Item Name:	Designing Energy Efficient Vehicles
Item Type:	Curriculum-Embedded
Subject and/or Course:	Science, Physics, Grade 11-12
Common Core Standards:	**CCSS** CCSS.ELA-Literacy.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts… CCSS.ELA-Literacy.RST.11-12.2 Determine the central ideas or conclusions… CCSS.ELA-Literacy.RST.11-12.7 Integrate and evaluate multiple sources… CCSS.ELA-Literacy.WHST.11-12.1a Introduce precise, knowledgeable claim(s), establish the significance of the claim(s)… CCSS.ELA-Literacy.WHST.11-12.4 Produce clear and coherent writing… CCSS.ELA-Literacy.WHST.11-12.5 Develop and strengthen writing… **NGSS:** Secondary to HS-ESS3-2, secondary to HS-ESS3-4 When evaluating solutions, it is important to take into account a range of constraints… HS-ESS3-3 The sustainability of human societies and the biodiversity… HS-ESS3-4 Scientists and engineers can make major contributions… HS-ESS3-3 New technologies can have deep impacts on society…. HS-LS3-2 Make and defend a claim based on evidence... HS-LS2-6 Evaluate the claims, evidence, and reasoning… MS-ESS1-6 Apply scientific reasoning to link evidence to the claims…
Developer/Source:	Dr. Susan E. Schultz and Ohio Performance Assessment Project (OPAP) Science Teachers Stanford Center for Assessment, Learning, and Equity (SCALE) Modified for the Innovation Lab Network (ILN) Performance Task Bank
Item Features:	Administration: Curriculum-embedded Length of time for response: 2-3 weeks Method of scoring: Analytic rubric (SCALE Scientific Practices Rubric) Opportunity for student collaboration: Daily Opportunity for teacher feedback and revision: Limited

Collection of performance assessment items compiled by

SCALE
Stanford Center for Assessment, Learning, & Equity

Subject area/course: Science, Physics

Grade level/band: 11–12

Task source: Stanford Center for Assessment, Learning, and Equity (SCALE)

Designing Energy Efficient Vehicles

STUDENT INSTRUCTIONS

A. Task context

It may be hard for us to imagine, but if we continue to consume oil and natural gas at the current rate, the earth's entire accessible source for these resources will be depleted in another 10-12 years! To avoid this, we have to find ways to conserve our use of these resources by decreasing energy consumption and making products more energy efficient. Cars and trucks are responsible for nearly 90% of the energy consumed for travel in the United States. So one method for significantly reducing transportation energy consumption is to make our vehicles more energy efficient.

Your Task

You are an intern in the engineering department of the American Auto Industry (AAI). As a member of the engineering design team, you need to design a more energy efficient vehicle. Your team will need to research and define the term "energy efficient" before beginning any design. Based on your research, your team will design, build, and experimentally test your vehicle. After analyzing the initial data of your vehicle's performance, your team will re-design, re-build, and re-test an "improved" version of your vehicle. Your team will use the experimental findings to make recommendations to the AAI.

B. Final product

For this task you will need to work collaboratively with a team of students to:

- Research and share what you have learned about energy efficiency in existing cars or trucks.
- Design, build, and test your vehicle to determine which factor(s) affect the energy efficiency.
- Re-design, re-build, and re-test your improved vehicle.
- Make an oral presentation to the AAI panel to share your improved vehicle, experimental procedures, analysis, and findings (see oral presentation criteria).

Individually you will:

- Write a formal lab report that clearly explains the original and improved designs of your vehicle, procedures for testing the vehicles, analysis, and findings of your experiment (see lab criteria).
- Reflect and share what you learned from this task.

ANSWERS TO SOME QUESTIONS YOU MIGHT HAVE

C. What do I need to know or do to be successful on this task?

1. **On this task, you will show that you know these things:**
   - Identify the factors affecting the energy efficiency of vehicles currently on the market.
   - Apply your knowledge of Newton's Laws of Motion, velocity, and acceleration.

2. **On this task, you will show that you are able to do these things:**
   - Measure your vehicle's energy efficiency and apply scientific principles and evidence to solve design problems, as well as possible unanticipated effects, to revise your vehicle design.
   - Generate a testable question, make a hypothesis, design and build a vehicle, create procedures that can be replicated by another person to test your vehicle, gather and represent the data, and use calculations to determine the energy efficiency of your vehicle.
   - Redesign, rebuild, and retest your vehicle's performance based on your findings.
   - After testing your improved vehicle, you will also represent the data, analyze the information, construct an explanation using evidence from your experiments, and prepare an oral presentation of your findings.
   - Synthesize and evaluate your experimental evidence to make recommendations for designing more energy efficient vehicles.
   - Provide constructive feedback to your peers on their draft lab reports and take into consideration feedback they provide you.
   - Prepare a lab report that details your findings and recommendations and correctly cite your sources.
   - Communicate your recommendations to the AAI panel clearly, creatively, and effectively using evidence to support your conclusions in a way that will engage the audience.

D. What materials will I need to complete this task?

You will need access to the Internet for research. To design and build your vehicles you will have access to a variety of vehicle choices, including Mousetrap Racer, Rubber Band Powered Car, CO_2 Car Kit, Solar Powered Car, Electric Car, Wind/Fan Car, Wind-Up Toys, Pull Back Car, or another type with your teacher's approval. If you need any equipment or materials not normally in your classroom, please ask your teacher if these items can be made available. Your teacher will supply the "track" for testing your vehicles. You will also need access to presentation software or poster- making materials for your oral presentation.

E. How long will I have to complete this task?

Your teacher will provide the due dates for completing each portion of the task.

Due Date	What You Need To Do	Product
	Research and define the term "energy efficient"	Lab Report
	Design and build an energy efficient vehicle	
	Test the performance of your vehicle	
	Analyze and interpret your findings	
	Design, revise, and retest an "improved" vehicle	
	Compare and contrast the performance of the "initial version" with the "improved version" of the vehicle (including calculations)	
	Draw your conclusions	
	Get feedback on your draft lab report	
	Prepare a final report with a list of recommendations for the NAI	
	Group Presentation	Oral Presentation
	Reflect on learning	Essay

F. How will my work be scored?

Your work will be scored using the Scientific Practices Rubric (9–12) and the Effective Communication Oral Presentation Rubric. You should make sure you are familiar with the language that describes the expectations for proficient performance.

