview, he collected the prelab papers that the students had to have completed prior to the lab.

“Pass the prelab papers forward so that I may grade them while you are in lab.”

“But I don’t understand all of the questions Mr. Hammond,” replied Charlene.

“That’s all right. It won’t count that much on your grade if you get one wrong.”

At that moment the class as a whole rose their voice in unison, “That’s not fair Mr. Hammond.” “We didn’t understand certain things either,” replied some students in the back left corner of the room. “I don’t think it’s fair if you don’t help us with our home work,” replied other students.

“Homework is for me to evaluate whether you have studied outside of class and whether the knowledge has been learned,” said Mr. Hammond. “I will go over one question if you all agree to one. Charlene what was the problem number? Is it all right with the class if we work problem number 46?” asked Mr. Hammond. Several of the students agreed that that would be a good problem to go over.

“OK, let’s read the problem and then start.

A) Write a balanced equation that represents the complete dehydration of the compound $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

B) When 2.1454 g of unknown hydrate was dehydrated by heating, 1.1304 g of the anhydrous salt remained. What percent of the original compound was water?

C) How many moles of water were driven off during heating?

D) The formula weight of the hydrous salt is 201.22 amu. Determine the number of moles of the anhydrous salt.

E) Calculate the number of moles of water per mole of hydrate.

OK, Mark, give me the answer to A.”

“It’s $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ goes to CuSO_4 plus five water molecules,” stated Mark.

Mr. Hammond answered, “Good job Mark, but we seem to be lacking one vital aspect of the equation. Jennifer do you know what it is.” No answer. Pause for four to six seconds.

“It’s the symbol for heat that needs to go over the arrow,” yelled Jennifer.

“Javier, you raised your hand, what is the item that is missing from the equation,” questioned Mr. Hammond.

“It’s the triangle which represents heat being added to the reactants,” smiled Javier.

“Let me do the rest of the problem because we are running out of time. The hydrate minus the anhydrate equals the weight of the water that was in the compound. That should be, 1.0150 g of water. The percentage is the part of the whole. Water is part of the entire hydrated compound. So we divide the weight of the water that was evaporated, 1.0150, by the original weight of the hydrate, 2.1454, multiply by 100 to get our percentage, and we get... How many significant numbers do I need?”

“Four,” yelled two of the students.

“No, you fell into the trap of the end zero,” replied Mr. Hammond. “It’s five. Part C is to convert our weight of water from B to moles. So we divide by 18.01 and get 5.639×10^{-2} moles of water. Part D is to determine the number of moles of hydrous salt that is 5.617×10^{-3} moles of anhydrous salt. So the ratio of moles is 10.

“How did you get the last step when we don’t know the molar ratio?” asked Tina.

“I can’t answer that now, we don’t have time. Ask your classmate or lab partner. We now have only thirty minutes to get the lab done, hurry up and get into your lab groups that you selected earlier this month,” said Mr. Hammond as the class passed forward the prelab. Several students were busy copying words and answers down as the papers were passed forward. Mr. Hammond noticed this, but decided to address this issue later. Charlene, Bob, and Jerry were a group, and worked along the back row of lab benches in the old lab that had been around since the building of the school in 1969. The other groups of three, with the exception of a group of two, were scattered about the old lab. Mr. Hammond seeing the group of two felt it was better to leave them in a group of two than to split them up and let each of them join another group forming two groups of four. Mr. Hammond knew that the lab was already too crowded for 30 students, and that a group of two might actually do better than a larger group.

While the students were getting the materials for the lab out of their lab drawers, Mr. Hammond was yelling where to get the knowns and unknowns for the lab, “The knowns and unknowns are in the corner of the room by the window. Your group needs one of each. The Barium Chloride is the white stuff, and it is known to have a molecular formula with two water molecules. There are four different unknowns; choose one and be sure to write the unknown number down on your lab sheet.”

Charlene, Bob, and Jerry began their lab by reading the instructions word for word. One person read the directions, another got the materials they needed, and the third person lighted the Bunsen burner. “Hey Charlene, you’d better get your hair out of the way or it might catch on fire,” stated Jerry.

Bob poured the sample onto a piece of weighing paper that was placed on top of the analytic balance. Mr. Hammond came over to observe the students. “How much does your sample weigh, Bob?”

“It weighs 2.345 grams. Oh but that’s with the paper. Shoot.”

“What do you need to do?” asked Mr. Hammond.

“He needs to weigh the paper first, then subtract that weight from the total amount,” interjected Jerry.

“He could also just zero the balance with the paper on it,” added Charlene.

“Could he weigh the paper with the compound now, dump the compound into the crucible, then come back to the scale and weigh the paper,” asked Mr. Hammond.

“I guess I could, but the paper could get wet, or I might spill some compound on the floor in route to the crucible, but yeah I could,” replied Bob.

“You all have to determine what is the best process and why. I will not answer those questions for you. But be sure that when you decide upon a process, that it is consistent throughout the lab,” added Mr. Hammond.

As Mr. Hammond walked around the lab one last time before going to his desk to grade prelabs, Jerry asked his group members, “What did he mean by ‘throughout the lab?’” The other group members just shrugged it off as one of those analytical items that were of no concern to them.

The group proceeded with the lab. After realizing that they had left the burner on all this time, they looked around to see if Mr. Hammond had noticed, but he was busy at his desk correcting the pre-labs. Jerry added the compound to the crucible, used his finger to get the last bit out. Charlene began to heat the crucible with the lid off. White smoke or steam began to rise from the compound. Bob made some observational notes in his lab book. After the group observed no more steam or evaporation from the compound, they put the lid on the crucible and let it sit for a while to cool.

