University of California, Los Angeles
&
Rancho Bernardo (CA) High School
Poway Unified School District

LESSON STUDY RESEARCH PROJECT FALL 2002

~

REFLECTIVE REPORT

University of California, Los Angeles
Rancho Bernardo (CA) High School

LESSON STUDY RESEARCH PROJECT

Researcher
Celeste Barnette Campbell
Doctor of Education Candidate
Educational Leadership Program
University of California, Los Angeles
campbellceleste@hotmail.com
(858) 259-6959
12964 Long Boat Way
Del Mar, CA 92014-3842

Research Assistant
Tiffany Roberts Geroux

Science Lesson Study Team Members
Ian Campbell
Jennifer Grimm (student teacher)
Jay Hendricks
Ken Ozuna
Lisa Smedley

English Teacher Collaborators
Maureen Garland
Jane Wakeham Lopez
Kurt Trecker
Liz Winn-Willis

Rancho Bernardo High School
Paul Gentle, Principal
Website: RBHS.org
(858) 485-4800
13010 Paseo Lucido
San Diego, CA 92128-4499

Poway Unified School District
Dr. Donald Phillips, Superintendent
Website: PowayUSD.com
13626 Twin Peaks Road
Poway, CA 92064-3034
(858) 748-0010

Table of Contents

INTRODUCTION

> *The ultimate purpose of engaging in lesson study is to nurture "deep and grounded reflection about the complex activities of teaching." The lesson that is developed through this process is merely a byproduct.*
> *(Fernandez & Chokshi, 2001, p. 10)*

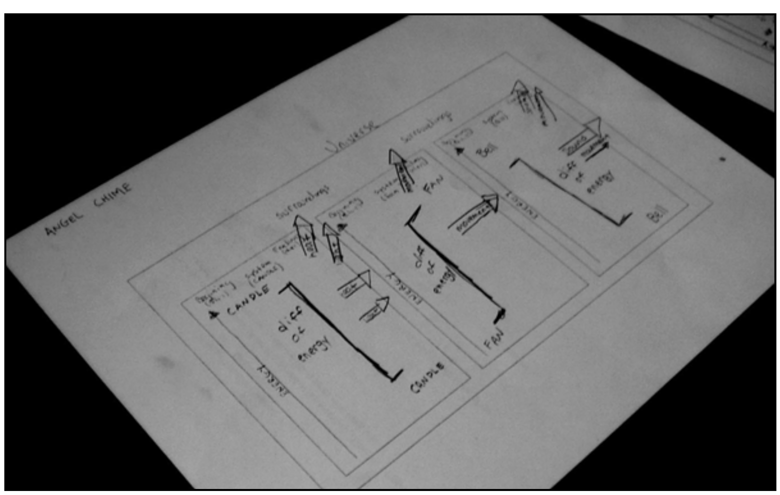
This report is a summary of one team of high school teachers' first attempt at Japanese lesson study. The composition and dissemination of such a report is the final step in the lesson study cycle. Our hope is that other educators who are considering engaging in this worthwhile process can learn from our experiences.

We have included our reflections on our three-month lesson study adventure (Part 2) as well as some logistical details to bring our experiences to life (Part 3). For additional information about the general lesson study process, please consult the bibliography or one of the following websites:

Lesson Study Research Group at Teachers College, Columbia University
www.tc.edu/centers/lessonstudy/

Mills College US-Japanese Education Project
www.lessonresearch.net

Global Education Resources, L.L.C.
www.globaledresources.com



PART 1
Project Context

> *"Research lessons expand teachers' ideas of what teaching can be."*
> *(Lewis & Tsuchida, 1998, p. 17)*

Japanese Lesson Study

While the United States educational system has seen very little improvement in student learning over the past 50 years, in Japan, teaching practices and student achievement have changed markedly (Lewis & Tsuchida, 1998; Linn, Lewis, Tsuchida & Songer, 2000; Stigler & Hiebert, 1999; Yoshida, 1999a). The reasons for Japanese students' superior academic performance compared to United States students are myriad, but instructional improvements can be clearly linked to a component of the Japanese professional development system called lesson study (Lewis, 2000b).

Lesson study is a collaborative process in which teachers engage in sustained, intellectually rigorous study of what they teach and how they teach it (Sparks, 1999). Over the course of several weeks or months, a team of teachers plans a classroom lesson jointly. One team member teaches the lesson to a classroom of students while the other teammates observe. The teachers discuss the success of the lesson based on the students' understanding and make revisions. The lesson is often re-taught and refined once more before the final results are shared with other educators. Lesson study is essentially a form of action research in which the teachers are researchers and the classroom is a laboratory for experimenting with new ideas about learning.

Research Project Purpose

In Japan, lesson study has contributed to steady improvements in instructional practice and student achievement (Lewis & Tsuchida, 1998; Linn, Lewis, Tsuchida & Songer, 2000; Stigler & Hiebert, 1999; Yoshida, 1999a). Studies to determine whether this success will be replicated in the United States are in their infancy and focus predominantly on elementary schools (Fernandez & Chokshi, 2001; Perry, Lewis & Akiba, 2002). The adaptation of lesson study to the United States high school setting has not been formally studied.

This research project is intended to begin filling this research void; namely to begin to understand how American high school teachers approach the lesson study process (see Figure 1). Over the course of three months during the fall of 2002, researcher Celeste Campbell, documented a team of suburban public high school teachers' experiences as they navigated through the lesson study cycle. Study findings will be detailed in a doctoral dissertation, which is projected for completion in June 2003.

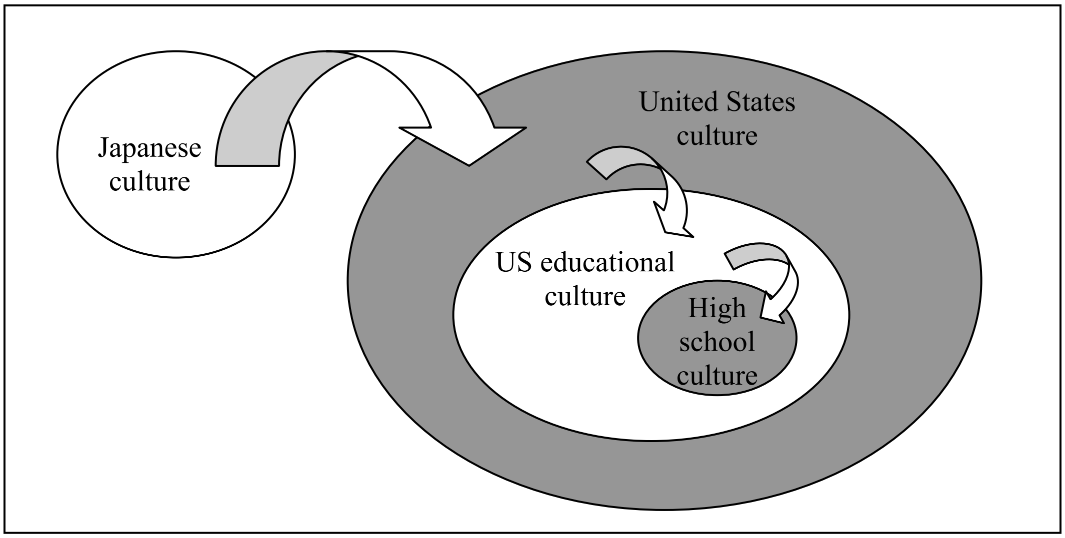


Figure 1. At least three cultural filters potentially impact the translation of lesson study from Japan to the United States high school culture.

Study Participants

We, the nine teachers who participated in this research project, comprise the faculty of the Rancho Bernardo High School Biophysical Science and English Academy. The academy serves approximately 320 randomly selected freshmen. These students represent the full range of ability levels with the exception of the top five percent of freshmen, who are enrolled in honors science and English classes.

Four science teachers made up the core lesson study team and participated in every step of the lesson study process. Four English teachers and one science student teacher participated in the goal setting retreat, review of the research, observation and discussion of the two research lessons, and the reflective team interview (all steps of the process except the actual development of the energy unit and research lessons).

Our entire academy team meets weekly for approximately eighty-five minutes during a commonly scheduled planning period to develop connections between the biophysical science and English curricula. Additionally, the academy science teachers meet as a group and the academy English teachers meet as another group for at least an hour each week to develop discipline-specific lessons.

We feel strongly that our team's extensive prior collaborative experience (especially the core science team) is especially noteworthy and will be addressed further in our team and individual reflections on the process (see Part 2). The tenured science teachers have been working together for four years in the academy setting, with one member having been involved with the academy since its inception eight years ago. The English teachers' participation ranges from one year to four years.

PART 2

Lesson Study Reflections

This section details our thoughts about the benefits we reaped, the challenges we encountered, and the lessons we learned as we undertook this process.

Team Reflections

Background. Our team met for lesson study meetings primarily during our commonly scheduled preparation period (3rd period) on a lab day (see Table 1). We also met occasionally during our shorter preparation periods on Monday, Tuesday or Friday.

Table 1

Rancho Bernardo (CA) High School Bell Schedules (2002-2003)

Monday ***Professional Time Day*** (AKA banked time)		
Professional Time	7:30	8:50
Break	8:50	9:05
Per 1	9:10	9:55
Per 2	10:01	10:43
Per 3	10:49	11:31
Lunch	11:31	12:01
Per 4	12:07	12:49
Per 5	12:55	1:37
Per 6	1:43	2:25

Wednesday/Thursday ***Lab Days*** (AKA block schedule)		
Per 1/2	7:35	9:20
Break	9:20	9:35
Per 3/4	9:41	11:21
Lunch	11:21	11:56
Per 5/6	12:02	1:42
Tutorial	1:50	2:25

Tuesday/Friday ***"Regular" Days***		
Per 1	7:35	8:35
Per 2	8:41	9:36
Break	9:36	9:46
Per 3	9:52	10:47
Per 4	10:53	11:48
Lunch	11:48	12:23
Per 5	12:29	1:24
Per 6	1:30	2:25

Time-related considerations.

- Spending two hours per week on lesson study was challenging because our other responsibilities and obligations suffered (planning for our other classes, grading papers, returning parent phone calls, setting up labs, getting organized, and simply reflecting). "I'm used to having down time where I can sit down, get organized…. [We were] constantly scheduled to be doing something else… I really missed it to a point where it really started to frustrate me."
- Because a substantial number of high school teachers coach teams or advise extra-curricular activities, after-school meetings can be impossible to schedule.
- We would have preferred to have used our weekly professional time (banked professional development time) for lesson study, but this year that time was designated for other purposes.
- Most of us believe that an experienced lesson study team should be able to complete a lesson study cycle in two months of weekly 1.5 to 2 hour meetings.
- The experience this team has working together (4 years plus) reduced the amount of time many of the tasks would have taken a group that had to work out group norms, common vision, etc.

Step 1: Goal selection. The first step on the lesson study process is the development of a long-term research focus and the identification of a specific content topic around which the research lesson will be designed. We tackled the development of both the long-range goal and the academic content goal during a one-day, off-site retreat. Details of that workshop are included in Part 3 of this report and specific worksheets we used are included in Appendix A.

- We have not reached consensus as to whether the time spent selecting a long-range goal was excessive or appropriate. One member said, "I think we saw this as our one and only time to do this and so we wanted to pick something that was really important. Whereas, if you knew you were going to be doing this continuously and over years and years and years…that wouldn't be such an important part." Another member countered, "I would not have changed the time that we spent selecting the long-range goal because I think that it's incredibly important that it's spelled out exactly the way you want it to be…. You want to come out with [a goal] that you can really work with and then stay with it the whole time."
- The goal setting process would have taken much longer if we didn't already agree on our approach to students and instruction due to our experience working together for so long.
- The academic content topic/goal we selected (energy) met all of the criteria laid out in the goal selection guidelines (see Appendix A). The mistake we made was picking a topic we had never taught before. As a result, we had to plan an entire unit from scratch rather than just revising one lesson.

Step 2: Research review. The research review step involves the gathering of information on the academic topic around which the research lesson will be designed (energy in our case), research on how to effectively teach this topic, research on student learning related to this topic (such as anticipated student misconceptions), and sample lessons. Meeting details can be found in Part 3 and supporting documents in Appendix B.

- This was a very labor-intensive, but invaluable component of the process.
- Again, because we selected a topic that was unfamiliar to us, "we spent a lot of time teaching each other just what energy was or what we thought it was."
- The specific suggestions on how to teach energy were the most helpful (see Appendix B).
- Celeste (the researcher and lesson study facilitator) pulled together all of the research into a "literature review" (see Appendix B) that helped to focus our discussions. Due to a lack of time, "I don't think it would have gotten done if [Celeste] would have left it to us."

Step 3: Lesson/unit planning. The lesson plan format used by Japanese teachers is extremely detailed and includes not only the activities of the teacher, but also the anticipated reactions of the students. Refer to Part 3 of this report and Appendices C, D & G for more details on our approach to this step.

- We now strongly agree with the lesson study literature that recommends avoiding creating lessons from scratch. However, because we are in the early stages of preparing lessons for a new biophysical science course, we selected a unit topic few of us had ever taught.

- Because we selected a topic that none of us had ever taught before, we often thought we were talking about the same thing (for example, what an energy diagram looks like), when really, we had very different mental pictures. “We were talking about the same subject, but I don’t think we were always speaking the same language.”
- Normally, when we talk about a topic we are all familiar with, we end up teaching very similar lessons, but because “none of us had experience with energy, [the two research lessons] ended up being very different.”

Step 4: Observation of the research lesson. This step is the axis around which the entire lesson study process rotates. We intentionally labeled this step as *observation* of the research lesson as opposed to the *teaching* of the research lesson, because the emphasis is on gathering student learning data and not on the activities of the teacher.

- “I got a lot more out of just being with one kid or one group [during the second observation] and seeing their whole process” than I did when I tried to observe the whole class during the first observation.
- How to effectively observe a lesson is a skill that we could have practiced before the actual high-stakes research lessons.
- Some of us who were observing the research lessons missed out on several opportunities to teach the collaboratively planned lesson to our own students and found this to be frustrating. After all the work that went into the lesson, we wanted the chance to implement it ourselves and have our students benefit as well. “Why was I involved in this if I didn’t get a chance to use the lesson in my class? If it’s that important, I should be able to use it.”