Subject area/course: Science, Physics

Grade level/band: 11–12

Task source: Stanford Center for Assessment, Learning, and Equity (SCALE)

Designing Energy Efficient Vehicles

TEACHER'S GUIDE

A. Task overview:

Student teams will research and define the term "energy efficient". Based on their research, teams will design and build a vehicle. Then they will experimentally test the vehicle's efficiency. After analyzing the initial data of the vehicle's performance, teams will re-design, build, and test an "improved" version of their vehicle. Teams will use the experimental findings to make recommendations to the American Auto Industry (AAI) for releasing a new fleet of energy efficient vehicles in 2015.

B. Aligned standards:

1. **Common Core State Standards**

   CCSS.ELA-Literacy.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

   CCSS.ELA-Literacy.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

   CCSS.ELA-Literacy.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

   CCSS.ELA-Literacy.WHST.11-12.1a Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

CCSS.ELA-Literacy.WHST.11-12.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CCSS.ELA-Literacy.WHST.11-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

2. **Critical abilities**

Research: Conduct sustained research projects to answer a question (including a self-generated question) or solve a problem, narrow or broaden the inquiry when appropriate, and demonstrate understanding of the subject under investigation. Gather relevant information from multiple authoritative print and digital sources, use advanced searches effectively, and assess the strengths and limitations of each source in terms of the specific task, purpose, and audience.

Analysis of Information: Integrate and synthesize multiple sources of information (e.g., texts, experiments, simulations) presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to address a question, make informed decisions, understand a process, phenomenon, or concept, and solve problems while evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Experimentation and Evaluation: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. Evaluate hypotheses, data, analysis, and conclusions, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Communication in Many Forms: Use oral and written communication skills to learn, evaluate, and express ideas for a range of tasks, purposes, and audiences. Develop and strengthen writing as needed by planning, revising, editing, and rewriting while considering the audience.

Use of Technology: Present information, findings, and supporting evidence, making strategic use of digital media and visual displays to enhance understanding. Use technology, including the Internet, to research, produce, publish, and update individual or shared products in response to ongoing feedback, including new arguments or information.

Interpersonal Interaction and Collaboration: Develop a range of interpersonal skills, including the ability to work with others, to participate effectively in a range of conversations and collaborations.

Modeling, Design, and Problem Solving: Use quantitative reasoning to solve problems arising in everyday life, society, and the workplace, e.g., to plan a school event or analyze a problem in the community, to solve a design problem or to examine relationships among quantities of interest. Plan solution pathways, monitoring and evaluating progress and changing course if necessary, and find relevant external resources, such as experimental and modeling tools, to solve problems. Interpret and evaluate results in the context of the situation and improve the model or design as needed.

3. **Next Generation Science Standards**

Secondary to HS-ESS3-2, secondary to HS-ESS3-4. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

HS-ESS3-3. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

HS-ESS3-4. Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

HS-ESS3- 3. New technologies can have deep impacts on society and the environment, including some that were not anticipated.

HS-LS3-2. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.

HS-LS2-6. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

MS-ESS1-6. Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

C. Time/schedule requirements:

The following schedule is an estimate of the number of school days required for students to complete this task. Time requirements will vary based on grade level, schedule constraints, class size, class length, and academic readiness.

Day	What Students Need To Do	Product
Day 1	Intro: Get familiar with the task requirements, expectations, and due dates	
Day 1	Part 1: Research and define the term "energy efficient"	Lab Report
Days 2 - 8	Part 2: Design and build an energy efficient vehicle	
	Part 3: Plan your investigation	
	Part 4: Test the performance of your vehicle	
	Part 5: Analyze and interpret your findings	
	Part 6: Modify (or re-build) and retest an "improved" vehicle	
	Part 7: Compare and contrast the performance of the "initial version" with the "improved version" of the vehicle (including calculations)	
	Part 8: Draw your conclusions	
Day 9	Part 9: Write a draft lab report with a list of recommendations for the AAI	
Day 10	Part 10: Get feedback on your draft lab report	
Day 12	Part 11: Final report due	
Day 14	Part 12: Group Presentation	Oral Presentation
Day 15	Reflect on learning	Essay

D. Materials/resources:

Students will need:

- Access to the Internet for research
- Copies of the lab criteria and oral presentation criteria
- Presentation software or poster-making materials
- Access to a variety of vehicle choices such as Mousetrap Racer, Rubber Band Powered Car, CO_2 Car Kit, Solar Powered Car, Electric Car, Wind/Fan Car, Wind-Up Toys, Pull Back Car, or another type with your approval
- A "track" for testing their vehicles

- Tools such as coping saws, pliers, scissors, hot-melt glue gun and glue, rulers, drill and bits, utility knife, etc.
- Materials for construction of the vehicles. Typical materials for cardboard vehicles with rubber band "motors" might include: several types of cardboard, several types of plastic drinking straws, metal wire and metal clothes hangers, craft (popsicle) sticks, many types of tape, several sizes of wooden dowel rods, several sizes of wooden craft wheels, various metal washers, metal can lids, old CDs, rubber bands, etc.

E. Prior knowledge:

Students will need to:

- Understand the concepts of motion, forces, and energy
- Be familiar with design and building skills

Students may have prior misconceptions. For example, they may think that:

- The principles and engineering that affect efficiency of the student models that are built in this task directly transfer to the production of real-world vehicles
- The term "efficiency" means the same when regular people describe vehicles and when physicists describe scientific systems
- Vehicles in this task and in the real world extract most of the energy from the power source
- The conservation of energy does not apply to these systems since we cannot account for the energy at the end

F. Connection to curriculum:

This performance assessment could be used as a culminating activity for a unit on motion or energy in a physics or physical science course.

G. Teacher instructions:

Below is a comprehensive list of *suggested* ways to facilitate, organize, and scaffold student work, based on pilot implementation conducted by SCALE in real classrooms. You will, of course, need to choose which ideas meet the needs of your students, their previous experience with open-ended projects, and practicalities of your classroom/school, and adapt them accordingly.