While the crucible was cooling, the group members got their second compound or unknown. They chose a white compound, the same as the group next to them. Bob had initiated this, because he knew it might be easier to compare answers with their neighbors. Bob began to yawn as the group weighed their compound in a clean, dry crucible.

Charlene took control of the group. She realized that she didn’t have time to do the lab after school, because she was on the soccer team. She used the tongs and lowered the hot crucible down to the counter top. After the new crucible with the unknown was placed on the clay triangle, She began to heat the sample. Jerry took the first sample over to the balance and weighed its contents on a piece of weighing paper. He had to scrap the contents from the crucible onto the paper. This was not proper lab technique, but he remembered to keep things consistent. He should have weighed the crucible first with and without the sample and done an easy subtraction to determine the weight.

By the time Jerry was just about to finish scraping the last micrograms of sample from the crucible, Mr. Hammond arose from his desk to check on the students. He noticed Jerry scraping

the sample. He yelled to him across the lab that that was poor lab technique. Jerry acknowledged and continued. Mr. Hammond went from group to group instructing them that there were only five minutes left in the period. Mr. Hammond was pleased with the group's work next to Jerry, Bob, and Charlene. They had finished their second heating and cooling, and began to weigh their unknown sample.

Bob was jealous of the other group. He knew that he was tight with time. Charlene was dreading the lab. She had to walk all the way across campus to her next class. She approached Mr. Hammond, "I have to leave right after this class to get to my next class across campus, and the sample will not be cooled by then. What do I do?"

"I think your lab partners might be able to stay for a couple of minutes if they could to weigh the sample, record the data, and clean up. Then you could call them tonight for the data. Ask them."

"I can't stay any longer, what about you Bob," asked Jerry.

"Yeah I can. I have lunch next period. Call me for the data tonight," said Bob.

As the bell rang Bob emptied the contents of the crucible into the drain and saw the white powder turn a dark blue like it was when it started. He decided that that was cool, and when he got a chance and remembered, he would write that down as an observation. Walking out of class, Bob hooked up with his long friend Rich, "Hey Rich, let me see your data. I need to copy it down."

"OK sure, but what happened with your data?"

"It spilled into the sink so we didn't get a good weighing," replied Bob.

"See you all tomorrow guys," spoke Mr. Hammond as he headed off to lunch. "Just make sure that you are doing your own work and calculations. Don't get answers from each other."

"OK, sure," sounded the boys in unison.

Mr. Hammond walked away knowing that his lunch would be cut short because he had to straighten up the lab for the next class. He felt good with the hurried job in the lab. The labs were due the next day, and he would grade them with leniency since they were forced to complete the lab so quickly. Maybe he would give them some time in class the next day to write their lab reports and conclusions. He would wait and see what happens.

Appendix B

Heating the Discussion with Thermodynamics: Chemistry

It was a cold February day and Mr. Jackson, the chemistry teacher, was warming the class with two Bunsen Burners. The students started entering the room before the warning bell. This first period class was a mix of students with different backgrounds. Most of the students were juniors, and would be going on to physics next year. Some students were sophomores who were probably going to take AP Chemistry or AP Biology next year. Their last tests had an average of 74, which is a B minus in his class. Mr. Jackson was busy getting ready for the new unit on thermodynamics. He knew that he had to get through the unit as quickly as possible, because the other chemistry teacher was already giving the chapter test on thermodynamics.

When the bell rang, Mr. Jackson called roll. "Abraham, Bell, Campbell, Cendoit, Crayjick, ... Ramirez, ...Yancey, and Zimmerman." He then proceeded with his introduction, "Today we are going to start a unit on thermodynamics. We will cover the salient points of this chapter in one week because we are behind. So just look in your book for answers if you have any misunderstanding about concepts. Does anybody know what thermodynamics means?" At that moment Peter Duckworth entered the room late, "Hey Mr. J. what's up? Sorry I'm late."

"Just have a seat," replied Mr. Jackson. Peter sat down in his seat that he did not like too much. The seats had been arranged alphabetically at the beginning of the year, but since Peter came in to class two months after it had started, he had to sit in the last row on the right in the back of class. Peter had been in drug rehabilitation for two months. He was allowed to come into this class because of his desires and wishes to take science from Mr. Jackson.

Peter's transition back into school was a difficult one. Every now and then he was called to the office or sent there by another teacher. Mr. Jackson actually enjoyed Peter's presence in class. He was smart, insightful, and excited. Peter always spoke out, got out of his chair, and made innuendoes about sex and other people. Peter did not make these comments out of malice or to purposefully offend anyone. Mr. Jackson had made a decision to use Peter as a catalyst for discussions and inquiry into science.

For several weeks, Mr. Jackson had made Peter the person who demonstrated all the activities, led the discussions, and started the labs. Recently, Peter had been getting on Mr. Jackson's nerves. He was getting out of his chair more often, continuing to walk around class, and speaking out too often. Mr. Jackson realized that this was Peter's way of feeling accepted. Mr. Jackson let Peter do what he wanted whenever he wanted. Peter and Mr. Jackson had an unwritten contract about behavior in class: As long as Peter didn't get too unruly, then he could get up out of his seat and wonder around.

"Thermodynamics, what does it mean," asked Mr. Jackson.

"Doesn't it have something to do with heat, because the word thermo is in it," suggested Tom, an A student who was going to the nearby university with a full ride scholarship next year.

“That’s correct. What other images come to mind when we see this word, or the word heat as Tom mentioned?”

“It means that things are in motion like bodies if you know what I mean,” interrupted Peter.

“It also means the opposite, or cold. We can also think of heat as temperature,” added Tom.