Step 5: Post-lesson discussion. This step involves the debrief session that follows the teaching and observation of each research lesson. Due to the nature of the university research project in which we were participating, our first time through, we were provided very little structure. Additional details on our first and second attempts at this step are included in Part 3 of this report and in Appendix F.

- “The debrief and revision was the only time I wasn’t exhausted by the end of [the meeting]. I wanted to keep talking…. To me, that was the most valuable and most important part of the whole thing.”
- We now wish we had spent more time on the post-lesson debrief and the revision of the lesson.
- The instructor of the second research lesson left the first debrief knowing what changes he was going to make, but we didn’t make those decisions as a team and many of the revisions were a surprise to the rest of us. We would have liked to have worked through this process together.
- The second debrief took a negative turn about halfway through. We seemed to be saying that two of the four kids in each group weren’t getting it, which implies that the lesson wasn’t working. What we should have been asking was, “If only two out of four people are missing it, what could we do to make it better?”
- Training in how to observe and coach peers would have helped.

Role of facilitator. Celeste Campbell, the university project researcher, served as the facilitator of the overall lesson study process. She designed the agendas for the meetings and developed the worksheets that are included in the appendices.

- It is critical for someone with knowledge of lesson study to take on a leadership role. That person would manage the process logistics, set deadlines, provide direction, and serve as the "bad guy" sometimes to keep the team on track.
- Establishing and continuously reinforcing the purpose of the lesson study process is vital for the leader to do.
- "I don't think as a facilitator that you should lead people by the hand. I like it better this way because I think everybody needs to stumble through it first and then realize that there are better ways to do it. Personally, I learn a lot more from making mistakes."

Pros and cons of the English teachers' participation. Because the academy in which we teach is interdisciplinary (science and English) and emphasizes collaboration, we invited the academy English teachers to participate in the steps leading up to the actual lesson and unit development. They also served as observers during the research lessons and participated in the post-lesson discussions.

- It was helpful to have the non-science teachers present for the goal setting and for some initial lesson brainstorming because they helped to ground us. We were forced to explain our thoughts thoroughly rather than throwing out science concepts and assuming everyone knew what we meant. "I think we honestly would have developed a lesson that's way over the kids' heads if it had not been for these guys being a part of the initial process."
- It would have been a waste of the English teachers' time for them to participate in all the unit and lesson planning meetings.
- The English teachers' involvement in the observations and post-lesson debriefs was extremely valuable to the science team, as they were able to suggest pedagogical strategies that are more commonly used in English classrooms.

Miscellaneous issues.

- Securing substitute teachers so the non-instructing team members could observe the two research lessons proved to be quite difficult (financially and logistically).
- The support and understanding of the site administration and other teachers is critical.
- We had several new things to contend with that made this process more challenging: a new course, new standards, and a new process – lesson study. "If you have a standard curriculum that doesn't change every five years, you know what those long-term goals are and it's not something that would have to take so much time."
- Seeing the video (*The Secret of Trapezes*, Lewis, 1999b) was vital so we could visualize the process and the team members' roles. "If you hadn't brought that videotape in, I would have been utterly lost."
- Lesson study may be contrary to the trend in education being driven by standardized tests. "Lesson study and its design are focused on experiential learning which means…you can't be one inch deep and a mile wide…. You're going to have to cut out

> curriculum that's being covered now…. I think [trying to disseminate lesson study is] working against the swing of the pendulum."

Individual Reflections

We were each invited to compose a brief narrative addressing our impressions of lesson study following our three-month experience.

Looking back over the lesson study process, I feel pretty satisfied. The thing that I remember and liked the most were the discussions about the curriculum (which were sometimes heated) and the discussions about the best outcomes we could expect from our students. I find these kinds of interactions to be very stimulating and I believe they are the one thing that I can point to that has kept me excited about teaching the last ten years. This is so because the ninth grade academy does very similar things as lesson study, but not as in depth. I'm not sure that being involved in this project has changed my everyday practice since it is so similar to what we already do, although I did really like the visual graphic organizers that we created. I believe it was easier for the students to focus on and understand and very easy for me to evaluate their understanding.

The biggest problem that we had with the process was how time intensive it was. To do justice to this type of project, you need an incredible amount of time to do it correctly and high school science teachers in the United States generally don't have that kind of time. Also, I think that any teacher engaging in lesson study needs to be trained in the specifics of what and how the process works before they do an initial lesson. I believe if we did this entire process again, we would do a much better job. In Japan, the teachers have done this over and over again. Even though this was our first attempt, I believe my students have a much better understanding of how energy works.

Ian Campbell (18 years teaching science)

For me, the most worthwhile component of our lesson study project was the observation piece. I would have to say that being provided the opportunity to truly focus on and observe a single student in the learning process was priceless.

Initially I found it frustrating to spend what I felt at the time to be too much time deciding upon a topic for this lesson study project. It took us an entire release day to reach consensus and we finally decided upon the concept of energy. Looking back, this was a valuable experience that I could not grasp at the time, and it was enhanced by having non-science teachers involved. The goal-setting process was valuable because we picked a topic that we, as science teachers, felt is essential and universal to all areas of science. We thought we had sufficient understanding of the content and that students could benefit from a well-developed lesson/unit plan. The value of having our English teacher colleagues as part of the initial research and development cannot be overstated. As we bounced ideas off of these well-educated individuals, we quickly realized that even these non-science education professionals had misconceptions about energy. Shortly thereafter we came to the conclusion that even we science professionals had some inconsistencies and gaps in our understanding of energy.

The biggest challenge was without a doubt finding time to devote to this process without compromising the quality of the lessons concurrently taking place in our classrooms. It was also difficult to find time to meet outside of our common planning period. I truly believe that if we hadn't had this common time, most if not all of us would have dropped out of this valuable project well before it was finished.

The project reminded me of the value of collaboration and teamwork in education and how little we are encouraged and provided the structure and opportunity to work together. It seems that in the American education system, or at least the one I am familiar with in our school district, we have so much else on our plates that it is nearly impossible for the vast majority of teachers to be involved in lesson study.

The thing I have taken with me to my classroom is how the dynamic of the high school classroom can be influenced by the delivery of a lesson and how differently students interact with one another. I learned that what students understand and verbalize, compared to what shows up in a written format can be two different things. In other words, it often takes a variety of assessments before a teacher can accurately determine the depth of a student's knowledge.

The biggest change for me was to be more open regarding how I assess my students. If I base my evaluation on a single assessment, chances are good that I will be misled as to the true understandings of my students. Some students will appear to have a better understanding and many will appear to have a poorer understanding than they really do.

As an interdisciplinary team I am well aware of the benefits of team planning. This was only reinforced through this process. I think the most valuable new things that I learned are that assessments may be misleading and that there is value to devoting time to developing one quality lesson/unit per academic term as a team rather than working in isolation or being overwhelmed by the amount of content we are expected to cover, even if collaboration is more time consuming. Finally, I have a better understanding of the group dynamic in a classroom from a student's perspective as a result of the observations I performed during the lesson study process.

Jay Hendricks (11 years teaching science)

My first impression was excitement and curiosity about lesson study. I was told that lesson study was going to change the way I teach forever. I thought that was a bold statement. I was hooked I had to see what this was about.

An inability to visualize the objective and end product was my primary challenge. One of my beliefs about teaching is that there can be no comprehension without picturing, or I should say comprehension occurs with picturing. I had difficulty picturing lesson study. I just couldn't picture how we were going to do it. I kept thinking we could combine the two research lessons into one. Also, my vision of energy diagrams did not seem to match up with my teammates'. We were not in agreement as to what energy was.

Time was another challenge…a whole lot of time…time for meetings, time for planning, time for lesson study, time for research and then more time for research. Celeste did most of the research, which saved a lot of time. Her research turned out to be essential.

What did I learn? Well I certainly learned about energy. I knew much of it before, but now I really understand. That alone was a journey, let me tell you. I now feel like I can break energy down and build it back up again. Everything that I teach from now on will have a new energy twist to it.

The best learning occurred during the debriefs following the research lessons, which turned out to be less about the lesson and more about good teaching skills. I think the lesson we taught was just a vehicle for what I was to learn. For instance, during the first debrief I became convinced that I should have the students draw energy diagrams before we started with the lesson. I figured out that a good graphic organizer is one that allows the teacher to clearly evaluate if the students are meeting the objectives of the lesson. A graphic organizer needs to be like good data (with stress on accuracy and replicability). The funny thing was that in the first debrief I knew I needed a better graphic organizer and in the second debrief I labeled in my mind what a good graphic organizer was. So, in a sense I made the graphic organizer better but I didn't know what or why it was better until the second debrief occurred. I just knew it worked out smoother when my students used it.

I was disappointed with the process because I thought I could have learned more from lesson study. I wanted more suggestions in the frame of, "When I do this, the students will do that." I felt like I could have done more.

Overall costs and benefits: It is funny because so much time was spent on the energy lesson and my growth occurred from the debriefs. Aside from my deeper understanding of energy, my growth could have come from teaching any other lesson. It seems that so much time and effort went into this lesson when the real reward came more from just teaching it in front of my team. When lesson study lessons are published, does the reader learn about the lesson or what the team learned about teaching from the lesson? Did my team have to struggle with so much research on energy or could we have gotten similar growth from a topic we knew already? I feel that I would not have gotten as much out of this experience if I had not been one of the teachers teaching a research lesson.

Ken Ozuna (8 years teaching science)

Lesson study has the potential to be a highly rewarding professional improvement program. It allows teachers to connect with research and then implement best practices, reflect, and then improve upon it. It builds communication and collaboration between peer teachers who, oftentimes, are isolated. It allows for lesson review and improvement by assessing the student reaction, reception, and mastery of the lesson. If only the school system had built-in scaffolding for such an ambitious and worthy program!

There are obviously several roadblocks or drawbacks, which need to be addressed within the current system for it to work well. Lesson study is a very time intensive program dedicated to improving teaching by focusing for weeks or even months on one lesson. This is a huge investment of time for teachers who are already very busy and have a full plate. Professional growth time could be utilized, but would need a serious overhaul, with ample time dedicated to this project alone. Proper grouping is key and it would be difficult for several unconnected teachers to suddenly be thrown in together to build a vision and work toward a common goal. I was fortunate to be on a team with well-established camaraderie and we were able to speak freely as we already had a strong rapport.

Despite the time investment, there were many rewards. Developing the lesson with the team was valuable, but watching the lesson and the post-lesson debriefing was the most rewarding for me. I enjoyed hearing the unique perspectives of my peers on points I had overlooked or not considered. Teaching is often an isolating experience and it was wonderful to see other techniques, strategies, and abilities, and then have an opportunity to share and reflect.

I also enjoyed focusing on a small student group for the observation to get a better understanding of student learning. The group dynamic was fascinating and enlightening. Each child demonstrated their understanding in unique ways: some were speakers, some were writers, some were facilitators, but they were all interested, participating, and trying to express themselves. While observing the lessons it is important to be clear as to what you are looking for and how to go about it. The preplanning paperwork did not properly prepare me and I felt scattered and unfocused with so much going on during the observation of the first research lesson. Assessing learning is tricky business, but worthwhile work!

A key component to a smooth lesson study process is the leader. An experienced leader who can anticipate and deal with the uncertainties and time constraints of this process is essential. I feel I underutilized my leader and that was a mistake. It is important to communicate throughout this process, and although the lines were open, a busy schedule prevented me from utilizing her more effectively. Our coordinator gently guided us along and did a substantial amount of the work. Much of the really great research was found by her and shared with us. I truly enjoyed the research suggestions, misconceptions, and lesson ideas. I have never taught from such a pool of information before and felt like I was truly growing professionally. I wish teaching had more time allotted for putting research into practice.

The biggest difference between the two research lessons, is what I will be bringing back to my classroom. In one class, the teacher debriefed the posted work and in the other lesson, the students presented their work. Having the students explain and post their findings to the class worked best. Their explanations were quite revealing about their understanding of energy transfers. Without this component, it was truly difficult to quickly assess their learning. Lesson study has been challenging, but also rewarding.

Lisa Smedley (9 years teaching science)

I have the advantage of having been a part of this team for several years now. We collaborate frequently, tweak our instruction, and share ideas on a routine basis – all similar components to lessons study. I find this enormously valuable. While I balked at the idea initially thinking it would cramp my style, I now would not want to teach any other way.

Having been through Japanese lesson study now, I find that two big ideas come to mind. First, what can I do differently to make each student accountable and secondly, what can I change about my instruction to make assessment easier and more reliable? Having reflected on the specific lesson we taught, I think group size and individual accountability on a product are areas that I need to play with. These are things that I might not have really looked so closely at if I hadn't been able to observe another teacher. When I am actively teaching, I'm directing my attention to those students who are paying attention and am really unaware of the number of students who are not engaged (or their reasons for not being engaged). As an observer, I was able to gather data and speculate on reasons for their non-involvement.

While participating in lesson study, I found myself frustrated by the amount of time spent on just one lesson. I was also frustrated by the amount of time that it took to let students "discover" energy loss. I'm not sure the experience will be any more memorable for them than if they were simply shown energy transfer. Finally, I was frustrated with our second debriefing session. I couldn't help thinking that the teacher must have felt we were criticizing him as we looked for ways to improve the lesson. I am very curious to know his reaction.

I thoroughly enjoy the collaboration that our team has and that lesson study affords. I think it is important that teachers consent to being a part of it – our team works better because we've all agreed to do mostly the same thing but to allow for some variance in teacher/student style. Collaborating as we do, we do not each need to reinvent the wheel. We share the task of lesson planning and curriculum designing, and take responsibility for each other's students. We can differentiate our instruction with the time we save by not having to do each individual piece of the lesson design ourselves.

Maureen Garland (12 years teaching English)

As I reflect back on the lesson study research project of fall 2002, I see a melding of many emotions. Some of these emotions took the form of anxiety, frustration, and revelations. I realized half way through the lesson study process that dissecting teaching and learning techniques can include all of those emotions. I feel I've seen more positive revelations than frustrations throughout our time together. One of my greatest revelations was, once again, reaffirming the notion that team collegiality provides students with the tools to all subject matter. Lesson study took that collaboration piece and pushed it to another level; a level much more definitive in measuring student learning. This focus on student learning became a much clearer objective through lesson study than previous notions that teacher-directed lessons were the most important component in education. This shift of focus will hopefully help me to keep student interest and learning a number one priority.