You'll notice that throughout we have tried to provide students with opportunities to make choices and take the lead in decision-making to complete the task. In this same vein, we encourage the use of peer-review and revision.

<u>Possible Engagement Activities (The Hook)</u>

Getting started:

- Ask students to investigate TV videos, Internet ads or print advertising for automobiles that are marketed as environmentally friendly or economical. Have them focus on the types of features that are cited that supposedly provide the vehicle with its fuel economy.
- Allow students to choose a favorite or interesting vehicle to research. Gather data on properties of the vehicle, but also note the characteristics that the car company touts as contributing to the efficiency of the vehicle. Try to establish if the properties might affect efficiency, or if it is strictly a sales pitch.
- Lead a student discussion as to which vehicle is more efficient: a school bus with 50 passengers or a Toyota Prius with 4 passengers. Have students think of efficiency in terms of the amount of energy (fuel) used to move each passenger a certain distance. Compare this definition of efficiency to the more standard physics concept of the percentage of energy that is transformed or extracted from a source.
- As the finite amount of fossil fuels is consumed, there are some different options. Ask students to consider the pros and cons of the following:
    - Reduce the use of fuels which will greatly affect our way of life
    - Convert to other sources of energy such as solar, biofuels, nuclear, etc.
    - Extend the life expectancy of fossil fuels by using them more efficiently

Introduce the Task

- After the introductory activity, review the task description and respond to any student questions.
- Suggest students design a template to be used to collect information and record references at the time data is being collected.
- Tell students that personal reflections should be written in a journal/log throughout the project.

Review Expectations

- Review the due dates/task timeline.
- Review expectations for working together in a group – the roles students should take on and the norms for behavior (for more details, see "Student Support" section).
- Allow students time to look at the assessment rubric(s). Clarify the criteria and respond to student questions.
- Explain that, as they work in their groups, they will be responsible for gathering information and making their own decisions. As the teacher, you will provide help/resources only when everyone in the group agrees that they need help or if there is information they can't find themselves.

Part 1: Research and define energy efficient (Team Activity)

Students will research and share what they have learned about the term “energy efficient,” including:

- Energy efficiency for vehicles is defined in terms of the linear distance traveled using the energy stored in one rubber band, one mousetrap spring, or one CO2 canister.
- Compare this definition of energy efficiency to the definition of efficiency commonly used by physicists.
- Explore if our definition of efficiency is reasonable and what (if any) modifications might be beneficial.
- Identify the variable they will include in the design of their vehicle and explain how they think changing this variable will help them make a more energy efficient vehicle.

Individual Task: Students will need to summarize what they have learned from the research gathered by their team, refer to the lab criteria, and write a content specific introduction for their lab report.

Part 2: Design and build an energy efficient vehicle (Team Activity)

Vehicle choices include Mousetrap Racer, Rubber Band Powered Car, CO_2 Car Kit, Solar Powered Car, Electric Car, Wind/Fan Car, Wind-Up Toys, Pull Back Car or another type with your approval. Students will need to use the team’s knowledge about the factors affecting energy efficiency:

- Brainstorm the design features of their vehicle
- Make a drawing of their vehicle labeling all the parts and a list of materials needed to construct the vehicle
- Write a description of a vehicle explaining the features of the vehicle and a rationale for why this will make a more energy efficient vehicle
- Explain the connections between their vehicle design and Newton’s Laws of Motion
- Review their drawing and rationale with their teacher for approval
- Build their vehicle and record any modifications that they make during the construction process
- Draw a picture or take a photograph of their vehicle

Individual Task: Students will need to write a summary of the design features for their vehicle and the rationale for why these features will produce a more energy efficient vehicle. Remind them to refer to the lab criteria.

Part 3: Plan their investigation (Team Activity)

Students should plan how they are going to determine the energy efficiency of their vehicle. They should refer to Lab Report Criteria when planning and writing their plan.

Individual Task: Students will need to record the procedures used to test their vehicle.

Note: Testing performance should be a measure of the distance the vehicle travels on a horizontal surface (carpet, gym floor, classroom tile, etc.) or on a "track", along with collecting some information on the motion of the vehicle during the horizontal run (time/displacement data). This additional data will be necessary in order to describe and analyze the motion of the vehicle.

Part 4: Test the performance of the vehicle (Team Activity)

While conducting the experiment, students should take notes and record data. They should measure, calculate, and/or estimate an adequate number of the following characteristics of the vehicle so they can describe its performance when completing the course:

- Mass of the car
- Static friction
- Rolling or dynamic friction
- Average speed of the vehicle while completing the run on the course
- Final speed
- Typical acceleration during the first section (first meter, first quarter, etc.) of the run
- Amount of energy that can be stored or extracted from the vehicle's "power" source

Individual Task: Students will gather all data from testing the performance of their vehicle and refer to the lab criteria when writing this portion of their lab report.

Note: Descriptions of the vehicle's motion (speeds, accelerations, forces, etc.) may be established using any available tools (tape timers, ultrasonic range finder, photo-gates, stopwatches & tapes, etc.). The major emphasis here is to use physics tools to describe the motions and forces involved with a "real" vehicle. Obviously, as with any measurement, there will be a degree of error inherent to the attempt. Getting students to recognize the likely amount and source of the errors is important to this task.

Part 5: Analyze and interpret findings (Team Activity)

This is an essential part of the investigation. Students need to carefully examine the data they have collected and determine what they can say about the results of the investigation based on the evidence. Once again, students should refer to the lab criteria.

Individual Task: Students will need to write the analysis and interpretation section of their lab report.

Part 6: Redesign, modify (or re-build), and test the performance of an "improved" vehicle (Team Activity)

Based on the performance and analysis of the data of their initial vehicle, students should:

- Select ONE feature to improve the performance of their vehicle
- Redesign their vehicle to try to improve the vehicle's performance
- Build the "improved" version of their vehicle
- Clearly identify all of the variables to be studied (independent and dependent variables including controls if applicable)
- Using the same course and methods, repeat their investigation to test their "improved" vehicle
- Be consistent in their methods in order to make a "fair" comparison

Individual Task: Students will write a summary of the re-design features of their "improved" vehicle and the rationale for why these features will produce a more energy efficient vehicle. Include these items in the materials and procedural sections of their lab report.