Mr. Jackson was pleased at the progression and instant answers that Tom was providing. This would make the day go a lot faster. He knew he could count on Tom. “So basically, thermodynamics is the study of heat and its transformation into mechanical energy. So we’re bringing in energy and mechanical stuff with this definition. This sets the basis for our unit. Over on the sideboard is the outline for the unit for the next week. We have to cover it quickly because the other class is ahead of us. Copy it down so that you know what’s coming up.”

The outline on the board was as follows:

Monday	Intro. to heat and temperature (mini-lab)
Tuesday	Heat content, heat capacity, and specific heat
Wednesday	Problems; calorimetry; laws of thermodynamics
Thursday	Lab (specific heat of a metal)
Friday	Review: thermal chemical equations
Monday	Test

“OK, let’s get on with the task ahead of us. Take out your notes. I’ll be lecturing some today, and you’ll have homework every night on what we have learned. Thermodynamics deals with the microscopic level of chemistry, such as the kinetic energy of atoms and molecules, pressure, temperature, and their roles in chemical reactions. We have a basis for thermodynamics in the conservation of energy. Just like the conservation of mass in a chemical reaction, there is conservation of energy. Energy or matter is neither gained nor destroyed in the process of a chemical reaction. In the microsystem, energy is conserved, but not in the sense that we know it. Heat can be transferred from molecule to molecule. In reactions, heat energy can be used up or created. Heat itself cannot be measured directly. Instead, heat flow must be calculated from its effect on the temperature of a given quantity of a substance. Therefore, heat is always measured indirectly.”

“Here is a good analogy or model between the relationship of heat and work and energy: Consider a hair dryer with an electric fan and a heater. The electric fan does work on the air by forcing the air to move. The heater converts electrical energy to heat, which increases the temperature of the air. The heated air does work on the water molecules in your hair. The kinetic energy of the water molecules is increased so that they evaporate.”

Peter had gotten up during this brief introduction and walked over to the pencil sharpener to sharpen his pencil, “Damn, this thing still doesn’t work well.” He sat down while Mr. Jackson continued.

“Absolute zero represents the coldest temperatures we know. It is the temperature at which no atoms move. When you raise the temperature, you also raise the heat, and the energy, and the

motion, and the work. All of these principles are directly related to each other. As an object becomes hotter, its atoms and molecules move faster. As an object becomes colder, its atoms and molecules move slower.”

“So what does this have to do with thermodynamics?” asked Peter. “It’s like shit, we just learned about phases of matter.”

“Watch the language Peter,” replied Mr. Jackson. “We’ll get to that. As I was saying, as molecules move faster, the heat and temperature rise. I’ll demonstrate this with a quick demo.”

Peter quickly made his way to the front. “I’m here, what do I do?”

Mr. Jackson handed him the thermometer, “Here measure the temperature of the water in this bowl.

“Whoa, I hope this isn’t a rectal thermometer, is it?” This comment was received with laughs from the students.

“Why yes it is? You might be able to use it or borrow it some time when you’re sick, but only if you want?” replied Mr. Jackson trying to contain Peter and his comments.

“Holy Cow, I won’t want to touch this after it’s been inside of you,” said Peter. More laughter came from the students. Mr. Jackson easily would have sent another student to the office if other students had said the same thing, but Peter needed a break in life. Other teachers did not like him because of his drug reputation and his hyperactivity. Mr. Jackson felt as if his energy could be transferred into learning opportunities in science. Science wasn’t just lecture and learn. Science, to Mr. Jackson, was doing activities, asking questions, and inquiring about how things worked. Mr. Jackson felt that if there was anybody who could help Peter, it would be himself.

“Peter, calm down,” warned Mr. Jackson. A student in the front row seemed to be getting irritated, but Mr. Jackson hadn’t noticed. “Could you just measure the temperature of the water?”

Peter placed the thermometer in the water and read it to be 23.8°C. “OK. Write that on the board Peter.” Peter turned to the board and wrote in very large numbers that took up one side of the chalkboard, 23.8°C. Mr. Jackson turned on a hand-held blender and stuck it in the water. Mr. Jackson had brought the hand held blender from home, since there were few supplies and materials in the school. He hoped that Peter or any other student wouldn’t break the blender. The blender was the only one that Mr. Jackson and his wife had. “What am I doing now?” he asked the class.

“Making a mess,” responded Peter.

Several other students yelled out answers. “You’re giving it heat,” yelled Sandra.

“The water is being electrolyzed with energy,” stated Manny.

“There is a transfer or conservation of energy from the blender to the water,” suggested Theodore.

“It seems like the motion of the blender is moving molecules more rapidly, so the energy is increasing in the water, and the temperature is the same as the energy, so the heat is the same, but it gains with the heat and temperature,” replied Twan.

“Good Twan. Temperature is how much heat there is, and heat is the amount of energy it has,” explained Mr. Jackson. “Remember that the molecules are moving faster, so there’s more energy and temperature.” After three minutes of blending and ideas being shouted out by the class, Mr. Jackson asked Peter to measure the temperature again of the water.

“Whoa, it looks like it’s bigger. It’s 25.9°C now. Hey that’s pretty cool Mr. Jackson,” remarked Peter. As Peter returned to his seat he made a detour to the window to see what was happening outside.

Mr. Jackson didn’t notice Peter and continued with an explanation, “The water, after blending it for a few minutes, contains more heat than before.”

“Another demonstration is the burning of a peanut. I am going to light a peanut which will burn and heat this cup of water. If we know how much water we have, the beginning and ending temperatures of the water, we can determine the heat capacity of the peanut. We will get to specific heat and heat capacity later in the unit, but I wanted to show you how to calculate the heat capacity or amount of energy released from burning.” Mr. Jackson set up a ring stand with an iron ring. On the iron ring he put a metal can. Under the can he placed a twisted paper clip that was stuck through the peanut. Mr. Jackson lit the peanut. The data was written on the board: mass of water = 15.0g, the initial temperature was 23.8°C, and after the peanut burned out the temperature was 27.5°C.