Jane Wakeham Lopez (34 years teaching English)

I was intrigued by the idea of lesson study and that we, the Academy team, would be modeling what the Japanese do on a regular basis, a somewhat new concept to the American style of teaching. The Academy program is somewhat similar to lesson study in that we collaborate regularly as a group to enhance our teaching and lessons. I immediately saw the benefits and the impact that I was going to make from being on the Academy team. When we started lesson study and saw the similarities between the Japanese style and our program, I realized why it is successful in the Japanese school system.

There were many rewarding and beneficial aspects to lesson study. The process involved requires that teachers be researchers in the classroom, and as a part of this process teachers learn from their peers and from the different ideas and ways they present material to students. Then from the research, teachers on the team come up with a lesson together and modify it according to what is best for the students' learning. This gives teachers the opportunity to improve their instruction by getting different ideas on how to teach what they are already teaching and it gives them the chance to see it from another perspective. As teachers we rarely get the chance to observe our great co-workers in action or the chance to really talk to them in depth about what they are doing it their classrooms. What I found the most valuable, which helped me immensely as a new teacher, was coming up with a goal for our students that we, as a team, agreed upon. This process was time consuming, but when we finally came up with our goal and everyone agreed on it, it felt great. Not only did we bond as professionals who share the same passion for teaching and for making a positive impact on our students' lives and minds, but we were able to come up with a common goal for students' learning. This beginning activity made me really think about myself as a teacher and what I wanted my students to learn. As a final part of the lesson study, I also enjoyed watching my peers teach the lessons that they worked so hard on developing and seeing how the students reacted to the lesson.

While there are many benefits in the Japanese lesson study, I encountered some frustrations as well. Once we figured out the goal for the study and the overall framework of the lesson, the English side of the team did not participate in creating the actual lesson. Even though the English side initially went to many of the meetings, we did not have to be involved in the entire process and I was thankful for that. The science team spent many hours preparing for the one lesson. It seemed that all this time and energy was being spent on one lesson, but what about the rest of the semester? Also, during the debriefing stage, I put myself in the teachers' shoes who had put his time and energy in delivering a lesson, in which we all observed. Once the lesson was observed, we were then to "constructively criticize" the teacher's lesson in order to try and improve it. I was conscious of the teacher's feelings and felt uncomfortable, but at the same time, I felt pressured to give feedback and be a part of the team. It is hard when nine or so other teachers are watching you teach a lesson, knowing that they are there to evaluate it and work on how it could be fixed. I guess this kind of thinking is not a part of Japanese teachers' thoughts, or they would not be as successful as they are in their lesson study program.

Overall, the entire process and collaboration has made me a better teacher and has made me realize even more the importance of student-directed lessons, where teachers work extensively to improve their teaching.

Liz Winn-Willis (2 years teaching English)

PART 3
Process Logistics

Time Allocation

Our lesson study team met for twenty-seven hours over the course of fifteen meetings during the fall of 2002. 80% of this meeting time took place during the regular school day. The time we expended outside of the formal meeting times (for individual research, etc.) is not accounted for in Figure 2 or Table 2.

Two important points should be considered when reviewing this time data:

- This lesson study process was embedded in a broader university research project. Table 1 separates the meeting time that was devoted to lesson study tasks from meeting time used to accomplish purely research project-related tasks (such as reflective journal writing). Just shy of twenty hours were devoted to the lesson study process.
- The teachers on the core lesson planning team (the four tenured science teachers) have at least four years experience developing lesson plans together. This relationship has resulted in shared philosophies about teaching and learning and well-honed group norms. A team without such a history of common understandings would likely require more time to complete many of the lesson study steps.

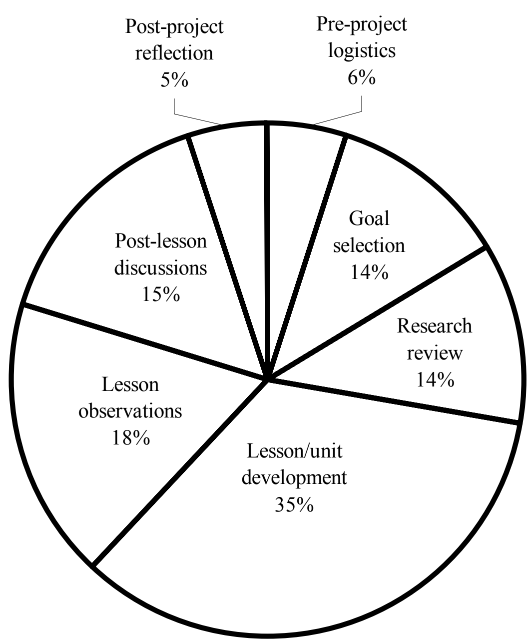


Figure 2. Time allocation per lesson study task.

Table 2
Meeting time allocated to lesson study and research project tasks
(Time rounded to nearest quarter hour)

Meeting description	**Time allocated to:** *Lesson study tasks (hours)*	**Time allocated to:** **Research project tasks (hours)**	**Total meeting duration (hours)**
1) Pre-project logistics	*0.00*	1.00	1.00
2) Goal development retreat			6.00 (includes 1.75 hours for breaks, meals & a campus tour)
a) Process/project introduction	*1.00*	0.00	
b) Long-range goal selection	*1.75*	0.25	
c) Academic content goal selection	*0.50*	0.50	
d) Research review preparation	*0.25*	0.00	
3) Research review	*1.25*	0.50	1.75
4) Research review	*0.75*	0.25	1.00
5) Lesson priorities development	*1.00*	0.25	1.25
6) Unit outline development	*1.25*	0.25	1.50
7) Unit outline development	*1.00*	0.00	1.00
8) Lesson blueprint development	*0.75*	0.25	1.00
9) Lesson blueprint development	*1.50*	0.00	1.50
10) Lesson plan matrix development	*1.25*	0.25	1.50
11) Research lesson #1	*1.75*	0.00	1.75
12) Post-lesson discussion #1	*1.50*	1.75	3.25
13) Research lesson #2	*1.75*	0.00	1.75
14) Post-lesson discussion #2	*1.50*	0.00	1.50
15) Final team reflection	*1.00*	0.25	1.25
TOTALS	***19.75***	**5.50**	**27.00**

Meeting Summaries

Meeting #1: **Pre-project logistics**
September 9, 2002 from 2:45 to 3:45 pm

- Celeste distributed and previewed the project binders (funded by the school site).
- Celeste updated the team on recent meetings with site and district administrators and improvements made to the research project by her dissertation committee.
- Informed consent forms were distributed, reviewed and signed.
- We agreed on tentative meeting dates and times for the semester.
- To prepare for the goal development retreat, we were asked to read chapter seven in *The Teaching Gap* (Stigler and Hiebert, 1999) (copies of this book were provided by the district). Chapters six and eight were also recommended. To facilitate goal development, we were asked to think about weak spots in the biophysical science curriculum, to think

about concepts that have been especially difficult for students to grasp or us to teach, and to bring evidence of these challenges if possible (student work samples, etc.). We were also asked to consider where we would likely be topic-wise in December.

Meeting #2: **Goal development retreat**
September 27, 2002 from 8:50 am to 2:45 pm

The entire team met at another district high school site for a full day retreat. Our principal generously paid for the continental breakfast, snacks and catered lunch.

- Before the retreat, we read chapter seven of *The Teaching Gap* and started the morning session with a five-minute individual quick write addressing the prompt: "How does the process described in *The Teaching Gap* compare with what you are already doing in the academy?" We spent another hour discussing our impressions of lesson study based on our reading.
- In order to identify a long-range or "big picture" goal, we reviewed course goals and standards and the school's "Essential Schoolwide Learning Results" (a required product of the Western Association of Schools and College's accreditation process). Each of us highlighted key phrases from these documents then discussed our "favorites" in two small groups. Each group posted their suggested statements for the larger group to consider. We each voted for two goals by adhering small stickers next to the goals that most resonated with us. The top three vote getters were:
    - "To communicate thoughtfully using evidence to develop logical interpretation"
    - "To apply literacy skills in order to make scientific connections"
    - "To research, analyze, and apply information in order to become critical thinkers in changing conditions"
- We were then given examples of "big picture" goals developed by other lesson study teams. We were also given goal development guiding questions (see Appendix A) and were asked to revise our statements in light of this new information. We revised our suggested long-range goals to read:
    - "To develop students who communicate thoughtfully and clearly using evidence to develop logical interpretation"
    - "To develop students who are independent thinkers and have the desire to solve relevant problems"
- Following a large group discussion, we decided on seven key words/phrases we wished to incorporate into our long-range goal: *communicate, relevant knowledge, problem solver, independent, logical thinker, value* and *desire.*
- The draft version of the long-range goal coming out of this retreat was:
    - **"To foster students who apply critical thinking in their lives"**
- For the purposes of the university research project, we recorded our reflections on this long-range goal definition process.
- We next shifted to the task of identifying an academic content topic/goal. We referred again to the course outline and related standards. We also considered examples of goals and guiding questions from other lesson study teams (see Appendix A).
- We decided to focus on the **Law of Conservation of Energy**.

- The academic content goal-setting portion of the retreat concluded with another reflective journal writing and a whole group debrief of the day.
- To prepare for the next step in the lesson study process, the review of relevant research, we brainstormed potential sources of information to consult and agreed upon homework assignments for each team member. Sources generated during the brainstorming session included:

<table>
<tr><th>Categories of Inquiry</th><th>Sources of Information</th></tr>
<tr><td rowspan="5">Brushing up on The Law of Conservation of Energy (the content itself)</td><td>Tutorial on the “Law of Conservation of Energy”</td></tr>
<tr><td>Internet sources</td></tr>
<tr><td>Science and general education journals</td></tr>
<tr><td>Newspapers</td></tr>
<tr><td>Connections between the content and the real world (relevance)</td></tr>
<tr><td rowspan="6">Approaches to teaching the Law of Conservation of Energy (sample lesson plans, instructional strategies, etc.)</td><td>Previously used lesson plans</td></tr>
<tr><td>Other teachers’ lessons</td></tr>
<tr><td>Science and general education journals</td></tr>
<tr><td>Ask ERIC</td></tr>
<tr><td>Internet sources besides Ask ERIC</td></tr>
<tr><td>Related fiction</td></tr>
<tr><td rowspan="2">Anticipated student misconceptions of the Law of Conservation of Energy</td><td>Research on student misconceptions</td></tr>
<tr><td>Pre-test of student knowledge</td></tr>
</table>

Meeting #3: **Research review**
October 9, 2002 from 9:45 to 11:20 am

- As part of the university research project, we started the meeting by recording in our journals how we went about researching the topics we volunteered for at the goal development retreat.
- The majority of the meeting was spent sharing our research findings. In the course of the discussion, the broad academic content goal, the Law of the Conservation of Energy, was narrowed to “energy transfer between various forms of energy.” Specific lesson/unit objectives were tentatively agreed upon:
    - Students will be able to identify various types of energy
    - Students will understand the concept of energy transfer
    - Students will be able to identify energy transfers that occur in everyday life
- The meeting concluded with a revision of homework assignments in light of the more focused academic content goal.
- We recorded our reflections on this session in our individual journals.
- Between meetings, we were sent a copy of this meetings’ transcript, the web citations located by our teammates, a summary of “energy facts,” and the table of contents from the *Handbook of Research on Science Teaching and Learning* (Gabel, 1994) with an offer from Celeste to copy any sections we deemed would be helpful to our assignments.

Meeting #4: **Research review continued**
October 23, 2002 from 10:15 to 11:20 am

- We started the meeting by reflecting in our journals on our research progress since the last session.
- We viewed and discussed a Japanese science lesson study team in a video entitled, *The Secret of Trapezes* (Lewis, 1999b). The purpose of watching and discussing this video was to address two lingering questions from our previous meeting:
    - How do the long-term goal and academic content goals intertwine?
    - What is the best timing for a research lesson within a broader unit? Should the research lesson be scheduled as an anticipatory lesson at the beginning, as a discovery lesson in the middle, or as a summative assessment at the end?
- As we continued to share our research findings, a list of desired lesson/unit characteristics began to emerge:
    - What students know and think about the topic should be uncovered (through writing, talking, etc.)
    - The lesson should attempt to dispel student misconceptions
    - Students' misconceptions should be made explicit to them
    - The students should attempt to solve a real world, context-rich problem
    - The students should generate data to make a discovery
    - The lesson should emphasize qualitative (vs. quantitative) data

Meeting #5: **Lesson priorities development**
October 30, 2002 from 10:00 to 11:20 am

- We were asked in a reflective journal prompt to identify and defend "the most important lesson characteristic" for our research lesson. Most of us wanted to be sure the lesson/unit would include "real world" problems. Dispelling student pre- or misconceptions was also highly valued.
- Celeste shared a quote from *The Teaching Gap* (Stigler & Hiebert, 1999): "The useful research lesson should be designed with a hypothesis in mind: some idea to be tested and worked out within the context of classroom practice" (p. 113). She also shared an example developed by the New Mexico State University lesson study project (http://mathstar.nmsu.edu/lesson_study/index.html):
    - Problem: Students don't seem to be able to visualize math problems
    - Question/hypothesis: Will work with visualization of math relationships help students solve fraction problems?
- The question was then posed: "Do we want to select an instructional approach to investigate through our research lesson?" We chose not to select a formal instructional strategy goal.
- Subsequent discussion flowed into the development of a rudimentary outline of the energy unit.
- We decided which teachers would teach the first and second research lessons.

Meeting #6: **Unit outline development**

November 13, 2002 from 10:00 to 11:35 am

- At this point in the process, we were feeling a sense of urgency and anxiety about the time this project was requiring and how our other responsibilities were being neglected. To accelerate the research phase and transition the team into the more action-based lesson/unit planning stage, Celeste compiled two research summaries, "Teaching & Learning about Energy" and "Teaching for "Conceptual Change" (see Appendix B). We read through these two documents and discussed points of confusion until a common understanding was reached.
- We began filling in a unit plan template (see Appendix C) detailing tentative learning activities for each day of the three-week energy unit.
- We determined the days and periods during which the two research lessons would be taught. After much discussion, we decided it would be best to teach the two lessons on consecutive lab day periods (a Wednesday and Thursday) rather than spacing the lessons a week apart. We felt having all the teachers in synch regarding the order of their lessons was worth the trade off of staying late after the first lesson to debrief the observation and refine the lesson blueprint.
- We reflected on the research review process in our journals.