Part 7: Compare and contrast the performance of the two versions (Team Activity)

Students will compare and contrast the data from their initial and "improved" vehicles and include their analysis in their lab report.

Individual Task: Students will include this analysis in their lab report.

Part 8: Draw conclusions (Team Activity)

Students will review their analysis and interpretations of the data and write the conclusion section of the lab report.

Individual Task: Students write the findings and address limitations in this section of the lab report.

Parts 9 - 11: Prepare draft and final lab reports (Individual Activity)

Students should:

- Get peer and/or teacher feedback on the draft
- Revise and submit a final lab report

Part 12: Present findings (Team Activity)

Students will make an oral presentation using visuals (PowerPoint or poster) to the American Automobile Industry. They will share the design and experimental findings of their vehicle and provide recommendations on how to improve the energy efficiency of vehicles. When preparing their presentation, students should refer to the Oral Presentation Criteria.

H. Student support:

Planning for Group Interaction

Student grouping can vary, but group sizes of 2 or 3 for teams seemed to work well. It may help group dynamics to assign students to specific roles (i.e., facilitator, materials manager, reporter, recorder, etc.) in order to promote student learning and/or utilize student skills. No matter what the team size, it is critical that each team keeps detailed records, and thus there must be at least one recorder for each team. As a classroom norm, encourage students to share their ideas, make a plan, and encourage all students to participate in the investigation.

This task is likely not the first group activity. Yet, students need to be aware of the parallel nature of team and individual activities. You should make sure that students recognize that team research, experimentation, discussion, planning, and documentation are the jointly assembled basis for each student's individual final report and possible presentation.

I. Extensions or variations:

There is a significant difference between the factors that make for an efficient vehicle in this task and those that matter for real world efficient vehicles. You may want to have students provide suggestions to the National Physics Teachers' Vehicle Committee so students would recognize the many shortcoming of this model if upgraded to the real world.

J. Scoring instructions:

This task is accompanied by two corresponding rubrics to be used to score your students' work. Training for utilizing the rubrics to score the student responses will be provided through a webinar, and information about where you can access that training will be provided to you. It is important that you use the specified rubrics according to the instructions provided in the webinar. If you have questions during the scoring process, you should feel free to contact your Point of Contact from the research team.

This task will be scored using the Scientific Practices Rubric (9–12) and the Effective Communication Oral Presentation Rubric.

SCIENTIFIC PRACTICES RUBRIC

INITIATING THE INQUIRY
What is the evidence that the student can formulate questions and models that can be explored by scientific investigations as well as articulate a testable hypothesis?

SCORING DOMAIN	EMERGING	E/D	DEVELOPING	D/P	PROFICIENT	P/A	ADVANCED
ASKING QUESTIONS	• Formulates a general scientific question • Provides limited or irrelevant content information		• Formulates a specific scientific question • Provides general content information that is related to the question		• Formulates a specific and empirically testable scientific question • Provides specific and relevant content information to lend support for the question		• Formulates a specific, testable, and challenging scientific question • Provides specific and relevant content information to provide insight into the inquiry
DEVELOPING AND USING MODELS	• Drawings, diagrams, or models relevant to the investigation includes major conceptual or factual errors, or are missing • Discussion on limitations or precision of model as a representation of the system or process is flawed or missing		• Constructs generally accurate drawings, diagrams, or models to represent the process or system to be investigated • Makes note of limitations or precision of model as a representation of the system or process		• Constructs accurate drawings, diagrams, or models to represent the process or system to be investigated • Explains limitations and precision of model as a representation of the system or process		• Constructs accurate and precise drawings, diagrams, or models to represent the process or system to be investigated and provides an explanation of the representation • Explains limitations and precision of model as a representation of the system or process and discusses how the model might be improved
STATING A HYPOTHESIS	• Articulates a prediction that has limited relationship to the question under investigation		• Articulates a relevant prediction of the expected results, but variables are unclearly stated		• Articulates a hypothesis about the investigated question, with a basic and accurate description of the variables ("if.. then…")		• Articulates a hypothesis about the investigated question, with accurate and specific explanation of the relationship between variables ("if.. then…because")

PLANNING AND CARRYING OUT INVESTIGATIONS
What is the evidence that the student can design and perform investigations to explore natural phenomena?

SCORING DOMAIN	EMERGING	E/D	DEVELOPING	D/P	PROFICIENT	P/A	ADVANCED
DESIGNING THE INVESTIGATION	• Experimental design is not aligned to the testable question • Discussion of how the model can guide or inform the design or an aspect of the design is missing		• Experimental design is related but not explicitly aligned to testable question • States in general terms how model was used to guide, inform, or test the design or an aspect of the design		• Aligns experimental design with testable question • Explains how model was used to guide, inform, or test the design, or an aspect of the design		• Explains the alignment between the experimental design and the testable question • Explains how model was used to guide, inform, or test the design, or an aspect of the design
IDENTIFYING VARIABLES	• Identifies variables of investigation but confuses dependent and independent variables • Makes no connection between the plan and variables		• Accurately identifies the relevant independent and dependent variables • States how the plan will control relevant independent OR dependent variables		• Accurately identifies and explains why the variables are dependent and independent in the investigation • Explains how the plan will control relevant independent AND dependent variables		• Accurately identifies and explains why the variables are dependent and independent in the investigation and identifies possible confounding variables and effects and tries to control for them • Explains how the plan will control relevant independent and dependent variables, and the possible confounding variables or effects
DEVELOPING PROCEDURES	• Includes vague or incomplete lab procedures; or uses inappropriate tools, instruments, or types of measurement • Amount of data to be collected is omitted		• Describes lab procedures including tools/ instruments used, but is not clear or detailed enough to be replicated • States the amount of data to be collected with no rationale		• Describes detailed, clear, and replicable lab procedures including tools /instruments and types of measurements gathered • Provides a rationale for the appropriate amount of data needed to produce reliable measurements		• Describes detailed, clear, and replicable lab procedures including rationale for using the tools /instruments and types of measurements gathered • Provides a rationale for the appropriate amount of data needed to produce reliable measurements
COLLECTING DATA	• Gathers data from a single trial of the experiment • Limitations or precision of data are not mentioned		• Gathers data from several repetitions of the experiment that are clearly outside the reasonable range • Mentions limitation or precision of data		• Gathers data from several repetitions of the experiment that are not consistent within a reasonable range • Explains limitation or precision of data		• Gathers data from several repetitions of the experiment that are consistent within a reasonable range • Explains limitation or precision of data and impact on conclusions

REPRESENTING, ANALYZING, AND INTERPRETING THE DATA

What is the evidence that the student can organize, analyze, and interpret the data?