“We discussed that heat is conserved since heat is a type of energy. $Q_{\text{released}} = Q_{\text{gained}}$. To calculate the heat gained by the water we use the equation, $Q = mc\Delta T$. Go ahead and calculate the heat gained,” suggested Mr. Jackson.

“What’s c Mr. Jackson?” asked Matt.

“Oh yeah, that is the heat capacity of water which is 1.0 cal/g°C,” responded Mr. Jackson.

Twan was the first student to finish and raised his hand. Mr. Jackson had to find his calculator before he could finish his calculations. While Mr. Jackson was calculating his answer Peter got up from his chair and went back into the lab to see if he could get the materials for his own lab. “Sit down Peter,” yelled Mr. Jackson. Peter slowly walked around before finding his seat. It appeared to Mr. Jackson that Peter had already calculated the answer.

“The correct answer is what....” asked Mr. Jackson.

“It’s 55.5,” mentioned Sarah.

“Good job, Sarah, but what are the units?” asked Mr. Jackson.

“They’re calories,” mentioned Peter. Mr. Jackson ignored this and waited for another student to answer.

Mr. Jackson chose Mike who was raising his hand. “Yes Mike?”

“It’s 55.5 Joules.”

Mr. Jackson then began the introduction to the mini-lab. “The mini-lab that you will do today involves melting ice cubes and determining the relationship between heat and temperature, and how energy and motion are involved. In the lab are hot plates for your groups, beakers for you to heat water, and the ice cubes are in the cooler. You will heat two different amounts of water in two separate beakers to the same temperature. Then you will see how quickly the ice melts. Work in your groups of three that were assigned last week. Are there any questions before we get started?”

“Which lab is this?” asked Tina.

“Oh that’s right, I don’t have lab sheets or questions. What I want you to do is answer this one question, what is the relationship between temperature, heat, energy and motion? You have equipment in the lab, so go back there and just explore. Write a procedure for your process so that I can determine how you came to understand the relationship. Be careful of the hot plates!”

As the students went back to the lab, Peter said, “Cool, we get to burn things with fire. I love a good bonfire. What small animals or cats are there to experiment with? We used to do this all the time after school.”

“Man I can’t believe you did things like that! I’m sick and tired of your mouth; why don’t you just get out of here!” yelled Tony at Peter. “You just come in here and talk like everybody likes you and thinks you’re funny. You’re disgusting and sick. And you,” he said turning to Mr. Jackson, “don’t give a damn if we learn or not. What’s your problem? Peter is sick, and he gets his way. He never goes to the office. I’m sick of this stuff. I’m leaving before I feel the need to waste ‘im.” Tony got up and left the class with his books. As he was exiting the class, his books and papers that were loosely thrown together spilled on the floor. “Shit, I can’t believe this. This class is a joke, I have to get an A for my college entrance, and you’re a horrible teacher allowing him to have his way at our expense.” Tony kicked at his papers and books and walked down the hall.

Mr. Jackson went after him to get him back, “Tony, I’m sorry. What can I do?”

“You’ve already done enough.”

“Look, I have to give him some extra help, he has had a rough life. No one treats him well.”

“Well you treat him good, but not us,” referring to the other students. “ I have sat in class for long enough. I don’t have to hear this stuff. Just leave me alone.”

Mr. Jackson was unsure of what to do. Tony walked down the hall and out of sight around the corner. Mr. Jackson picked up the book and papers. After collecting the items, he entered the classroom and went to his desk.

While Mr. Jackson was contemplating what to do and say, Tina and her group were copying the answers and procedure from another group. It made no difference to them since this was just a mini-lab. Mr. Jackson looked up from his desk in the front of the room and saw Tina’s group next to another group. At this moment, Mr. Jackson was not worried about how the lab finished, or what grade the students would get. His focus was on the student who left his class. He felt that Tony would be better off outside of class today. Mr. Jackson didn’t know where Tony had gone, but at least for now, calm would preside.

“Peter, could you come here please?” asked Mr. Jackson.

“What a wuss!” remarked Peter.

“Hey, I don’t want to hear any of that. He was really angry with you. I think you should be more considerate to others. I don’t mind you getting up and moving around or cuttin’ up, but when it bothers other people you have to stop. Now go back and join your group. We’ll try to do a better job tomorrow,” scolded Mr. Jackson. As Peter walked back to his desk, Mr. Jackson wondered whether one student was worth the fight.

Appendix C

Linear Motion

Hakeem entered the room only to find it rearranged so that all of the desks were pushed up against the sides of the room. The middle was cleared out, and the front of the room had a long table. Hakeem was not sure what to expect, because the first two weeks of class had been somewhat unusual. It all started with a physics show put on by the teacher, Mrs. Johnson, the first day. She blew things up, she rolled balls and circles of different shapes, density and size down ramps, she shined a laser into lenses, and she electrolyzed some simple electrical motors and said that the “horsepower” was doing work. After that first day, each class was filled with demonstrations and problems. Not that this was bad, but Hakeem couldn't understand the relevance of all of these demonstrations. The teacher only worked out two or three problems a day.

The bell rang as Hakeem sat down in a seat near the front of the class. Mrs. Johnson strolled into the classroom with a remote controlled car. As she walked in she began to talk, “Go speed racer, go speed racer, go. What am I doing?”

No immediate reply came until she ran over a student's foot with the four-wheel drive car. “You're acting weird,” said one child.