Meeting #7: **Unit outline development continued**
November 22, 2002 from 9:50 to 10:50 am

- We continued to discuss the overall energy unit design and to fill in the unit plan template (see Appendix C).

Meeting #8: **Lesson blueprint development**
November 26, 2002 from 9:50 to 10:50 am

- We agreed on outside observers to invite to the second research lesson and post-lesson debrief (department colleagues, site administrators, district administrators, and Celeste's UCLA dissertation committee). Celeste sent out invitations over Thanksgiving break.
- Celeste provided a filled-in unit plan template detailing the decisions we made at the previous meeting (see Appendix C).
- We continued to flesh out the lessons that would lead up to the research lessons. The learning activities for the actual research lessons were touched upon, but nothing was decided definitively.
- Celeste shared the purpose of the lesson plan blueprint as it is used on Japan (to serve as a research tool for the lesson observers and to provide background information for visitors).
- We were not ready to fill in the 4-column lesson plan matrix, but Celeste conducted a group interview of sorts to begin building the introductory portions of the blueprint.

Topics discussed included:

Research focus
What is the long-term research goal/research theme?

About the unit
What is the working title for this unit?
What are your objectives for this unit?
How do the unit objectives relate to your long-term research goal?
How does this unit fit in course and in the broader curriculum?
    What have the students learned about energy prior to this unit?
    What will the students learn about energy after this unit?
What is the instructional sequence for this unit (desired conceptual development; learning flow)?

About our students
How would you describe your students currently? What kind of learners are they?
What is the current reality related to your long-term research goal?
What else is it important for the observers (or readers of your project report) to know about your students?
What do you want outside observers (or readers of your project report) to know about the academy setting – as it relates to this lesson?

About the lesson
What is the working title for the lesson?
What are your aims for the lesson?
What preconceptions are you hoping to eradicate?
What should students know at the end of this lesson?
What else do you want your students to gain from this lesson?
How does this lesson relate to your long-term research goal? What aspects of this lesson address the long-term goal?

Meeting #9: **Lesson blueprint development continued**
December 4, 2002 from 10:00 to 11:20 am

- We were two days into teaching the energy unit at this point so we began the meeting by sharing how our students were reacting to the first two lessons. Both lessons were designed to explore the students' preconceptions about energy and we were pleased with the results.
- Celeste distributed a first draft of the research lesson blueprint including information garnered from the group interview at the last meeting.
- Celeste shared examples of completed research lesson matrices from other lesson study teams (many examples are available on the Lesson Study Research Group website at lsrg@columbia.edu). We still did not feel ready to fill in the 4-column matrix for the research lesson.
- The remainder of the meeting was spent finalizing plans for the next few energy lessons.

Meeting #10: **Lesson plan matrix development**
December 9, 2002 from 2:45 to 4:00 pm

- We were two days away from teaching and observing the first research lesson during this meeting. We sketched out a draft of the lesson matrix.
- We shared our reaction to drafting such a detailed blueprint in individual journal entries.
- The teacher who volunteered to teach the first lesson filled in the details of the lesson matrix and created the student handouts at home alone. He e-mailed these documents to Celeste later that evening and she compiled the first complete research lesson blueprint (see Appendix D).

Meeting #11: **Research lesson #1**
December 11, 2002 from 7:35 to 9:20 am

- Because of the university research project purpose (to better understand how American high school teachers approach the lesson study process), we were given very little guidance as to effective observation approaches. Most of us attempted to gather data on the entire class and moved from group to group during the lesson.

Meeting #12: **Post-lesson discussion #1**
December 11, 2002 from 9:45 to 11:20 & 2:50 to 4:30 pm

- Immediately following the lesson, we completed individual reflections on the success of the lesson itself and on our individual data collection strategies.
- The post-lesson discussion started with the lesson instructor sharing his impressions of the lesson followed by the other team members' comments.
- Discussion quickly moved to improvements that would be made in the lesson before the second research lesson.
- The post-lesson debrief continued after school. Two teachers taught the same lesson to their own classes between the first and second parts of the post-lesson discussion. They shared their experiences with the rest of us.
- Additional revisions were suggested for the second research lesson. Refinements were also made in the blueprint introductory information.
- Celeste shared guidelines established by experienced lesson study teams on effective observation strategies (see Appendix E). We discussed these suggestions and the second research lesson instructor assigned each of us either an individual student or a small group to observe the following day.
- Finally, we discussed ways to improve the post-lesson discussion in light of guidelines established by other lesson study teams (see Appendix F). A more structured agenda was agreed upon and we each volunteered for roles within that structure.

Meeting #13: **Research lesson #2**
December 12, 2002 from 12:00 to 1:45 pm

- We each observed our assigned group or individual student and made notations on our updated lesson blueprint (see Appendix G).

Meeting #14: **Post-lesson discussion #2**
December 12, 2002 from 2:40 to 4:15 pm

- Before this meeting began, we described in our journals how our observation strategies differed for this lesson and how those changes impacted the data we gathered.
- Following a more traditional Japanese agenda for this post-lesson discussion, the meeting began with an introduction of the participants and guests, followed by a review of the agenda.
- The lesson instructor detailed the goals of the lesson and unit. He also addressed the steps of the lesson study process for the benefit of the district office visitors (an assistant superintendent and the director of curriculum, instruction, standards and assessment for the district's secondary schools).
- The first lesson's instructor explained the changes that were made between lessons.
- The remainder of the meeting focused on observations gathered during the lesson, starting with the lesson instructor and then other members of the lesson development team. The two visitors posed insightful questions to our team throughout the discussion.
- The meeting concluded with Celeste extending her appreciation to the guests and the lesson study team.

Meeting #15: **Final team reflection**
December 18, 2002 from 10:10 to 11:20 am

- Each of us completed a worksheet designed to capture our opinions on how much time should be allocated to each phase of the lesson study process (see Appendix H).
- Celeste explained the components of the final team report and facilitated a group interview using the questions listed in Appendix H. The purpose of this session was to gather our reflections on the lesson study process for this team report.
- We were invited to compose individual reflective statements after the meeting based on the prompts detailed in Appendix H.

BIBLIOGRAPHY
Lesson Study

Boss, S. (2002). A closer look at learning. *Principal Leadership, 2*(7), 12-16.

Ertle, B., Chokshi, S., & Fernandez, C. (2002). Lesson study tools. Retrieved 2002 from Lesson Study Research Group Web site: www.tc.columbia.edu/lessonstudy/tools.html

Fernandez, C., Cannon, J., & Chokshi, S. (2001). *A U.S.- Japan Lesson study collaboration reveals critical lenses for examining practice.* Unpublished manuscript, Teachers College, Columbia University, New York.

Fernandez, C., & Chokshi, S. (2001). *Translating lesson study for a U.S. context.* Unpublished manuscript, Teachers College, Columbia University, New York.

Fernandez, C., & Chokshi, S. (2002). A practical guide to translating lesson study for a U.S. Setting. *Phi Delta Kappan, 84*(2), 128-134.

Fernandez, C., Chokshi, S., Cannon, J., & Yoshida, M. (in press). Learning about lesson study in the United States. In M. Beauchamp (Ed.), *New and old voices on Japanese education.* Armonk, New York: M. E. Sharpe.

Fernandez, C., & Yoshida, M. (n.d.). *Lesson study as a model for improving teaching: Insights, challenges and a vision for the future*. Unpublished manuscript, New York City.

Lewis, C. (Producer). (1999a). *The secret of magnets* [Videotape]. Oakland, CA: Mills College. (Available from http://www.lessonresearch.net)

Lewis, C. (Producer). (1999b). *The secret of trapezes* [Videotape]. Oakland, CA: Mills College. (Available from http://www.lessonresearch.net)

Lewis, C. (Producer). (2000a). *Can you lift 100 kilograms?: The lesson research cycle* [Videotape]. Oakland, CA: Mills College. (Available from http://www.lessonresearch.net)

Lewis, C. (2000b, April). *Lesson study: The core of Japanese professional development.* Paper presented at the American Educational Research Association Annual Meeting, New Orleans, LA.

Lewis, C. (2002a, January). Does lesson study have a future in the United States? *Nagoya Journal of Education and Human Development,* (1), 1-23.

Lewis, C. (2002b). *Lesson study: A handbook of teacher-led instructional change*. Philadelphia: Research for Better Schools.

Lewis, C. & Tsuchida, I. (1997). Planned educational change in Japan: The case of elementary science instruction. *Journal of Educational Policy, 12*(5), 313-331.

Lewis, C., & Tsuchida, I. (1998, winter). A lesson is like a swiftly flowing river: American lessons and the improvement of Japanese education. *American Educator,* 14-17 & 50-52.

Linn, M. C., Lewis, C., Tsuchida, I. & Songer, N. B. (2000). Beyond fourth-grade science: Why do U.S. and Japanese students diverge? *Educational Researcher, 29*(3), 4-14.

Manzo, K. K. (2002). North wind bows to the rising sun. Retrieved September 30, 2002 from Education Week Web site: www.edweek.org/ew/ew_printstory.cfm? slug=04japan.h22

Murata, A., & Takahashi, A. (2002). *District-level lesson study: How do Japanese teachers improve their teaching of elementary mathematics?* Paper presented at the National Council of Teachers of Mathematics, Las Vegas.

Perry, R., Lewis, C. & Akiba, M. (2002, April). *Lesson study in the San Mateo-Foster City School District.* Paper presented at the American Educational Research Association Annual Meeting, New Orleans, LA.

Ready, D. E. (2002, spring). Crafting better lessons [Electronic version]. *Alliance Access,* (1), 1-2 & 4-5.

Regents of the University of California (Producer). (2001). *Three perspectives on lesson study* [Videotape]. (Available from http://www.lessonresearch.net)

Research for Better Schools. (2002). What is lesson study? *Currents, 5*(2), 1-16.

Shimahara, N. K. (1998). The Japanese model of professional development: Teaching as craft. *Teaching and Teacher Education, 14,* 451-462.

Sparks, D. (1999, November). Using lesson study to improve teaching [Electronic version]. *Results,* 2. Retrieved July 30, 2001, from http://nsdc.org/library/results/res11-99spar.html

Stepanek, J. (2001). A new view of professional development. *Northwest Teacher, 2* (2), 2-5.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York: The Free Press.

Watanabe, T. (2002). Learning from Japanese lesson study. *Educational Leadership, 59*(6), 36-39.

Willis, S. (2002). Creating a knowledge base for teaching: A conversations with James Stigler. *Educational Leadership, 59*(6), 6-11.

Yoshida, M. (1999a). *Lesson study: A case study of a Japanese approach to improving instruction through school-based teacher development*. Unpublished doctoral dissertation, University of Chicago.

Yoshida, M. (1999b, April). *Lesson study [jugokenkyu] in elementary school mathematics in Japan: A case study.* Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

BIBLIOGRAPHY
Teaching and Learning about Energy

Benyon, J. (1990). Some myths surrounding energy. *Physics Education, 25*(6), 314-316.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

Carr, M., Kirkwood, V., Newman, B., & Birdwhistell, R. (1987). Energy in three New Zealand secondary school junior science classrooms. *Research in Science Education, 17*, 117-128.

Committee on Undergraduate Science Education. (1997). Misconceptions as barriers to understanding science. Retrieved October 12, 2002 from Web site: http://bob. nap.edu/readingroom/books/str/4.html

Driver, R., & Warrington, L. (1985). Students' use of the principle of energy conservation in problem situations. *Physics Education, 20*(4), 171-176.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. London: Routledge.

First in the World Consortium. (1999). First in the world physics project. Retrieved October 17, 2002 from Web site: http://gbn.glenbrook.k12.il.us/academics/ science/lamaster/Web%20pages/Intro%20page.html [Note: as of the publication of this report, this URL was not accessible]

Freedman, R. A. (1996). Challenges in teaching and learning introductory physics. Retrieved October 12, 2002 from Web site: http://www.physics.ucsb.edu/ ~airboy/challenge.html

Gabel, D. L. (Ed.). (1994). *Handbook of research on science teaching and learning*. New York: Simon & Schuster Macmillan.

Heller, P., & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics, 60*(7), 637-644.

Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics, 60*(7), 627-636.

Keogh, B., & Naylor, S. (1996). Teaching and learning in science: A new perspective. Retrieved September 16, 2002 from Web site: http://www.leeds.ac.uk/educol/ documents/000000115.htm

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 631-645.

Kruger, C. (1990). Some primary teachers' ideas about energy. *Physics Education, 25*(2), 86-91.

McClelland, G. (1989). Energy in school science. *Physics Education, 24*(3), 162-164.

Minstrell, J. (2001a). Facets of students' thinking: Designing to cross the gap from research to standards-based practice. In K. Crowley & C. D. Schunn & T. Okada (Eds.), *Designing for science: Implications from professional, instructional, and everyday science*. Maway, NJ: Lawrence Erlbaum Associates.

Minstrell, J. (2001b). The role of the teacher in making sense of classroom experiences and effecting better learning. In D. Klahr & S. Carver (Eds.), *Cognition and instruction: Twenty-five years of progress*. Mahway, NJ: Lawrence Erlbaum Associates.

Minstrell, J., & Van Zee, E. H. (2000). *Inquiring into inquiry learning and teaching in science*. Washington, D.C.: American Association for the Advancement of Science.

National Research Council. (2000). *Inquiry and the national science education standards*. Washington, D.C.: National Academy Press.

Prideaux, N. (1995). Different approaches to the teaching of the energy concept. *School Science Review, 77*(278), 49-57.

Roseberry, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1), 61-94.

Sandoval, W. A., Deneroff, V., & Franke, M. L. (2002). *Teaching as learning, as inquiry: Moving beyond activity in the analysis of teaching practice.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Scott, P. H., Asoko, H. M., & Driver, R. H. (1991). Teaching for conceptual change: A review of strategies. In R. Duit & F. Goldberg & H. Niederer (Eds.), *Research in physics learning: Theoretical issues and empirical studies*.

Solomon, J. (1982). How children learn about energy or does the first law come first? *School Science Review, 63*, 415-422.

Solomon, J. (1985). Teaching the conservation of energy. *Physics Education, 20*(4), 165-170.

Solomon, J. (1992). *Getting to know about energy in school and in society*. London: Falmer Press.