SCORING DOMAIN	EMERGING	E/D	DEVELOPING	D/P	PROFICIENT	P/A	ADVANCED
REPRESENTING THE DATA *Accurately labeled includes title, column titles, description of units, proper intervals.*	• Uses spreadsheets, data tables, charts, or graphs but does not accurately summarize and/or display data • Constructs spreadsheets, data tables, charts, or graphs with major omissions or errors		• Uses spreadsheets, data tables, charts, or graphs to accurately summarize and display data; format does not allow for examining the relationships between variables • Constructs spreadsheets, data tables, charts, or graphs with minor errors (e.g., missing labels)		• Uses spreadsheets, data tables, charts, or graphs to accurately summarize and display data to examine relationships between variables • Constructs accurately labeled and appropriately organized spreadsheets, data tables, charts, or graphs		• Uses multiple methods (spreadsheets, data tables, charts, graphs) to accurately summarize and display data to examine relationships between variables • Constructs accurately labeled and expertly organized spreadsheets, data tables, charts, or graphs
USING MATHEMATICS AND COMPUTATION-AL THINKING	• Expresses relationships and quantities (units) using mathematical conventions with major errors • Evaluation of whether the mathematical computation results "make sense" is omitted		• Expresses relationships and quantities (units) using mathematical conventions with minor errors • Makes note of whether the mathematical computation results "makes sense" without reference to the expected outcome		• Accurately expresses relationships and quantities (units) using appropriate mathematical conventions • Explains whether the mathematical/computation results "make sense" in relationship to the expected outcome		• Accurately and consistently expresses relationships and quantities (units) using appropriate mathematical conventions • Consistently evaluates whether the mathematical/computation results "make sense" in relationship to the expected outcome
ANALYZING THE DATA	• Analyzes data using inappropriate methods or with major errors or omissions • Consistency of outcome with initial hypothesis is not compared		• Accurately analyzes data using appropriate methods with minor omissions • Compares consistency of outcome with initial hypothesis		• Accurately analyzes data in using appropriate and systematic methods to identify patterns • Compares consistency of outcome with initial hypothesis and identifies possible sources of error		• Accurately analyzes data in using appropriate and systematic methods to identify and explain patterns • Compares and explains consistency of outcome with initial hypothesis, and explains possible sources of error and impact of errors
GENERATING INTREPRETA-TIONS	• Inferences drawn from data are absent • Makes no mention of variables needing further investigation		• Draws inferences from data without discussing strengths or weaknesses • Makes note of variables that need further investigation		• Explains the strengths OR weaknesses of the inferences drawn from data using grade appropriate techniques • Suggests relationships or interactions between variables worth further investigation		• Explains the strengths AND weaknesses of the inferences drawn from data using grade appropriate techniques • Suggests relationships or interactions between variables worth further investigation and poses new analysis

CONSTRUCTING EVIDENCE-BASED ARGUMENTS AND COMMUNICATING CONCLUSIONS

What is the evidence that the student can articulate evidence-based explanations and effectively communicate conclusions?

SCORING DOMAIN	EMERGING	E/D	DEVELOPING	D/P	PROFICIENT	P/A	ADVANCED
CONSTRUCTING EVIDENCE-BASED ARGUMENTS	• Argument is missing or unclear; supporting data or scientific theory are missing • Counterclaim (possible weaknesses in scientific arguments or in their own argument) is missing		• Constructs a scientific argument and mentions data OR acceptable scientific theory but does not explain how it supports the claim • Identifies a counterclaim (possible weaknesses in scientific arguments or in one's own argument) without mentioning evidence		• Constructs a scientific argument, explaining how data and acceptable scientific theory support the claim • Identifies a counterclaim (possible weaknesses in scientific arguments or in one's own argument) using evidence		• Constructs and evaluates a scientific argument explaining how data and acceptable scientific theory support the claim • Explains and evaluates a counterclaim (possible strengths and weaknesses in scientific arguments or in one's own argument) using evidence
COMMUNICATING FINDINGS	• Attempts to use multiple representations to communicate conclusions with inaccuracies or major inconsistencies with the evidence • Implies conclusions with no discussion of limitations		• Uses multiple representations (words, tables, diagrams, graphs and/or mathematical expression) to communicate conclusions with minor inconsistentencies with the evidence • States conclusions and general discussion of limitations		• Uses multiple representations (words, tables, diagrams, graphs, and/or mathematical expressions) to communicate clear conclusions consistent with the evidence • Explains conclusions with specific discussion of limitations		• Uses multiple representations (words, tables, diagrams, graphs, and/or mathematical expressions) to communicate clear and specific conclusions consistent with the evidence • Explains conclusions and impact of limitations or unanswered questions
FOLLOWING CONVENTIONS	• Uses language and tone inappropriate to the purpose and audience • Attempts to follow the norms and conventions of scientific writing with major, consistent errors, for example in the use of scientific/technical terms, quantitative data, or visual representations		• Uses language and tone appropriate to the purpose and audience with minor lapses • Follows the norms and conventions of scientific writing with consistent minor errors, for example in the use of scientific or technical terms, quantitative data, or visual representations		• Uses language and tone appropriate to the purpose and audience • Follows the norms and conventions of scientific writing including accurate use of scientific/technical terms, quantitative data, and visual representations		• Uses language and tone appropriate to the purpose and audience • Consistently follows the norms and conventions of scientific writing, including accurate use of scientific/technical terms, quantitative data, and visual representations

12/08/10 **Rubber Band Car**

Intro:

The definition of energy efficiency that I found was it "is the ratio between the useful output of an energy conversion machine and the input, in energy terms" (Wikipedia). In my groups project the output is the distance traveled by the car and the input is the rubber bands placed in the car. My groups used multiple rubber bands to increase the distance traveled so we found the ratio between just one band and how far it traveled. This definition is a good and accurate definition but could have some improvement in my opinion. They could add to the definition about how and energy efficient car should but out larger and more beneficial numbers then are put into in. There should not be a larger input number than an output number or the car would not be considered efficient.