“You're playing with your son's Christmas gift,” yelled another student.

At that moment Hakeem's friend, Jesus strolled into class late. Mrs. Johnson seized the opportunity by asking Jesus very casually, “Jesus, why do you think I'm playing with this remote controlled car?”

Hakeem was surprised that Mrs. Johnson didn't scold Jesus for coming in late. Jesus replied, “You're showing that something moves.”

Mrs. Johnson continued her asking, “Go ahead and put your books down right there and help me with this demonstration. What Jesus and I will do for you today class is demonstrate the fact that linear motion can occur on the ground or in the air, and that motion has two main components, velocity and acceleration. Jesus, why don't you take control of the remote for a while.”

Mrs. Johnson walked over to the board and began to draw a straight line across it. While she was doing this, students were getting out their books and papers to start writing down all that she was about to do. Some students were sitting on desks, others were on tables, and some were actually in their seats. She marked the beginning and end of the line with hash marks. The beginning had a zero and the end had a question mark.

Jesus was rolling the car over people's feet and bumping it into desks and tables. Hakeem thought for sure that Jesus would get into some serious trouble for being late and for distracting the students with the car. Mrs. Johnson ignored Jesus and continued with the diagram. Below the line she put the letters “v” and “a.”

Mrs. Johnson turned back around to see Jesus bang the car into Marie's foot. "Jesus," stated Mrs. Johnson with a cool demeanor, "could you show us and explain with the car what velocity is or does?"

Jesus thought for a moment, and brought the car back to where he was. He looked at the long stretch of floor and started the car forward. The car raced to the back of the class when Jesus began his explanation, "The car has a velocity of 5 miles per hour."

"How do you know that it has that particular velocity?"

"Because it seems like it does, because it certainly isn't 100 mph. I should know I have driven that fast before." The class erupted with laughs.

Mrs. Johnson continued with her teaching, "Which way are you going?"

"Toward the back of the class."

"Does the direction of the moving object have something to do with velocity," asked Mrs. Johnson?

Marie answered, "No, it's just the distance that the car travels in a certain amount of time."

Mrs. Johnson realizing that there was a misconception and asked Jesus to drive the car in another direction. Jesus backed the car up, turned it around and headed for the door. The car was going slower this time. "What is the difference between what Jesus is doing now with the car and what he was doing with the car earlier?"

"He's being a safer driver by going slower," yelled Steve.

Hakeem didn't like all of these people yelling out answers. He was use to the simple classroom that had the teacher lecture, work out some problems on the board, and give an assignment. He quickly turned off all of the noise, pulled out his physics book, and began to read the chapter alone.

Mrs. Johnson wasn't paying attention to Hakeem, and continued with her lesson, "Besides the magnitude of the movement, what else is different? Roy?" Her question was met with a stare.

Another student offered a suggestion, "It's going in a different direction."

Mrs. Johnson, "You're right, Latishia. The car is moving in a different direction. We have established that the car is moving at a different magnitude and in a different direction." She wrote this information on the board. "Each demonstration that Jesus did was for velocity. How do we calculate the velocity?"

Marie stated, “The speed of the car is equal to the distance it traveled over the time it took to go that far. So we would measure the distance the car traveled, and then use a watch to time how long it took.”

“Good job Marie. Let’s go ahead and do that. Could you get a meter stick from the table and measure a distance? Jesus, could you start your car at the beginning of that distance?” While Jesus and Marie prepared for the measurement, Hakeem was reading his book. Mrs. Johnson never once looked over to see Hakeem in his own world. When Jesus and Marie were ready, Mrs. Johnson had Jesus start the car. Steve had volunteered to time the car on his stopwatch.

The car raced forward for two meters. The time was established as 4.2 seconds. Mrs. Johnson wrote the numbers on the board, and then instructed the class to work the problem. Jesus took out a piece of paper, and frantically wrote down what was already on the board, as well as the data for the problem. It took most of the students less than 30 seconds to get the answer. Danielle raised her hand, “It took the car .476190476 meters per second to get to the other end.”

“You are correct Danielle, but what about significant figures? Also we have to make sure that those are the units we want.”

“How about miles per hour?” shouted Steve.

Mrs. Johnson had anticipated this reply and was writing the conversion factors on the board so that the students could change units. 1 meter is equal to 3.28 feet, and 5280 feet equals 1 mile. The students saw what she had written on the board and began their calculation. She walked around the right side of the class helping the students with their work. She asked those students that were already done to help their neighbors with the problem. The room grew in noise as the students began to explain the problem to each other.

Mrs. Johnson asked Marie to work the problem on the board. Marie was hesitant because she did not finish the problem. Realizing this, Mrs. Johnson reassured her that it would be a class effort, and that everyone would help her. Marie walked up to the board and began writing down her work.

“I get stuck right here. I didn’t get the same answer as Jim next to me,” replied Marie. “I don’t know what to do, or where I went wrong.”

Steve offered his help, “Marie, you forgot that there are 60 seconds in a minute, and 60 minutes in an hour.”

“Oh yeah, so I need two conversion factors for the time.”

Mrs. Johnson was pleased with how the students were helping each other. “Steve, could you do the conversion factors another way so you wouldn’t have to write down two of them?”

Mrs. Johnson waited for a while, and then Steve replied, “What about one unit conversion factor of 1 hour equals 3600 seconds?”

“Good job. You can do it either way. Both ways are correct and will give you the correct answer which is what Marie?” Marie was busy redoing the problem with her calculator in hand up at the board using the new conversion factor.

“It’s 1.065 miles per hour. That’s slow. In fact that is too slow. What’s the matter with my answer?”