Trumper, R. (1990). Energy and a constructivist way of teaching. *Physics Education, 25*(4), 208-212.

Warren, J. W. (1983). Energy and its carriers: A critical analysis. *Physics Education, 18*(5), 209-212.

Watts, D. M. (1983). Some alternative views of energy. *Physics Education, 18*, 213-217.

University of California, Los Angeles
Rancho Bernardo High School
LESSON STUDY RESEARCH PROJECT

"Big Picture" Goal Examples

(Not necessarily exemplars!)

1. To foster students' ability to investigate problems in nature
2. To develop students who are active problem solvers
3. To develop students' scientific perspectives and ideas by conversing with nature
4. To foster students who take initiative as learners
5. To develop students who work cooperatively with others
6. To foster students who develop scientific ways of thinking
7. To help students become good problem solvers by providing a challenging open-ended problem
8. To provide opportunities for students to recognize the importance or working with their peers in order to deepen their understanding of science

"Big Picture" Goal Development
Guiding Questions
(Ertle, Chokshi & Fernandez, 2002)

1. What kind of students do you want to foster or develop at RBHS? What qualities or characteristics do you want your students to have when they graduate?

   Ex. I want my students to be curious about mathematics. They should not see math as something they are forced to learn in school, but otherwise have no interest in. I want them to realize that math is inherently interesting and I want them to be motivated to learn math, not only in school, but also from their peers and their environment.

2. What gaps do you see between your aspirations for your students and how students are actually developing at RBHS? How do the ideal characteristics compare to who your students are now?

   Ex. I have noticed that my students don't seem to care about math. They have no apparent curiosity about numbers or what they could mean. They don't ask questions, or really want to discover the answers to questions that I pose to them.

3. Select one “gap” that you would like to focus on during this lesson study project.

   Ex. The lack of student curiosity about mathematics.

4. Write a goal that states the quality you would like to develop in your students in order to address the gap you have chosen.

   Ex. To develop students who are curious about mathematics and who will engage in math to satisfy their curiosity.

Academic Goal Examples

(Again … don't assume these are exemplars!)

1. To help students understand how to find equivalent fractions

2. To enable students to investigate the design and operation of levers by changing the position from which effort is exerted and the amount of effort

3. To deepen students' understanding of the concept of area

4. By investigating the factors that affect the cycle of trapezes, to learn how to control variables and to consider measurement error

5. To deepen students' understanding of three-dimensional geometric objects

6. To develop a scientific perspective that the length of wire affects the cycle of the trapeze

Ideas for our focus topic (same thing as the academic goal):

Academic Goal Development
Guiding Questions

	Notes
1. Is our academic goal appropriate for exploring our "big picture" goal?	
2. Is the topic likely to foster rich discussion and teacher learning?	
3. Does the goal address a core curricular topic, essential learning, key concept, or foundational topic (preferably a topic that spans multiple grade levels)?	
4. Has the selected concept traditionally been challenging to teach and/or difficult for students to learn?	
5. Is the topic one that has been well documented in research on science teaching and learning?	
6. Does this topic fit naturally with the lesson study timeline (our research lesson will be taught in early December)?	

Appendix B
Research review tools

University of California, Los Angeles
Rancho Bernardo High School

LESSON STUDY RESEARCH PROJECT

Teaching & Learning
About Energy

Literature Review

Importance of teaching energy well

- "Energy is probably the most important concept in all of science" (First in the World Consortium, 1999, p. 2)
- "It would certainly be difficult to find any course in science where energy does not play some part – if it is not a central theme" (Watts, 1983, p. 213)
- "Student misconceptions of energy can be a roadblock to success in all of science" (First in the World Consortium, 1999, p. 1)
- "Energy is a concept of fundamental importance in science…. It is also a very difficult concept which is often taught very badly" (Warren, 1983, p. 212)
- Energy "is thought to be the most difficult of all concepts to teach" (Solomon, 1992, p. vii)

Evolving unit objectives?

Current long-term goal = "To foster students who apply critical thinking in their lives"

- To help students construct a more useful and scientific understanding of energy
- To move students from their everyday knowledge system to the scientific domain
- To reduce or eliminate students' use of non-scientific frameworks when describing energy processes

Pervasive misconceptions about energy

1) Energy is associated primarily with animate objects

- Young children most frequently associate energy with living things, especially humans (e.g. growth, exercise and food). (Gabel, 1994, p. 183); (Watts, 1983, p. 214)
- Energy is seen as liveliness. Watts in (Kruger, 1990, p. 86)

2) Energy is synonymous with (or directly related to) force

- Energy is confused with force (Kruger, 1990), p. 88; (Driver, Squires, Rushworth, & Wood-Robinson, 1994, pp. 144-145); (Gabel, 1994, p. 183); (Solomon, 1985, p. 166)

3) Energy is associated only with movement

- Energy is not an attribute of stationary objects; energy is associated with movement and action (Kruger, 1990, p. 88)
- Energy is an outward, overt display of activity (Watts, 1983, p. 214); (Gabel, 1994, p. 183)

4) Energy is stored within objects (related to misconception #7)

- Energy is a causal agent stored in certain objects (Driver et al., 1994, p. 144)
- Energy is a source of activity stored within certain objects (Watts, 1983, p 214)

5) Energy is fuel

- Energy is often confused with energy resources and with fuels (because these are common uses of the word *energy* in non-scientific conversations) (Carr, Kirkwood, Newman, & Birdwhistell, 1987, pp. 122-123)
- Students closely link energy with fuels and electricity (Driver et al., 1994, p. 145)
- Students confuse the principle of *conservation of energy* with the *conservation of energy resources* (i.e. the world is running out of fuels/energy resources) (Carr et al., 1987, pp. 125-126)

6) Energy behaves as a fluid

- Energy is a fluid (flow transfer model) (Driver et al., 1994, p. 146)

7) Energy is an ingredient or a product

- Energy is a reactive ingredient that is dormant and must be triggered to be released (Watts, 1983, p. 214); (Solomon, 1985, p 166); (Driver et al., 1994, p. 146)
  - Ex. Energy is not stored in food, it only gives you energy when you eat it
  - Ex. A seed has energy inside it, but it needs the sun to be activated
  - Ex. Energy is not stored in coal or oil, but is sparked off when it is burnt

8) Energy is not conserved

- Energy is active for a short period then disappears or diminishes (Driver & Warrington, 1985, p. 171)

<u>Implications for Instruction</u>

Two domains of knowledge

- Students develop two separate domains or knowledge systems for dealing with energy phenomena: a *science system*, which is used in school to solve problems posed by teachers and textbooks, and a *life-world* (or everyday) knowledge system (Solomon, 1992)
- Even successful students retreat to their out-of-school, intuitive conceptions when confronted by novel or difficult situations." Solomon in (Gabel, 1994, p. 183); (Driver & Warrington, 1985, p. 171)

Language issues

- The words *energy*, *work*, and *conservation* are not used in everyday language in the same way they are used in physics – this should be communicated explicitly to students (Solomon, 1985, p. 168)
- Energy does not change *form*; it only changes *location*. Energy is just energy, everywhere and always. (First in the World Consortium, 1999, p. 6)
- Avoid the use of the term *storage*. Only substances can be stored and energy is not a substance. (McClelland, 1989, pp. 163-164); (Benyon, 1990, p. 315)
- Teaching the definition of the conservation of energy in its <u>negative form alone</u> is <u>confusing</u> (i.e. energy is never created and never destroyed). Better definitions:
  - "There is the same amount of energy at the end of any process as at the beginning" (although it will be in different locations) (Solomon, 1985, p. 169)
  - When energy changes in form, the total amount of energy remains constant (Carr et al., 1987, p. 125); (Solomon, 1992, p. 130)

Invented construct

- Teachers should portray energy as a complex and abstract <u>human construct</u>, which is not directly measurable. Energy is a <u>number</u>, a <u>quantity that describes a system</u> (Prideaux, 1995, pp. 52-53)
- Teachers are advised to explain that "energy is a concept <u>invented</u> to bring together a number of phenomena associated with change" (Carr et al., 1987, p. 127); (Benyon, 1990, p. 315)
- Energy is an <u>abstraction</u> used in the theoretical analysis of phenomena, and is not a commodity, a phenomenon or a sensation (Trumper, 1990, p. 209); (Warren, 1983, p. 210)

Acknowledge oversimplifications

- Teachers often pose situations assuming students will view the system in simple terms, but the reality is often quite complex. The teacher must clearly <u>define</u> the <u>system</u> in question and <u>acknowledge</u> the <u>artificiality</u> of the question. (Carr et al., 1987, p. 120)

Changing systems

- Discussion of energy in static systems causes conceptual problems. It is advised to <u>analyze systems undergoing change</u>. (Carr et al., 1987, pp. 118-119)

- It is best to analyze situations from a systems point-of-view (rather than analyzing isolated objects), describing, then quantifying the energy inputs and outputs (Driver & Warrington, 1985, p. 175)

The sun and energy chains

- Tracing all energy chains back to the sun is neither simple nor sensible and often introduces unnecessary confusion. It is sufficient to explain that the sun is a major energy source. Cute example: a student who was asked to trace energy changes to the sun asked about falling rocks in another galaxy! (Carr et al., 1987, p. 121)

Gravitational potential energy

- GPE might best be avoided because "most treatments of GPE treat it as though it is contained within an elevated object. This is not the case…. The GPE associated with some object is contained within the gravitational field." (First in the World Consortium, 1999, p. 3)
- Potential energy is the energy of the system, not the energy of an individual body (McClelland, 1989, p. 164)
- Most students do not understand GPE. Some learners believe that an object posses GPE at the brink of a cliff or table, but not at some distance in from the edge (Kruger, 1990, p. 88). This idea comes from a focus on the "properties of individual bodies rather than on their positions in systems" (Kruger, 1990, p. 90); this confusion also arises when examining a static system rather than a system undergoing change (Carr et al., 1987, pp. 118-119)
- Discussion of GPE in a static system is especially troublesome. A good example of understandable confusion involves a raised stick of dynamite. Is the focus on the GPE (because the object is raised) or on the chemical potential energy? The teacher should clarify whether the object will be detonated or dropped before posing a question about its energy. (Carr et al., 1987, pp. 118-119)
- When a body of mass m is raised through a distance x above the ground, it is said to have acquired a potential energy of mgx. According to current teaching methods this energy is a substance, which has been put into the body. Actually nothing has been put into the body, which is unchanged except in position. If it is allowed to return to the ground, the gravitational field of the earth will do work on it equal to mgx. That is, potential energy is not something in the body. It is an abstract quantity. (Warren, 1983, p. 210)

Conservation of energy

- "Conservation in everyday situations does not appear to hold as energy becomes less useful according to the 2nd law of thermodynamics." For effective teaching it might therefore be necessary to first teach the second law. (Prideaux, 1995, p. 54)
- Before teaching the conservation principle, students should be taught about the direction in which natural energy changes take place and their efficiency (the 2nd law of thermodynamics) (Solomon, 1982, p. 419)
- "Conservation of energy is a counter-intuitive notion which will explain everyday situations satisfactorily only if energy transference, transformation and dissipation are understood" Solomon in (Kruger, 1990, p. 88); (Solomon, 1985, p. 169)

Bibliography

Benyon, J. (1990). Some myths surrounding energy. *Physics Education, 25*(6), 314-316.

Carr, M., Kirkwood, V., Newman, B., & Birdwhistell, R. (1987). Energy in three New Zealand secondary school junior science classrooms. *Research in Science Education, 17*, 117-128.

Committee on Undergraduate Science Education. (1997). Misconceptions as barriers to understanding science. Retrieved October 12, 2002 from Web site: http://bob. nap.edu/readingroom/books/str/4.html

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. London: Routledge.

Driver, R., & Warrington, L. (1985). Students' use of the principle of energy conservation in problem situations. *Physics Education, 20*(4), 171-176.

First in the World Consortium. (1999). First in the world physics project. Retrieved October 17, 2002 from Web site: http://gbn.glenbrook.k12.il.us/academics/ science/lamaster/Web%20pages/Intro%20page.html

Freedman, R. A. (1996). Challenges in teaching and learning introductory physics. Retrieved October 12, 2002 from Web site: http://www.physics.ucsb.edu/ ~airboy/challenge.html

Gabel, D. L. (Ed.). (1994). *Handbook of research on science teaching and learning*. New York: Simon & Schuster Macmillan. [chapters 2 & 5]

Kruger, C. (1990). Some primary teachers' ideas about energy. *Physics Education, 25*(2), 86-91.

McClelland, G. (1989). Energy in school science. *Physics Education, 24*(3), 162-164.

Prideaux, N. (1995). Different approaches to the teaching of the energy concept. *School Science Review, 77*(278), 49-57.

Solomon, J. (1982). How children learn about energy or does the first law come first? *School Science Review, 63*, 415-422.

Solomon, J. (1985). Teaching the conservation of energy. *Physics Education, 20*(4), 165-170.

Solomon, J. (1992). *Getting to know about energy in school and in society*. London: Falmer Press.

Trumper, R. (1990). Energy and a constructivist way of teaching. *Physics Education, 25*(4), 208-212.

Warren, J. W. (1983). Energy and its carriers: A critical analysis. *Physics Education, 18*(5), 209-212.

Watts, D. M. (1983). Some alternative views of energy. *Physics Education, 18*, 213-217.