My groups hypothesis was that the more rubber bands added to the car would increase the distance traveled and therefore increases the efficiency of the car. The variable that my group changed was the rear tires on the car. We made the tires larger and have more treed then that original ones. The bigger tires will have more grip on them allowing the tire to grab a hold of the floor and push it forward. The smaller tires were much smaller and smooth giving it less traction. We thought this would but a good adjustment to see how it affected the cars efficiency.

Reflection Essay: *On separate paper*

Drawing/Picture: *On separate paper*

Description of Car:

My group's car was a four wheeled rubber band powered car. Our car was made out of Legos and was rear wheeled drive. The car was built so that the rubber bands would attach near the front of the car and stretch back to the rear axle. On the rear axle there were two tiny gears. The bands were split up amongst the gears and placed in their groves. Once the bands were in the groves we would rotate the wheels so that the band would twist around the axel. When you let go of the car the car the rubber bands would rotate the gears attached to the axel that would spin the wheels pushing the car forward. The smaller gears allowed the car to get a great lunge and start off the line and allow it to accelerate so that it would glide once the rubber bands were completely unwound. There were a lot of extra Lego pieces used to support the car's axel and hold the rubber bands in place.

Our car's design can be compared to Newton's laws of motion in several ways. Its movement can be compared to his 1st and 3rd law. The wheels pushing on the floor making it move applies to his 3rd law because there is an equal and opposite reaction from the floor pushing it in the opposite direction pushing it across the floor. As the car begins to slow down this demonstrates his 1st law because it shows the car doesn't remain in motion because on opposite force begins to act against it. This force is the friction of the floor bringing it to a stop. We got our teachers approval for this lab and began to build the car. After building the car we tested it a few times and began to modify it. We adjusted the width, length, tire size, and the amount of bands we used.

Independent Variable: *Number of rubber bands used/ Weight*

Dependent Variable: *Distance Traveled/ Time/ Speed*

We planned to determine the efficiency of our car by taking the car adding rubber bands and recording the distance traveled. We would than divide the distance traveled by the number of bands to get the ratio of distance traveled per band. Our teacher approved my groups safety steps and we than tested our experiment.

Experiment Data:

My group altered the amount of bands used for our independent variable tested many different things. We did three test runs for each amount of bands and recorded the data for each run. We found the averages for the three runs and recorded it in a data table on the next page. After each run we exchanged the bands for new ones to keep the elasticity similar.

Original Car Data Table:

Bands	Avg. Distance (Ft)	Ratio (Band: Distance)	Avg. Time (Sec)	Avg. Speed (Ft/Sec)	Weight (g)
1	4	1:4	2.1	1.9	336
2	9	1:4.5	4.25	1.88	336
3	12	1:4	4.9	2.44	336
4	16	1:4	5.6	2.86	337
5	22	1:4.4	6.2	3.54	337
6	28	1:4.6	6.9	4.05	337
7	27	1: 3.8	6.8	3.97	338
8	24	1:3	6.3	3.8	338

Equation examples:

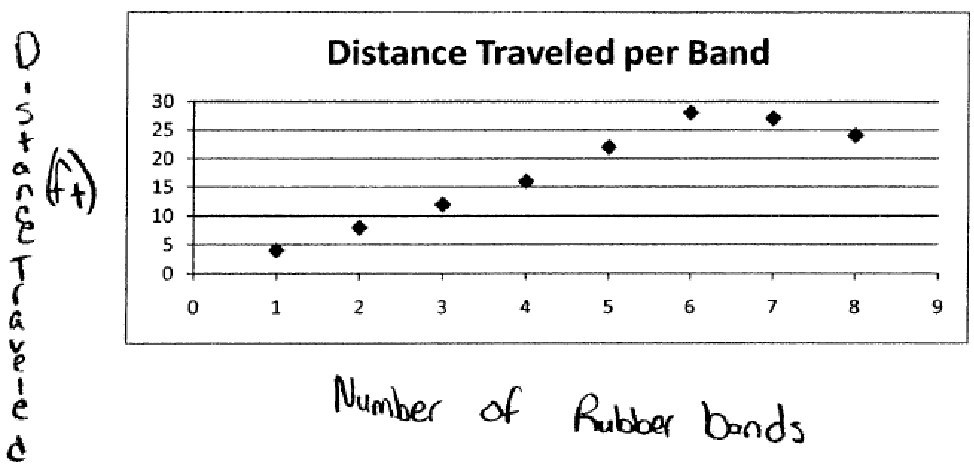
Avg. Distance- 3.5 ft + 5 ft + 3.5 ft = 12 ft /3(trials) = **4 ft**

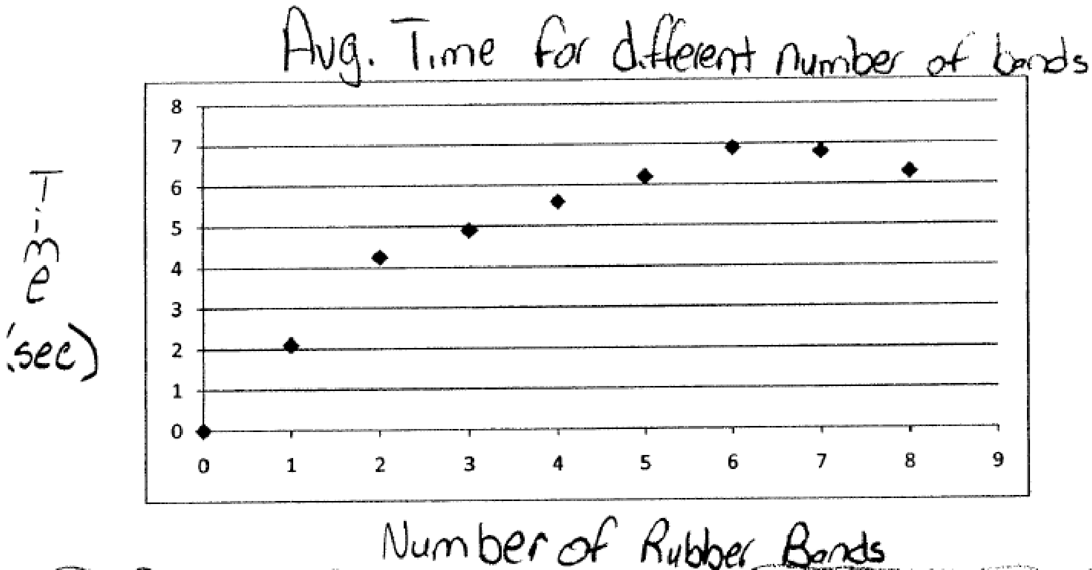
Ratio- 5 bands, 22 ft (traveled), 22ft/5 bands = **1:4.4** (For ever one band it goes 4.4 feet)