Mrs. Johnson replied, “Nothing is wrong with your answer. Maybe there is something wrong with the actual data collection. I do like that fact that you are reasoning your answer. Did the car seem to go that fast or faster? Based upon your experiences with velocity or speed, does the answer make sense? These are questions that you have to ask yourself each time you do a problem, before and after calculating an answer.

Steve started to raise his voice, “I started the watch a little late, plus I was at an angle, so I may not have known the exact starting and stopping points. Other than that the value seems accurate.”

“Good job Steve. What is the difference between speed and velocity? Someone mentioned speed earlier, but we have been talking about velocity.” No one really knew what to say. Mrs. Johnson asked Jesus to recreate both scenarios that he had demonstrated earlier. The car went straight to the end of the classroom, and then he made the car go through the door into the hall at about the same speed. Everyone laughed when the car wouldn’t come back. “That’s all right. Did the car have the same pace or rate of movement?”

“Yes,” responded the class as a whole. Mrs. Johnson then looked over at Hakeem and saw that he wasn’t participating in the discussion, and didn’t worry about it because the rest of the class was responding well to the material at hand.

“I say that the car had the same speeds, but different velocities. So what is the difference?”

“Direction,” stated Marie.

“Good job Marie. Velocity is a vector. That means that it has magnitude and direction. So we would say that the car was moving at 1.0265 mph in a westerly direction. How would we say the car’s speed?”

Latishia answered, “The car traveled 1 mph.”

“Good job. Here’s an extension; was the car always going that speed or did it change? And what is the difference between average speed and instantaneous speed?”

Mark decided to be bold and offered an explanation, “The average speed is over a period of time and the instantaneous is now, or at a certain time.”

“OK, I will accept that explanation. Does anyone else have any suggestions?” After a few suggestions Mrs. Johnson began to write an equation for speed. Speed equals distance divided by

time. She asked the students to help her write the equation for velocity. Velocity equals distance divided by time. While the students offered her these equations, she placed a triangle in front of the distance symbol and the t symbol for time under the line. “Does anyone want to guess why I put the triangles in front of the distance and time variables?”

Marie stated, “That’s because the distance is the total distance traveled. Same with the time.”

“So what else can we say about the triangles?”

Latishia replied, “It actually means that there was a change in the distance and a change in the time.”

“That’s correct. What about the difference between average and instantaneous speed?”

Steve replied, “Instantaneous is now, or maybe during one second of time, and average is over a period of time.”

Mrs. Johnson had just realized Hakeem was still reading his book, and decided to ask him a question, “Hakeem, is that correct?”

Hakeem just looked up and said yes.

Mrs. Johnson went on with her explanation, “The car actually traveled at an average speed which is what we calculated. The instantaneous speed was at any point during the trip. The speed at the beginning was 0.0 mph. At the end it was faster than the beginning. In the middle of the trip was where the average was mostly constant. Why was the velocity different at the beginning, middle, and end of the trip?”

Jesus responded, “It is due to the change in speed.”

“But what does that mean Jesus, or anyone”

Jesus said, “The car took some time to speed up or accelerate before it got to a point of constant speed.”

“In other words, the car had to accelerate to a point that it reached a constant velocity. So what is the difference between velocity and acceleration?”

Mark said that the velocity was changing while the acceleration was changing.

“Good idea. I think that’s right. Does anyone else have an answer or comment?” Mrs. Johnson looked down at her watch and realized that there were 20 minutes to go, so she quickly wrote the equation for acceleration which was acceleration equals the change in velocity over the change in time. She then put ‘ $a = 0$ ’ at the left side of the line under the left hash mark, and ‘ $a = 0$ ’ at the right hash mark at the end of the line. Below the two numbers she put ‘ $v = 0$ ’ on the left and $v = 1.02$ mph on the right. She then proceeded to put the homework assignment

on the board. “These are the question I would like you to do for tomorrow. Chapter 2, numbers 3, 4, 6, 7, 9, 10, 23, 25, and 48. These are due first thing tomorrow. Between now and the end of the period I would like you to grab a non-motorized car from the back, get with a partner, and experiment with the cars. I want you to be able to answer these questions that I am passing out. One paper per pair of students, and I want the papers back before you leave.”

She passed out the paper with seven questions on it:

- 1) How can you demonstrate the difference between velocity and speed? Give a real life example.
- 2) How can you prove that acceleration is based upon the change in velocity?
- 3) Why is acceleration zero at the end of the trip?
- 4) Is there a relationship between acceleration being zero and velocity being some value? If so what is that relationship?
- 5) Give an example of an object that travels at constant velocity; constant acceleration.
- 6) Where could an object travel at a constant velocity without stopping?
- 7) Would a ball being thrown straight up in the air change your perception of velocity and acceleration? How would it or wouldn't it? Explain.

The students each paired off into twos. Hakeem paired with Jesus, and the class began their work. It took a while for the class to settle down, but after a few minutes there was a lot of talking, but none of it seemed irrelevant. Mrs. Johnson walked from pair to pair to listen and hear what they were doing. She commented to some of the students, but never answered any questions directly. After about ten minutes, the bell rang and the students left for the day.

Later that afternoon, Hakeem went to talk with his counselor. He decided to drop out of physics, because he did not like the class, and the teacher wasn't a good teacher. The counselor decided to place Hakeem in wood shop for the semester until another class opened up next spring.

Mrs. Johnson ran into the counselor after school. “Oh Mrs. Johnson, Hakeem dropped out of your class today. He complained about not understanding anything, and feeling lost. He said that you were doing some unusual things in your class that were confusing him.”

“ I don't know what to say, but thanks for the comments.” Mrs. Johnson walked off to her mailbox and let Hakeem pass out of her mind forever.