University of California, Los Angeles
Rancho Bernardo High School
LESSON STUDY RESEARCH PROJECT

Teaching for Conceptual Change

Literature Review

"Teaching is seen in terms of conceptual development or change rather than the piecemeal accretion of new information"
(Scott, Asoko, & Driver, 1991), p. 1

Strategies for promoting conceptual change

Foster a constructivist approach
- A constructivist approach to learning builds on students' prior knowledge, what they already know and understand. This is an evolutionary approach whereby new knowledge and concepts are built into or from existing frameworks. (Prideaux, 1995, pp. 50-51)
- "Rather than seeing themselves as passive absorbers of information, pupils need to see themselves as actively engaged in constructing meaning by bringing their prior ideas to bear on new situations" (Driver, 1994, p. 7)

Provide opportunities for discussion and consideration of alternative viewpoints
- Peer discussion serves as a forum in which previously implicit ideas can be made explicit and available for reflection and checking. Students need to be aware of the range of different ideas that their classmates may have for explaining the same phenomenon (Driver, 1994, pp. 5-7)

Use the cognitive conflict approach (Scott et al., 1991, pp. 3-6)
- **Focus**: Make students aware of their own and other students' frameworks (preferably in the context of a real life situation). Students attempt to convince each other of the validity of their ideas.
- **Challenge**: Create a conceptual conflict by requiring students to explain a discrepant event (perhaps via instructor demonstration or student investigation).
- **Conceptual development**: Guide students to invent a new conceptual model that is consistent with the accepted scientific view.
- **Apply**: Create opportunities for students to apply the new ideas/theories across a range of contexts

Incorporate the development of existing ideas approach (Scott et al., 1991, pp. 7-8)
- **Initiate**: Pose an open-ended problem

- **Performance**: Students formulate questions or hypotheses, perform experiments, make observations, discuss, and formulate findings
- **Discuss findings**: in a class forum
- **Compare with science**: class findings are compared with scientific theory and possible reasons for the differences are discussed
- **Reflect**: students look back on the process to consider questions that have arisen

---

Suggested sequence for energy unit

(Based heavily on the recommendations found in Solomon, 1992, pp. 98-140)

Explore students' prior conceptions

- Techniques to explore students' thinking (Driver, 1994, pp. 9-10):
    - **Written statements** - students individually write down five statements including the word *energy* on strips of paper; small groups sort and categorize statements according to their own criteria (related to food, movement, fuels, etc.); share with class
    - **Card sort** – students are given cards with words related to energy and are asked in small groups to sort the cards in a manner that makes sense to them; share with class (words such as force, friction, work, gravity, potential energy, etc.)
    - **Drawings questionnaire** – students are given pictures or descriptions of situations and asked which involve energy; discuss in groups; share with class

Work

- **Rationale** for teaching work: so energy can be defined in terms of work
- Record this **definition** on the board: "Work is the force acting multiplied by the distance moved in the direction of the force"
- Present the following **scenarios** and ask small groups of students to discuss whether working is being done in each situation:
    a. A woman mowing the lawn (obvious effort – 90% success rate)
    b. A heavy weight lying on the edge of a high shelf (no distance moved so no work)
    c. A boy going downhill on a sled (just lying on sled - 50%)
    d. A wind up toy being wound up (obvious effort – 90%)
    e. The same wind up toy moving across the floor (machinery unwinding - 50%)
- **Anticipated misconceptions** include the association of work with *effort* and a requirement for a human actor to be present for work to be done
- As a whole class, try and get students to **generate a definition** of work that makes sense to them
- Have small groups **try out** the student **definition** on these cases:
    a. An apple hanging on a tree (no distance moved so no work)
    b. The apple falling to the ground (gravity is doing the work – 70%)
    c. A girl picking up the apple (human actor & effort – 90%)
    d. A girl holding the apple (no distance moved so no work)
    e. A boy eating the apple (human actor & effort – 90%)

"Forms" of energy and energy transfer

- **Rationale** for teaching energy forms: Naming the forms (even though energy doesn't actually change form since it is an abstract quantity) helps students identify the energy being transferred between systems. Later the differentiation can be explained between changing forms and changing location.
- "Getting to understand energy is a long and gradual task, during which the pupils' minds play with the idea in progressively more sophisticated ways" (Solomon, 1992, p. 107)
- **List** different "forms" of energy on the board (chemical, electrical, kinetic, nuclear, etc.)
- In small groups, have students construct an **analogy** for the transfer of energy. This analogy will be refined as students integrate additional properties of energy such as conservation and degradation. They are essentially forming a hypothesis to be tested against new knowledge as it is acquired. Later they will be asked to think about whether their analogy still makes sense in light of new understanding.
- Early on the students will likely use words like: *transferred, passed on, carried by, transformed, flow*
- Introduce **energy transfer diagrams** to show how energy changes its name and form
- Provide written **scenarios** or conduct **demonstrations** (walk around lab?) and have students diagram what energy changes are taking place? Early on it will be helpful to have all the possible vocabulary on the board to select from.

Dissipation and degradation (AKA the running down principle; 2nd law of thermodynamics)

- Conduct a series of **demonstrations** in which energy is obviously *liberated* into useless energy in the form of heat and sound (ex. model steam engine, pendulum)
- **After** the first demo, ask students to **discuss and record** (and diagram?) the energy **changes** that took place. Discuss alternative viewpoints as a class.
- **Before** the second demo, ask students to **predict** what will happen and then to **revise** their predictions in light of the demo. Discuss as a class.
- Students should begin to **anticipate** some *wasted energy*
- Ask students to describe in their **own words** the direction of energy changes. In what sense or direction is energy transferred? Students will essentially be formulating the 2nd law of thermodynamics in their own words. Joan Solomon's classes came up with, "In all energy changes, there is a running down towards sameness in which some of the energy becomes useless"
- Solomon (1992) goes into a lengthy explanation of why the word *sameness* describes the trend of energy processes better than disorder (p. 135). She uses the example of ice melting in a dish, stating that this process shows difference at first, but as the ice melts, the movement is towards sameness and uniformity
- Have students use their newly formulated running down principle to **analyze situations**.
- Once students are convinced that the trend in energy processes is for the energy to dissipate and degrade, it is much easier for them to grasp the conservation principle

Conservation of energy

- Begin by having students discuss **what** the term ***conservation*** **means** to them.
- **Common responses** include: "storing something," using something in small amounts," or "keeping animals in safari parks"
- **Guiding question** for this section, "Does energy increase, diminish or stay the same in energy changes?" Initially, students will say all movements tend to slow down and stop.
- Solomon (1992) discusses at length a probable explanation for this confusion. In non-energy examples, conservation is demonstrated by showing **reversibility** (e.g. water is poured from a tall, narrow container to a wider, shallow one then back again). The problem is that reversibility is not a property of energy transfer (pp. 124-125).
- The groundwork for understanding that energy flow is not reversible will have been laid when the students formulated their statements about the running down principle. If need be, you can ask, "What happens to the energy in the fuel we use? Can we run out of fuel? Can you change the energy back into fuel?" Students know intuitively that once the energy in fuel is expended, you can't change it back.
- **Need an open-ended problem, activity, demo…. Something!!**
- Have the students combine 2 principles (dissipation/degradation & conservation) into one statement in their **own words**. A good statement will be something like, "When there is an energy change, the total amount of energy in the system does not change, but some of the energy is changed into a useless form."
- If the teacher provides a definition of the conservation of energy, it is important to include a **positive statement** such as, "the total amount of energy does not change" or "the total amount of energy is the same at the end of a process as it was at the beginning."
- Have the students **refine** their initial energy **analogy** (this will be very challenging).

Application

- **???? Apply new learnings to a real life situation????**

Bibliography

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. London: Routledge.

Prideaux, N. (1995). Different approaches to the teaching of the energy concept. *School Science Review, 77*(278), 49-57.

Scott, P. H., Asoko, H. M., & Driver, R. H. (1991). Teaching for conceptual change: A review of strategies. In R. Duit & F. Goldberg & H. Niederer (Eds.), *Research in physics learning: Theoretical issues and empirical studies*.

Solomon, J. (1992). *Getting to know about energy in school and in society*. London: Falmer Press.

Day/Date	Monday Dec 2	Tuesday Dec 3	Wed/Thurs Dec 4 & 5	Friday Dec 6
Learning Objectives				
Learning Activities				
Day/Date	**Monday Dec 9**	**Tuesday Dec 10**	**Wed/Thurs Dec 11 & 12**	**Friday Dec 13**
Learning Objectives				
Learning Activities				
Day/Date	**Monday Dec 16**	**Tuesday Dec 17**	**Wed/Thurs Dec 18 & 19**	**Friday Dec 20**
Learning Objectives				
Learning Activities				

Appendix C
Lesson/unit planning tools

Day/Date	**Monday Dec 2**	**Tuesday Dec 3**	**Wed/Thurs Dec 4 & 5**	**Friday Dec 6**
Learning Objectives				
Learning Activities	Sentence strips – 5 statements using the word *energy* Compose first draft of explanation of energy changes/transfers Woffer bottle? Represent graphically or in a narrative?	Woffer bottle? Represent graphically and/or in a written narrative? Card sort	Walk-around lab – a "smorgasbord" of energy changes Describe what they observe graphically and/or in writing Refine explanation of energy changes	Follow-up from lab day Prep for calorimeter lab – talk about joules and calories
Day/Date	**Monday Dec 9**	**Tuesday Dec 10**	**Wed/Thurs Dec 11 & 12**	**Friday Dec 13**
Learning Objectives			***THE RESEARCH LESSON***	
Learning Activities	Calorimeter lab – part I	Calorimeter lab – part II Why isn't the output of energy the same as the input?	*Similar observations of energy changes as experienced last week (maybe limited to two)* *Describe what they observe graphically and/or in writing* *Refine explanation of energy changes*	Follow-up from lab day Prep for "Design a better mousetrap" (improve the efficiency of something)
Day/Date	**Monday Dec 16**	**Tuesday Dec 17**	**Wed/Thurs Dec 18 & 19**	**Friday Dec 20**
Learning Objectives				
Learning Activities	"Design a better mousetrap"	"Design a better mousetrap"	"Design a better mousetrap" Diagram energy change Refine explanation of energy changes?	Written assessment • Explain evolution of explanations of energy changes • Make connection between improved "mousetrap" and the real world - "So what?"

Learning objectives (in your own words)

Overall:
- Get rid of misconceptions so they can apply it to the real world

Week one:
- Realize that energy comes in many different forms
- Looking for the big (obvious) change

Week two:
- Realizing that some energy in a transfer always ends of being useless
- Figure out that in all energy transfers, some of it is lost or becomes a form that we can't get back
- Understand that when energy changes places or changes locations, it's not 100% efficient… it doesn't all go where you want it to go or expect it to go. Some of it ends up as sound or heat
- Start to try and identify where the losses are

Week three:
- Design something that will increase efficiency… decrease the loss
- Tie this in with what we've done and where we're going… so it doesn't feel like it's this completely isolated thing that's detached from what we're doing.

Energy change demos/ lab experiences:
- Bunsen burner
- Balls or cars and tracks
- Pendulum
- Endo- and exothermic reactions

Appendix D
Lesson #1 blueprint

University of California, Los Angeles
Rancho Bernardo High School

LESSON STUDY RESEARCH PROJECT

Draft 12/11/02

Research Lesson Blueprint

Course: Biophysical Science

Grade: 9th

Unit: **Unraveling the Mysteries of Energy**

Lesson: **Diminishing Returns** (understanding the second law of thermodynamics)

First lesson iteration
Wednesday, December 11, 2002
Jay Hendricks, Teacher
7:35-9:00 am
1st period
Room W-8

Second lesson iteration
Thursday, December 12, 2002
Ken Ozuna, Teacher
12:02-1:42 pm
6th period
Room 407

Unit development team
Ian Campbell, Jennifer Grimm, Jay Hendricks, Ken Ozuna & Lisa Smedley

Academy teammates/lesson observers
Maureen Garland, Jane Wakeham Lopez, Kurt Trecker & Liz Winn-Willis

Background Information

The Biophysical Science & English Interdisciplinary Academy

Our academy team, comprised of four science teachers (plus one student teacher this semester) and four English teachers, serves approximately 320 randomly selected freshmen. Our students represent the full range of ability levels with the exception of the top five percent of freshmen, who are enrolled in honors science and English classes.

As with most students, our clients are motivated to learn when they see an association between the academic content and their personal interests. We meet for several hours a week during a commonly scheduled planning period to develop connections between the biophysical science and English curricula.

Our current group of students is more academically advanced than those we have served in recent years, but we still feel their ability to think critically and deeply is not highly developed. We continually strive to develop application and analysis skills in our students.

About the Unit
"Unraveling the Mysteries of Energy"

Lesson study research goal

To foster our students' ability to think critically and to apply their academic learning to their everyday lives.

Rationale for focusing on energy

While reviewing the extensive research on teaching and learning about energy, we stumbled across this quote: "Student misconceptions of energy can be a roadblock to success in all of science" (First in the World Consortium, 1999, p. 1). Initially we thought this to be a bit exaggerated, but we now agree that energy is a dominant and unifying theme in all branches of science. Most of us now realize that we skirted around the concept of energy in our previous instruction because our own understanding of energy was not as deep as it is now.

Unit objectives

- The students will construct a more scientific understanding of energy to complement their everyday, intuitive conceptions of energy.
- The students will realize that in all energy changes, some of the energy ends up in unintended locations (usually sound and heat). The trend in energy processes is for energy to dissipate and degrade (the entropy principle or the 2^{nd} law of thermodynamics).
- The students will come to understand that in all energy changes, the total amount of energy in a system does not change. In other words, the total amount of energy is the same at the end of a process as it was at the beginning (the conservation of energy principle or the 1^{st} law of thermodynamics).
- Armed with a more scientifically sophisticated conception of energy, the students will become more efficient consumers of energy resources.

About the Lesson
"Diminishing Returns"

Research lesson objective

The students will realize that in all energy changes, some of the energy ends up in unintended locations.

Instructional Sequence of the Unit

"Getting to understand energy is a long and gradual task,
during which the pupils' minds play with the ideas
in progressively more sophisticated ways."
(Solomon, 1992, p. 107)

Phase I (lessons 1-2)
- ✓ Students will explore and communicate their preconceptions about energy.
- ✓ Students will experience simple energy changes.

↓

Phase II (lessons 3-6)
- ✓ Students will experience more complex energy changes.
- ✓ Students will realize that when following an energy change, energy ends up in a variety of locations.
- ✓ Students will graphically represent energy the changes in energy locations before and after a process (via energy diagrams).
- ✓ Students will begin to make generalizations about energy changes.

↓

Phase III = The Research Lesson (lesson 7)
- ✓ Students will continue to experience energy changes.
- ✓ Students will realize that in all energy changes, some of the energy ends up in unintended locations.

↓

Phase IV (lessons 8-11)
- ✓ Students will refine their generalizations about energy changes.
- ✓ Students will attempt to reduce the amount energy that ends up in unintended locations by redesigning a product or process.
- ✓ Students will make a connection between improving the efficiency of their "better mousetrap" and applications of this process in their everyday lives.
- ✓ Armed with a more scientifically sophisticated conception of energy, the students will learn how to become more efficient consumers of energy resources.