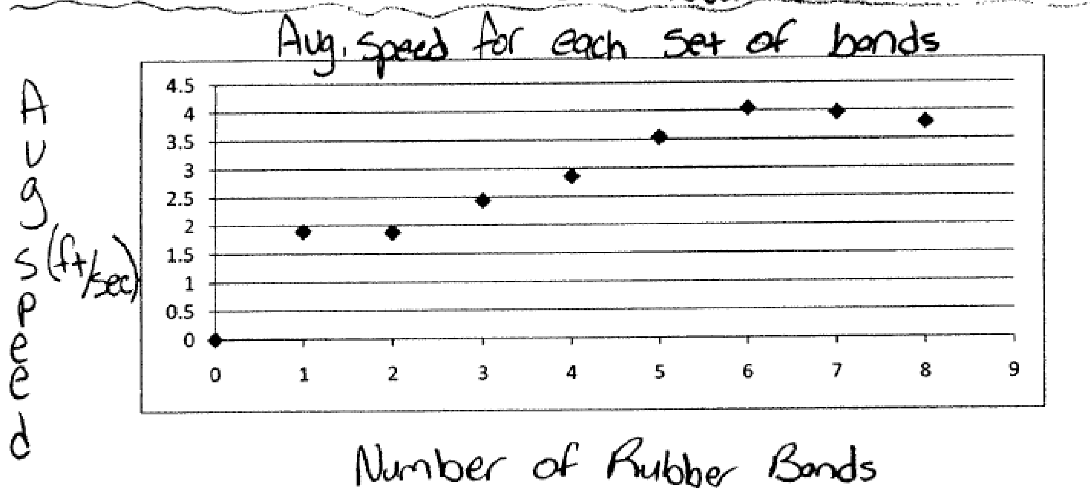
Avg. Time- 5.5 sec+ 5.6 Sec + 5.7 Sec = 16.8 sec/ 3 (trials) = **5.6 sec**

Avg. Speed- 27 ft (distance traveled), 6.8 sec (total time of travel) 27ft/6.8 sec = **3.97 ft/sec**

Graphs:







Our graphs show that the number of bands used in the original car do affect how far the car will travel. The car went the farthest distance with 6 bands and had the fastest speed. It showed that it also has the best ratio out of all the other amount of bands. For every one rubber band the car traveled 4.6 feet. After 6 bands the car began to have worse numbers and a worse ratio.

Car with Larger wheels chart:

Bands	Avg. Distance	Ratio (Band: Distance)	Time (Sec)	Avg. Speed (Ft/Sec)	Weight (g)
1	4	1:4	2.4	1.66	464
2	9	1:4.5	4.4	2.04	464
3	15	1:5	5.2	2.88	464
4	20	1:5	5.8	3.44	465
5	25	1:5	6.4	3.9	465
6	31	1:5.1	7.1	4.37	465
7	30	1:4.4	6.9	4.34	466
8	27	1:3.3	6.6	4.09	466

Equation Examples:

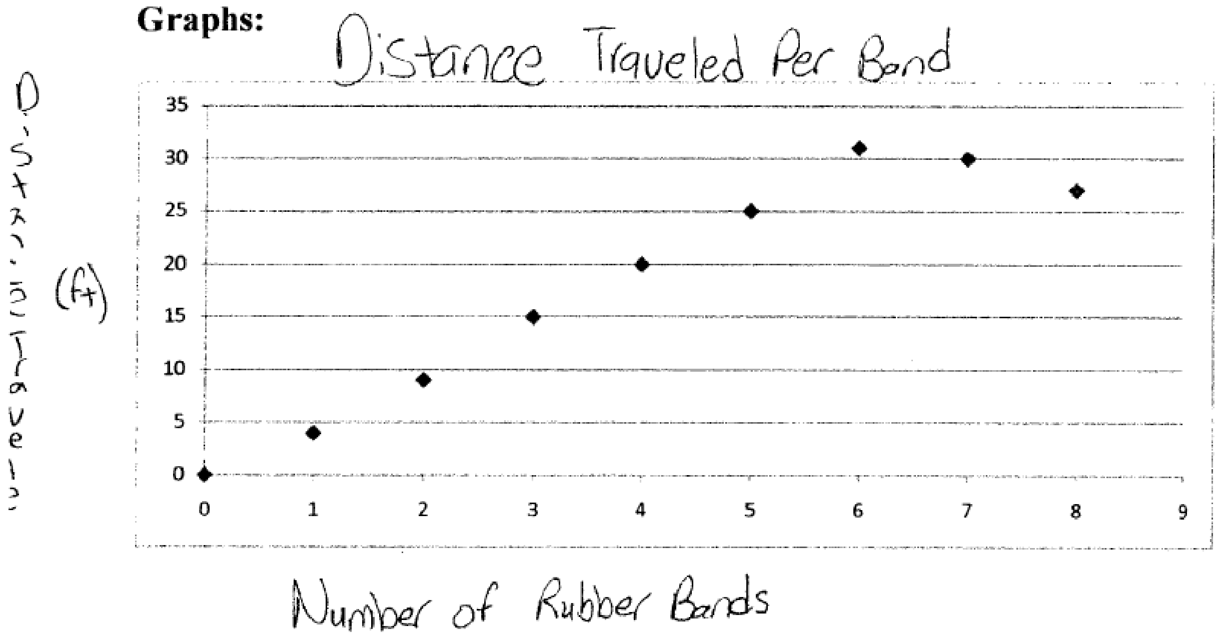
Avg. Distance- 3.5 ft + 5 ft + 3.5 ft = 12 ft /3(trials) = **4 ft**