Appendix D

Heating the Discussion with Thermodynamics; Physics

It was a cold February day and Mr. Jackson, the physics teacher, was warming the class with two Bunsen Burners. The students started entering the room before the warning bell. This first period class was a mix of students with different backgrounds. Most of the students were seniors, and would be going to college next year. Some students were juniors who were probably going to take AP Physics, Chemistry, or Biology next year. Their last tests had an average of 74, which is a B minus in his class. Mr. Jackson was busy getting ready for the new unit on thermodynamics. He knew that he had to get through the unit as quickly as possible, because the other physics teacher was already giving the chapter test on thermodynamics.

When the bell rang, Mr. Jackson called roll. "Abraham, Bell, Campbell, Cendoit, Crayjick, ... Ramirez, ...Yancey, and Zimmerman." He then proceeded with his introduction, "Today we are going to start a unit on thermodynamics. We will cover the salient points of thermodynamics in one week because we are behind. So just look in your book for answers if you have any misunderstanding about them. Does anybody know what thermodynamics means?" At that moment Peter Duckworth entered the room late, "Hey Mr. J what's up? Sorry I'm late."

"Just have a seat," replied Mr. Jackson. Peter sat down in his seat that he did not like too much. The seats had been arranged alphabetically at the beginning of the year, but since Peter came in to class two months after it had started, he had to sit in the last row on the right in the back of class. Peter had been in drug rehabilitation for two months. He was allowed to come into this class because of his desires and wishes to take science from Mr. Jackson.

Peter's transition back into school was a difficult one. Every now and then he was called to the office or sent there by another teacher. Mr. Jackson actually enjoyed Peter's presence in class. He was smart, insightful, and excited. Peter always spoke out, got out of his chair, and made innuendoes about sex and other people. Peter did not make these comments out of malice or to purposefully offend anyone. Mr. Jackson had made a decision to use Peter as a catalyst for discussions and inquiry into science.

For several weeks, Mr. Jackson had made Peter the person who demonstrated all the activities, led the discussions, and started the labs. Recently, Peter had been getting on Mr. Jackson's nerves. He was getting out of his chair more often, continuing to walk around class, and speaking out too often. Mr. Jackson realized that this was Peter's way of feeling accepted. Mr. Jackson let Peter do what he wanted whenever he wanted. Peter and Mr. Jackson had an unwritten contract about behavior in class: As long as Peter didn't get too unruly, then he could get up out of his seat and wonder around.

"Thermodynamics, what does it mean," asked Mr. Jackson.

"Doesn't it have something to do with heat, because the word thermo is in it," suggested Tom, an A student who was going to the nearby university with a full ride scholarship next year.

“That’s correct. What other images come to mind when we see this word, or the word heat as Tom mentioned?”

“It means that things are in motion like bodies if you know what I mean,” interrupted Peter.

“It also means the opposite, or cold. We can also think of heat as temperature,” added Tom.

Mr. Jackson was pleased at the progression and instant answers that Tom was providing. This would make the day go a lot faster. He knew he could count on Tom. “So basically, thermodynamics is the study of heat and its transformation into mechanical energy. So we’re bringing in energy and mechanical stuff with this definition. This sets the basis for our unit. Over on the sideboard is the outline for the unit for the next week. We have to cover it quickly because the other class is ahead of us. Copy it down so that you know what’s coming up.”

The outline on the board was as follows:

Monday	Intro. to heat and temperature (mini-lab)
Tuesday	Laws of thermodynamics, heat content, enthalpy
Wednesday	Energy and entropy
Thursday	Lab (heat output of a peanut)
Friday	Review: conduction, convection, and radiation
Monday	Test

“OK, let’s get on with the task ahead of us. Take out your notes. I’ll be lecturing today, and you’ll have homework every night on what we have learned. Thermodynamics deals with the macroscopic level of physics, such as mechanical work, pressure, temperature, and their roles in energy transformation. We have a basis for thermodynamics in the conservation of energy. Just like in chemistry, the conservation of energy is like the conservation of matter. Energy or matter is neither gained nor destroyed in the process of a chemical reaction. In the macrosystem, energy is conserved, but not in the sense that we know it. Our car engines do not put out the same energy that we put into it. Our cars are not efficient. Our cars lose heat. Heat is one of the foundations of thermodynamics. This is a good analogy. Heat is just like a waterfall. The water transfer to the lower water reservoir can not flow back up to the upper reservoir, and heat can only flow from a hot substance to a cold substance.”

Peter had gotten up during this brief introduction and walked over to the pencil sharpener to sharpen his pencil, “Damn, this thing still doesn’t work well.” He sat down while Mr. Jackson continued.

“Absolute zero represents the coldest temperatures we know. It is the temperature at which no atoms move. When you raise the temperature, you also raise the heat, and the energy, and the motion, and the work. All of these principles are directly related to each other. As an object becomes hotter, its atoms and molecules move faster. As an object becomes colder, its atoms and molecules move slower.”

“So what does this have to do with thermodynamics?” asked Peter. “It’s like shit, we just learned about phases of matter.”

“Watch the language Peter,” replied Mr. Jackson. “We’ll get to that. As I was saying, as molecules move faster, the heat and temperature rise. I’ll demonstrate this with a quick demo.”

Peter quickly made his way to the front. “I’m here, what do I do?”

Mr. Jackson handed him the thermometer, “Here measure the temperature of the water in this bowl.

“Whoa, I hope this isn’t a rectal thermometer is it?” This comment was received with laughs from the students.

“Why yes it is? You might be able to use it or borrow it some time when you’re sick if you want?” replied Mr. Jackson trying to contain Peter and his comments.