↓

Phase V (lesson 12)
- ✓ As a summative assessment, the students will explain the evolution of their understanding of energy changes (based on the generalizations about energy changes refined throughout the unit).

Lesson Plan Matrix

Teacher activities & questions (w/ time estimates)	Student activities & anticipated student reactions/ responses	Teacher support & things to remember	Points to notice; methods of evaluation
1. ***Setting*** ♦ Discussion of calorimeter activity from the previous class meeting focusing on what became of the energy in the nut (or to where did the energy go?). ♦ Discuss/review why given values for calories per nut do NOT match calculated values. ♦ Discuss what energy locations were 'intended' and 'unintended' results of burning the nut. *(15 min.)*	♦ The energy in the nut began as stored chemical energy and ended up as heat, light, sound, and motion. ♦ Students should realize that not all of the energy goes to heating the H_2O and a lot of energy (calories) are lost as escaped heat (into the can, air, surroundings, etc.), light, and sound. ♦ The energy that went to heating the water was intended while all other resulting 'locations' were unintended.	♦ Heat and light should be obvious to the students. The students are also familiar with the concept of energy stored in chemical bonds and should identify this concept as well. Sound and motion should have been less obvious to them. ♦ Instructor will record answers on the board/ overhead and promote discussion about what evidence is there for student observations. ♦ Refocus/redirect if student answers are incomplete or incorrect.	♦ Are students participating in discussion? ♦ Do students provide adequate logical support for their statements? ♦ Are student answers realistic and founded in testable evidence? ♦ Were students able to determine which resulting energy locations were intended/ desired and which were unintended/ undesired?
2. ***Activity Preview*** ♦ Model energy diagram using previous lesson of calorimeter. *(10 min.)*	♦ Students should identify ✓ All energy locations/forms ✓ Which were locations of origin and which were resulting locations ✓ Which locations were intended/	♦ Appropriate energy locations include ✓ Chemical (original energy located in nut) ✓ Heat (desired energy location is in H_2O; all other heat is an	♦ Students should be ✓ Engaged in discussion ✓ Copying the modeled energy diagram ✓ Labeling all energy locations ✓ Identifying which locations are

	desired and which were unintended/ undesired resulting energy locations ✓ Relative amounts of energy in resulting locations and designate it proportionally using vectors	undesired result) ✓ Light (an undesired result) ✓ Sound (a less substantial, undesired result) ✓ Kinetic motion of the air (results in heat) ♦ Incorrect response would be stored energy (position/ potential) ♦ Teacher will model a desired example of an energy diagram for this activity.	points of origin, desired, and undesired locations ✓ Using larger vectors to represent where larger amounts of energy are transferred
3. ***Application Activity*** ♦ New systems (angel chimes, light bulb, and either a toaster, blender, food processor, hand mixer or malt maker) will be analyzed and diagramed *(50 min.)*	Students will ♦ Investigate/ analyze the three systems (angel chimes, light bulb, and household appliance) ♦ Discuss and record answers to guiding questions (see attached) ♦ Discuss and develop energy diagrams for each of the three systems	♦ The instructor will circulate the room to ensure all students are on task and to answer any relevant questions. ♦ Students who ask what to do should be directed to read the provided instructions and/or consult group members.	♦ Student participation in manipulating and discussing all three systems ♦ Student's written responses to guided questions ♦ Development of an energy diagram for each of the three systems using the model discussed in the setting (calori-meter activity)
4. ***Post Activity Discussion*** ♦ Display and discuss separately all three systems *(20 min.)*	♦ One inaccurate conclusion students may draw is that the light bulb produces more light than heat. The accurate response would be	♦ Teacher should ask students how they could be sure if their conclusions are accurate (i.e. how can they test their statements?)	♦ Students should be ✓ Actively listening ✓ Actively participating ✓ Open to discussion ✓ Able to defend statements

	that more energy is transferred to heat than it is to light.		
5. ***Evaluation—Class Demonstration*** ♦ Students will be shown a wind-up clock and asked to draw an energy diagram like the model and those practiced in the activity. *(10 min.)*	♦ Students will be allowed to discuss with their neighboring classmates ♦ Students will produce an energy diagram for the clock demo.	♦ Instructor should circulate around room to promote accurate discussion and dispel misconceptions by redirecting or posing questions while students are working on energy diagrams.	♦ Students should be able to accurately identify ✓ All energy locations/forms ✓ Which were locations of origin and which were resulting locations ✓ Which locations were intended/ desired and which were unintended/ undesired resulting energy locations ✓ Relative amounts of energy in resulting locations and designate it proportionally using vectors

Evaluation of This Lesson

Were the students able to graphically represent that during an energy change, some energy ends up in unintended locations?

References

First in the World Consortium. (1999). First in the world physics project. Retrieved October 17, 2002 from web site: http://gbn.glenbrook.k12.il.us/academics/science/lamaster/Web%20pages/Intro%20page.html

Solomon, J. (1992). *Getting to know about energy in school and in society*. London: Falmer Press.

Student handouts and instructions

Name: Date: Period:

Energy Locations of a System
Intended or Not?

The Model—The Nut Calorimeter Activity

1. What were all of the locations/evidences of energy in the Nut Calorimeter activity?

2. Which energy location(s) in this system were point(s) of origin? *(Where did the energy start?)*

3. Which resulting energy locations were desired or intended? Explain.

4. Which resulting energy locations were not desired or were unintended? Explain.

5. List all of the resulting energy locations in order from most to least amount of energy.

   Most abundant
   - ♦
   - ♦
   - ♦
   - ♦
   - ♦

   Least abundant

6. Using vectors to represent the transfer of energy, draw an energy diagram for the Nut Calorimeter activity that accounts for all energy locations, depicts relatively how much energy was transferred to each location, and identifies which energy locations were desired/intended and which were undesired/unintended. (Your instructor will model this with you)

The Activity—The Three Systems

For each of the three systems, your group should

- ✓ Observe/manipulate it as it was intended
- ✓ Record in the table below all the locations/evidences of energy in the system
- ✓ Also in the table, identify those locations/evidences that were
  - points of origin for the energy,
  - desired/intended and undesired/unintended energy locations, and
  - a ranking of energy abundance

System → / *Data ↓*	**Light Bulb**	**Angel Chimes**	**Household Appliance**
All energy locations/ evidences			
Point(s)/ locations of energy origin			
Desired/ intended resulting energy locations			
Undesired/ unintended resulting energy locations			
Relative energy abundance ranking			

- Amongst your group members, discuss what the energy diagrams for each of the above systems should look like.
- Divide and conquer! Designate each group member a system and diagram them (each member does one system = one diagram per system per group)

****NOTE: A seating chart was also included in this lesson blueprint packet, but has been omitted to protect student privacy.**

University of California, Los Angeles
Rancho Bernardo High School
LESSON STUDY RESEARCH PROJECT

Observation Guidelines

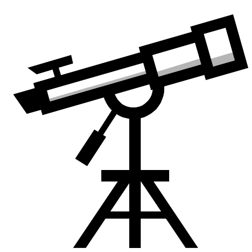
The observer's role:
To gather evidence of student learning
To collect data as directed in the lesson blueprint

Respect the natural atmosphere of the classroom

- Minimize interaction with the students. Refrain from assisting students.
- Circulate freely when students are working individually or in groups, but move to the side or back of the room during whole class discussions.
- Minimize side conversations during the lesson.
- Do not block the students' view of the board.

Become a researcher

- Focus on the lesson and the students' reaction to it, not teacher's actions. A hallmark of lesson study is to try and see the lesson from the students' point of view… to examine student thinking as opposed to analyzing the skill of the teacher.
- Draw on your experience with students, but also try to look beyond your assumptions to see with fresh eyes.
- Note how individual students construct their understanding through the lesson activities.
- Document the variety of solutions that individual students use to solve problems (including errors and misconceptions). Replicate the students' drawings and explanations in your notes.
- Record your observations directly on the lesson plan blueprint, seating chart, and handouts.
- Take notes on individual student responses noting student names.
- Assign someone to the record the time spent on different lesson parts.



Consider these questions when gathering data

- Was the goal of the lesson clear to the students and observers?
- Was the flow of the lesson coherent? Did it support student learning of the concept? Did the planned activities contribute to the goal?
- Were the students really interested? Engaged? Listening?
- Did the students understand the instruction?
- Did the classroom discussion help promote student understanding?
- Was the content of the lesson appropriate for the students' level of understanding?
- Did the teachers' questions engage and facilitate student thinking?
- Were students' ideas valued and incorporated into the lesson?
- What questions about teaching and learning did observing this lesson raise for you?

Bibliography

Chokshi, S., Ertle, B., Fernandez, C., & Yoshida, M. (2001). Lesson study protocol. Retrieved December 8, 2002, 2002 from Lesson Study Research Group Web site: http://www.tc.edu/lessonstudy/doc/Lesson_Study_Protocol.pdf

Delaware Writing Project. Guidelines for research lesson observation. Retrieved February 20, 2002, 2002 from Delaware Department of Education Web site: http://www.doe.state.de.us/englangarts/lsobserv.htm

Fernandez, C., & Chokshi, S. (2001). *Translating lesson study for a U.S. context.* Unpublished manuscript, Teachers College, Columbia University, New York.

Lewis, C. C. (2002). *Lesson study: A handbook of teacher-led instructional change*. Philadelphia: Research for Better Schools.

Yoshida, M. (2002). Lesson study guidelines for observing and debriefing the lesson. [lost original source – still seeking]

University of California, Los Angeles
Rancho Bernardo High School

LESSON STUDY RESEARCH PROJECT

Post-Lesson Discussion Guidelines

Post-lesson discussion purpose:
To deepen the participants' understanding of student thinking based on evidence gathered in the classroom

Agenda

1) Introductory information (~15 minutes)
    a. Introductions (Celeste).
    b. Review of the agenda and discussion etiquette (Celeste)
    c. Beginning with the teacher of the lesson, the lesson writing team talks about the goals of the lesson and unit; their planning process; and aspects of the lesson on which they want others to comment (Ken, Ian, Jay, Lisa & Jenn)
    d. The audience is informed of changes made between research lessons and the rationale for the changes (Jay)

2) Sharing of lesson observations
    a. *Positive comments* (~15 minutes) - Each observer, starting with the teacher of the lesson, offers one positive comment regarding the lesson.
    b. *Suggestions for improvement* (30-45 minutes) **-** Observers are invited to comment on one specific aspect of the lesson. Comments should reflect the fact that the lesson belongs to the entire writing team, not just the teacher who taught it. All comments should be grounded in actual observations from the lesson (referring to student work and discussions). This procedure continues for one or two rounds of comments.

3) General discussion (~15 minutes) – Members of the lesson writing team reflect on how the lesson study process has improved their understanding of how students think, the content matter of the lesson, and teaching in general. Other observers are invited to share their comments.

4) Final comments and thanks (<10 minutes) - A member of the writing team assimilates the post-lesson discussion into a final commentary (Lisa). Appreciation is extended to the team for their work to improve instruction (Celeste).

Appendix G
Lesson #2 blueprint

University of California, Los Angeles
Rancho Bernardo High School

LESSON STUDY RESEARCH PROJECT

Revision 12/12/02

Research Lesson Blueprint

Course: Biophysical Science

Grade: 9th

Unit: **Unraveling the Mysteries of Energy**

Lesson: **Diminishing Returns** (understanding the second law of thermodynamics)

First lesson iteration
Wednesday, December 11, 2002
Jay Hendricks, Teacher
7:35-9:00 am
1st period
Room W-8

Second lesson iteration
Thursday, December 12, 2002
Ken Ozuna, Teacher
12:02-1:42 pm
6th period
Room 407

Unit development team
Ian Campbell, Jennifer Grimm, Jay Hendricks, Ken Ozuna & Lisa Smedley

Academy teammates/lesson observers
Maureen Garland, Jane Wakeham Lopez, Kurt Trecker & Liz Winn-Willis

Background Information

The Biophysical Science & English Interdisciplinary Academy

Our academy team, comprised of four science teachers (plus one student teacher this semester) and four English teachers, serves approximately 320 randomly selected freshmen. Our students represent the full range of ability levels with the exception of the top five percent of freshmen, who are enrolled in honors science and English classes.

As with most students, our clients are motivated to learn when they see an association between the academic content and their personal interests. We meet for several hours a week during a commonly scheduled planning period to develop connections between the biophysical science and English curricula.

Our current group of students is more academically advanced than those we have served in recent years, but we still feel their ability to think critically and deeply is not highly developed. We continually strive to develop application and analysis skills in our students.

About the Unit
"Unraveling the Mysteries of Energy"

Lesson study research goal

To foster our students' ability to think critically and to apply their academic learning to their everyday lives.

Rationale for focusing on energy

While reviewing the extensive research on teaching and learning about energy, we stumbled across this quote: "Student misconceptions of energy can be a roadblock to success in all of science" (First in the World Consortium, 1999, p. 1). Initially we thought this to be a bit exaggerated, but we now agree that energy is a dominant and unifying theme in all branches of science. Most of us now realize that we skirted around the concept of energy in our previous instruction because our own understanding of energy was not as deep as it is now.

Unit objectives

- The students will construct a more scientific understanding of energy to complement their everyday, intuitive conceptions of energy.
- The students will realize that in all energy changes, some of the energy ends up in unintended locations (usually sound and heat). The trend in energy processes is for energy to dissipate and degrade (the entropy principle or the 2^{nd} law of thermodynamics).
- The students will come to understand that in all energy changes, the total amount of energy in a system does not change. In other words, the total amount of energy is the same at the end of a process as it was at the beginning (the conservation of energy principle or the 1^{st} law of thermodynamics).
- Armed with a more scientifically sophisticated conception of energy, the students will become more efficient consumers of energy resources.

About the Lesson
"Diminishing Returns"

Research lesson objective

The students will realize that in all energy changes, some of the energy ends up in unintended locations.

Instructional Sequence of the Unit

"Getting to understand energy is a long and gradual task,
during which the pupils' minds play with the ideas
in progressively more sophisticated ways."
(Solomon, 1992, p. 107)

Phase I (lessons 1-2)
- ✓ Students will explore and communicate their preconceptions about energy.
- ✓ Students will experience simple energy changes.

↓

Phase II (lessons 3-6)
- ✓ Students will experience more complex energy changes.
- ✓ Students will realize that when following an energy change, energy ends up in a variety of locations.
- ✓ Students will graphically represent energy the changes in energy locations before and after a process (via energy diagrams).
- ✓ Students will begin to make generalizations about energy changes.

↓

Phase III = The Research Lesson (lesson 7)
- ✓ Students will continue to experience energy changes.
- ✓ Students will realize that in all energy changes, some of the energy ends up in unintended locations.

↓

Phase IV (lessons 8-11)
- ✓ Students will refine their generalizations about energy changes.
- ✓ Students will attempt to reduce the amount energy that ends up in unintended locations by redesigning a product or process.
- ✓ Students will make a connection between improving the efficiency of their "better mousetrap" and applications of this process in their everyday lives.
- ✓ Armed with a more scientifically sophisticated conception of energy, the students will learn how to become more efficient consumers of energy resources.

↓

Phase V (lesson 12)
- ✓ As a summative assessment, the students will explain the evolution of their understanding of energy changes (based on the generalizations about energy changes refined throughout the unit).

Revisions Made Between Research Lessons

1) The energy transfer diagram of the calorimeter will be left on the board as a model.
2) Some of the systems used for the application activities will be changed. The second instructor will substitute a waffle iron and coffee maker for the light bulb, toaster, food processor, blender, hand mixer, and malt maker. Angel chimes will be used in both lessons.
3) Students will be provided with graphic organizers during the application activity with the intention of reducing the time spent drawing the set-ups, thus leaving more time for discussion of the concepts.
4) The handouts will be re-phrased to match the vocabulary and energy transfer diagram formats used by the second instructor.
5) The students will defend their energy transfer diagrams to the class (rather than the instructor interpreting the diagrams for the class).
6) Jiffy Pop popcorn will be substituted for the wind-up clock during the evaluation/class demonstration.

Lesson Plan Matrix

Teacher activities & questions (w/ time estimates)	Student activities & anticipated student reactions/ responses	Teacher support & things to remember	Points to notice; methods of evaluation
1. ***Setting*** ♦ Discussion of calorimeter activity from the previous class meeting focusing on what became of the energy in the nut (or to where did the energy go?). ♦ Discuss/review why given values for calories per nut do NOT match calculated values. ♦ Discuss what energy locations were 'intended' and 'unintended' results of burning the nut.	♦ The energy in the nut began as stored chemical energy and ended up as heat, light, sound, and motion. ♦ Students should realize that not all of the energy goes to heating the H_2O and a lot of energy (calories) are lost as escaped heat (into the can, air, surroundings, etc.), light, and sound. ♦ The energy that went to heating the water was intended while all	♦ Heat and light should be obvious to the students. The students are also familiar with the concept of energy stored in chemical bonds and should identify this concept as well. Sound and motion should have been less obvious to them. ♦ Instructor will record answers on the board/ overhead and promote discussion about what evidence is	♦ Are students participating in discussion? ♦ Do students provide adequate logical support for their statements? ♦ Are student answers realistic and founded in testable evidence? ♦ Were students able to determine which resulting energy locations were intended/ desired and which were unintended/ undesired?

	other resulting 'locations' were unintended.	there for student observations. ♦ Refocus/redirect if student answers are incomplete or incorrect.	
2. ***Activity Preview*** ♦ Model energy diagram using previous lesson of calorimeter. Leave diagram on the board for students to refer to in application activities.	♦ Students should identify ✓ All energy locations/forms ✓ Which were locations of origin and which were resulting locations ✓ Which locations were intended/ desired and which were unintended/ undesired resulting energy locations ✓ Relative amounts of energy in resulting locations and designate it proportionally using vectors	♦ Appropriate energy locations include ✓ Chemical (original energy located in nut) ✓ Heat (desired energy location is in H_2O; all other heat is an undesired result) ✓ Light (an undesired result) ✓ Sound (a less substantial, undesired result) ✓ Kinetic motion of the air (results in heat) ♦ Incorrect response would be stored energy (position/ potential) ♦ Teacher will model a desired example of an energy diagram for this activity.	♦ Students should be ✓ Engaged in discussion ✓ Copying the modeled energy diagram ✓ Labeling all energy locations ✓ Identifying which locations are points of origin, desired, and undesired locations ✓ Using larger vectors to represent where larger amounts of energy are transferred
3. ***Application Activity*** ♦ New systems (angel chimes, waffle iron and coffee maker) will be analyzed and diagramed. ♦ Graphic organizers will be distributed.	Students will ♦ Investigate/ analyze the three systems (angel chimes, waffle iron and coffee maker) ♦ Discuss and record answers to guiding questions	♦ The instructor will circulate the room to ensure all students are on task and to answer any relevant questions. ♦ Students who ask what to do should	♦ Student participation in manipulating and discussing all three systems ♦ Student's written responses to guided questions ♦ Development of

	(see attached) ♦ Discuss and develop energy diagrams for each of the three systems.	be directed to read the provided instructions and/or consult group members.	an energy diagram for each of the three systems using the model discussed in the setting (calori-meter activity)
4. ***Post Activity Discussion*** ♦ Students will display and defend their energy diagrams of each system to the class.	♦ One inaccurate conclusion students may draw is that the energy input is less than the energy output.	♦ Teacher should ask students how they could be sure if their conclusions are accurate (i.e. how can they test their statements?)	♦ Students should be ✓ Actively listening ✓ Actively participating ✓ Open to discussion ✓ Able to defend statements
5. ***Evaluation—Class Demonstration*** ♦ Students will be shown Jiffy Pop popcorn popping and asked to draw an energy diagram like the model and those practiced in the activity.	♦ Students will be allowed to discuss with their neighboring classmates. ♦ Students will produce an energy diagram for the demo.	♦ Instructor should circulate around room to promote accurate discussion and dispel misconceptions by redirecting or posing questions while students are working on energy diagrams.	♦ Students should be able to accurately identify ✓ All energy locations/forms ✓ Which were locations of origin and which were resulting locations ✓ Which locations were intended/ desired and which were unintended/ undesired resulting energy locations ✓ Relative amounts of energy in resulting locations and designate it proportionally using vectors

Evaluation of This Lesson

Were the students able to graphically represent that during an energy change, some energy ends up in unintended locations?

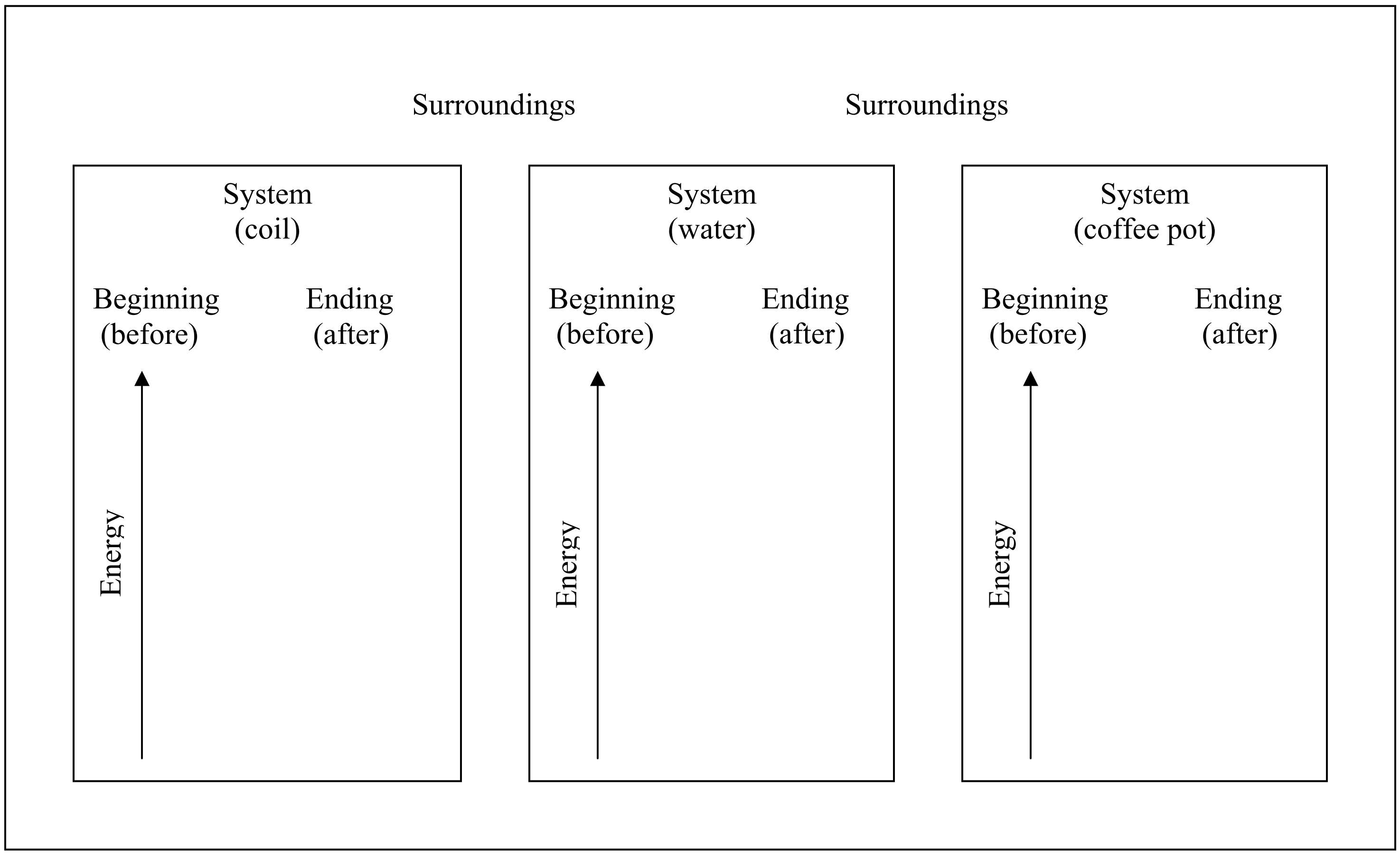
References

First in the World Consortium. (1999). First in the world physics project. Retrieved October 17, 2002 from web site: http://gbn.glenbrook.k12.il.us/academics/science/lamaster/Web%20pages/Intro%20page.html

Solomon, J. (1992). *Getting to know about energy in school and in society*. London: Falmer Press.

Coffee Maker

Universe



Energy Transfer Diagram
Questions

1. What is the intended purpose of the energy within the systems? (Hint: In a toaster the intended purpose of the energy among the systems is to toast bread)

2. How many energy transfers are there among the systems?

3. As energy transfers from one system to another system, where does some of the energy go? Explain.

4. Is it possible to completely transfer all the energy from one system to another system? Explain.

****NOTE: A seating chart was also included in this lesson blueprint packet, but has been omitted to protect student privacy.**

Time allocation per task

Task	*Our meeting time allocated to each task*	*Lewis' Recommend-ations*	*Your recommend-ations for an EXPERIENCED team*	*Notes*
Selection of long-range goal	1.75 hours	2-6 hours		
Selection of unit goal(s)	.5 hour			
Research review	2.25 hours	Lumps research and planning 6-12 hours		
Study of existing lessons				
Study of subject matter				
Planning of lesson/unit	6.75 hours			
Teaching/observing 1st lesson	1.75 hours			
1st debrief and lesson revision	1.5 hours	4-6 hours		
Teaching/observing 2nd lesson	1.75 hours			
2nd debrief and revision	1.5 hours	4-6 hours		
Reflect on learnings from process	1.0 hours			
TOTAL TIME	18.75 hours	16-30 hours		

Group reflection protocol

- Let's talk about the **time** factor, which is clearly the biggest challenge for implementing lesson study:
    - Most experts recommend 2-hour meetings once a week? What do you think would be an effective meeting length? What about the interval between meetings?
    - Now that you know what you are doing, how much time do you think should be spent on each task?
    - Lesson study researchers recommend teams participate in 2-3 cycles per year that last approximately 3-4 weeks. Teams that are new to lesson study would obviously need more time to learn about the lesson study process itself. What do you think is realistic and workable regarding the number of cycles per year and the length of time per cycle?
- Aside from time, what are the most noteworthy **challenges** that were encountered during this process?
- Let's talk about the role of a **facilitator** or coach with lesson study knowledge.
    - How important is this function for a novice lesson study team?
    - What support should this person provide?
    - What about for an experienced lesson study team?

[NOTE: the team did not respond to the remaining prompts due to a lack of time]

- For you to be willing to engage in subsequent lesson study cycles, what **supports and conditions** would have to be in place? (Remember – you wouldn't be starting from scratch so some steps will take significantly less time and you wouldn't be participating in a research project). What is a realistic model for sustained implementation in your school setting?
- Most education reforms fail because only their superficial features are implemented while their underlying essence is lost. Many groups throughout the country claim to be engaged in lesson study when they are merely meeting together to plan lessons, which they later distribute to others. What do you believe is the **essence** of LS that must be maintained?
- Respond to these statements
    - ♦ Lesson study is not so much about lesson planning as it is about **watching students learn**.
    - ♦ The main challenge to implementing lesson study in US high schools will be **striking a balance** between keeping the **essential elements** of lesson study intact, such as peer observation and data collection during live lessons, and adapting the model to fit the **reality** of US schools.
    - ♦ The yardstick for measuring the worth of a research lesson is **how much teachers learned** as they planned, conducted, and discussed the lesson, and whether this learning will **improve their future instruction**.

University of California, Los Angeles
Rancho Bernardo High School
LESSON STUDY RESEARCH PROJECT

Individual Reflection Statement

The final team report will include the group's reflections that I will extract from the conversation we just had. The report will also include individual reflections for each of you. Below is a list of prompts. Please ***compose a <u>narrative</u>*** *that addresses these topics. Don't feel like you have to respond to the questions one-by-one.*

Audience: *Your team's final lesson study report is likely to be read by at least 100 educators across the country. The primary audience will be* ***teachers who are thinking about engaging in lesson study****. Other lesson study "pioneers" will also be interested in your experience, as will university researchers.*

- What are your most vivid impressions from the process? What component/phase of the lesson study process has been the most meaningful/worthwhile?
- What were the biggest challenges or obstacles you encountered in this process?
- What are your most important learnings about the academic content, instructional practice or techniques, and student learning? What specific ideas will you take back to your classroom?
- How did your participation in this process lead you to think in new ways about your everyday practice?
- How do you think your participation in this lesson study process is going to benefit your students?
- Feel free to add anything else you wish.