“Holy Cow, I won’t want to touch this after it’s been inside of you,” said Peter. More laughter came from the students. Mr. Jackson easily would have sent another student to the office if other students had said the same thing, but Peter needed a break in life. Other teachers did not like him because of his drug reputation and his hyperactivity. Mr. Jackson felt as if his energy could be transferred into learning opportunities in science. Science wasn’t just lecture and learn. Science, to Mr. Jackson, was doing activities, asking questions, and inquiring about how things worked. Mr. Jackson felt if there was anybody who could help Peter, it would be himself.

“Peter, calm down,” warned Mr. Jackson. A student in the front row seemed to be getting irritated, but Mr. Jackson hadn’t noticed. “Could you just measure the temperature of the water?”

Peter placed the thermometer in the water and read it to be 23.8°C. “OK. Write that on the board Peter.” Peter turned to the board and wrote in very large numbers that took up one side of the chalkboard, 23.8°C. Mr. Jackson turned on a hand-held blender and stuck it in the water. Mr. Jackson had brought the hand held blender from home, since there were few supplies and materials in the school. He hoped that Peter or any other student wouldn’t break the blender. The blender was the only one that Mr. Jackson and his wife had. “What am I doing now?” he asked the class.

“Making a mess,” responded Peter.

Several other students yelled out answers. “You’re giving it heat,” yelled Sandra.

“The water is being electrolyzed with energy,” stated Manny.

“There is a transfer or conservation of energy from the blender to the water,” suggested Theodore.

“It seems like the motion of the blender is moving molecules more rapidly, so the energy is increasing in the water, and the temperature is the same as the energy, so the heat is the same, but it gains with the heat and temperature,” replied Twan.

“Good Twan. Temperature is how much heat there is, and heat is the amount of energy it has,” explained Mr. Jackson. “Remember that the molecules are moving faster, so there’s more energy and temperature.” After three minutes of blending and ideas being shouted out by the class, Mr. Jackson asked Peter to measure the temperature again of the water.

“Whoa, it looks like it’s bigger. It’s 25.9°C now. Hey that’s pretty cool Mr. Jackson,” remarked Peter. As Peter returned to his seat he made a detour to the window to see what was happening outside.

Mr. Jackson didn’t notice Peter and continued with an explanation, “The water after blending it for a few minutes contains more heat than before.”

“Here is something that everyone can do. Rub your hands together. You are now doing work on your skin. What is the effect of the work on your hands?” asked Mr. Jackson. He continued, “Work is easily turned into thermal energy, but is thermal energy easily turned into work? I’ll let you think about that for a while.”

Mr. Jackson then began the introduction to the mini-lab. “The mini-lab that you will do today involves melting ice cubes and determining the relationship between heat and temperature, and how energy and motion are involved. In the lab are hot plates for your groups, beakers for you to heat water, and the ice cubes are in the cooler. You will heat two different amounts of water in two separate beakers to the same temperature. Then you will see how quickly the ice melts. Work in your groups of three that were assigned last week. Are there any questions before we get started?”

“Which lab is this?” asked Tina.

“Oh that’s right, I don’t have lab sheets or questions. What I want you to do is answer this one question: What is the relationship between temperature, heat, energy and motion? You have equipment in the lab, so go back there and just explore. Write a procedure for your process so that I can determine how you came to understand the relationship. Be careful of the hot plates!”

As the students went back to the lab, Peter said, “Cool, we get to burn things with fire. I love a good bonfire. What small animals or cats are there to experiment with? We used to do this all the time after school.”

“Man I can’t believe you did things like that! I’m sick and tired of your mouth; why don’t you just get out of here!” yelled Tony at Peter. “You just come in here and talk like everybody likes you and thinks you’re funny. You’re disgusting and sick. And you,” he said turning to Mr. Jackson, “don’t give a damn if we learn or not. What’s your problem? Peter is sick, and he gets his way. He never goes to the office. I’m sick of this shit. I’m leaving before I feel the need to waste ‘im.” Tony got up and left the class with his books. As he was exiting the class, his books and papers that were loosely thrown together spilled on the floor. “Shit, I can’t believe this. This class is a joke, I have to get an A for my college entrance, and you’re a horrible teacher allowing him to have his way at our expense.” Tony kicked at his papers and books and walked down the hall.

Mr. Jackson went after him to get him back, “Tony, I’m sorry. What can I do?”

“You’ve already done enough.”

“Look, I have to give him some extra help, he has had a rough life. No one treats him well.”

“Well you treat him good, but not us,” referring to the other students. “ I have sat in class for long enough. I don’t have to hear this stuff. Just leave me alone.”

Mr. Jackson was unsure of what to do. Tony walked down the hall and out of sight around the corner. Mr. Jackson picked up the book and papers. After collecting the items, he entered the classroom and went to his desk.

While Mr. Jackson was contemplating what to do and say, Tina and her group were copying the answers and procedure from another group. It made no difference to them since this was just a mini-lab. Mr. Jackson looked up from his desk in the front of the room and saw Tina’s group next to another group. At this moment, Mr. Jackson was not worried about how the lab finished, or what grade the students would get. His focus was on the student who left his class. He felt that Tony would be better off outside of class today. Mr. Jackson didn’t know where Tony had gone, but at least for now, calm would preside.

“Peter, could you come here please?” asked Mr. Jackson.

“What a wuss!” remarked Peter.

“Hey, I don’t want to hear any of that. He was really angry with you. I think you should be more considerate to others. I don’t mind you getting up and moving around or cuttin’ up, but when it bothers other people you have to stop. Now go back and join your group. We’ll try to do a better job tomorrow,” scolded Mr. Jackson. As Peter walked back to his desk, Mr. Jackson wondered whether one student was worth the fight.