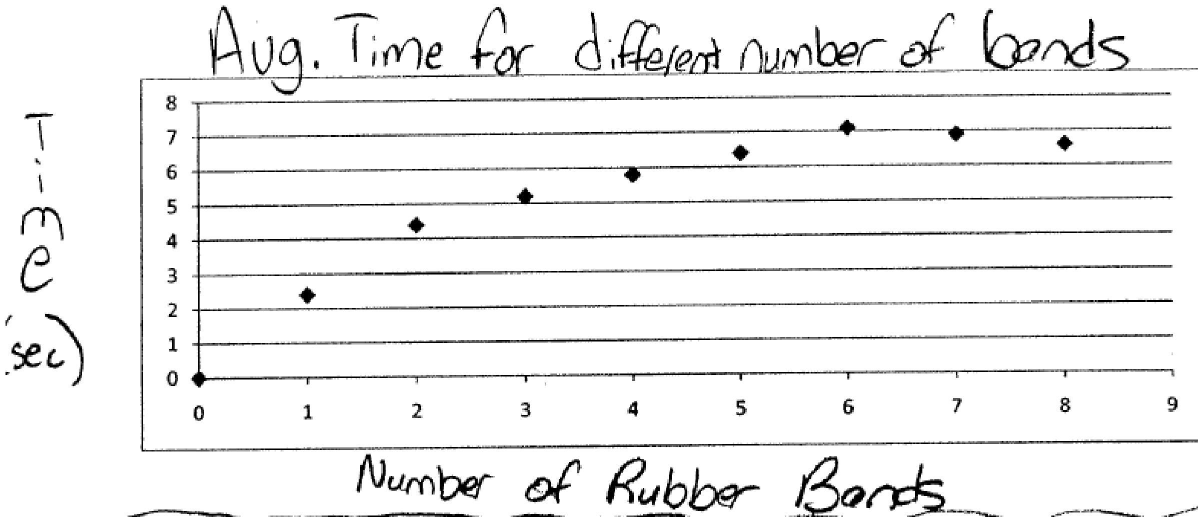
Ratio- 5 bands, 22 ft (traveled), 22ft/5 bands = **1:4.4** (For ever one band it goes 4.4 feet)

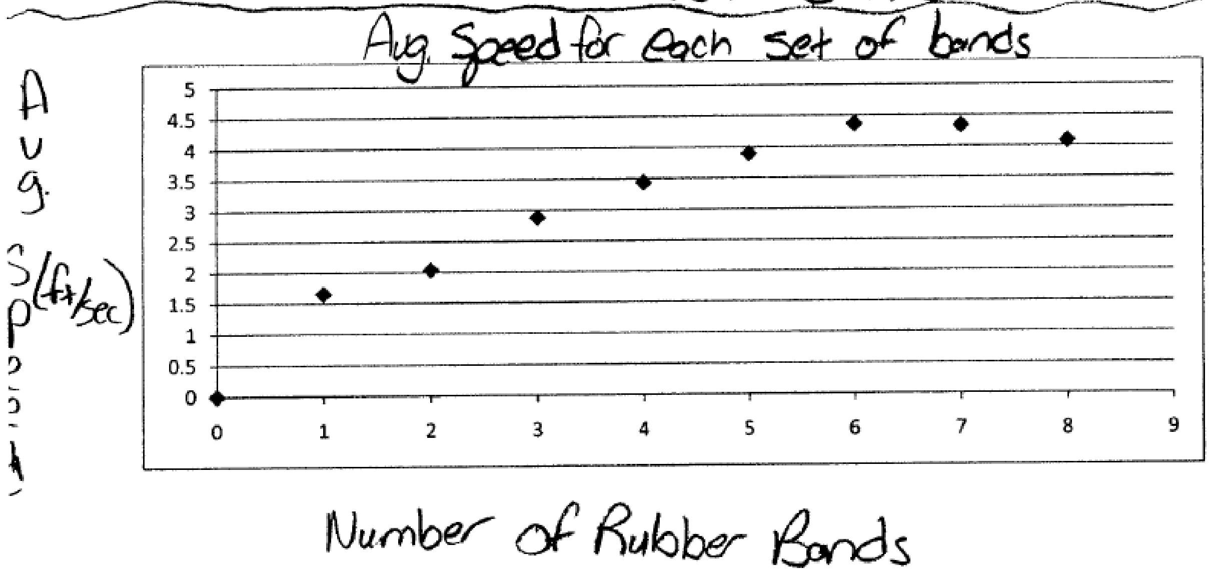
Avg. Time- 5.5 sec+ 5.6 Sec + 5.7 Sec = 16.8 sec/ 3 (trials) = **5.6 sec**

Avg. Speed- 27 ft (distance traveled), 6.8 sec (total time of travel) 27ft/6.8 sec = **3.97 ft/sec**

Graphs:







After making my adjustment I found that the number of bands still does affect the distance traveled by the car. With the bigger wheels it still travels farther with 6 rubber bands. The ratio is still greater with 6 bands also and it was 1:5.1.

Conclusion:

For both of our cars the final result was that both of them ran more efficiently on 6 rubber bands. The car with larger wheels had a better ratio than the original car though. It had a ration of 1:5.1, while the original has 1:4.6. The car with bigger wheels had more traction and resulted in it being the more efficient car. Our hypothesis was correct in the fact that more rubber bands would make it most efficient, but we did not predict with more rubber bands than 6 that it would begin to lose efficiency. Some sources of error could be in some of the rounding of numbers along with the math. Also we tested on different days and had to test in several different spots. The rubber bands also were different on each test and could have affected it some. We could test all at once and the same spot to limit these sources of error. I would also like to test in the future if we add even more gears if we could increase the speed and distance traveled.

Bibliography:

"Energy conversion efficiency". Wikipedia.
Wikipedia, Nov 29,2010. http://en.wikipedia.org/wiki/Energy_conversion_efficiency


Rubber bands
Rubber band holder
Support
Tires
support
Gears
Frame
axel

Factors affecting the energy efficiency of our car were the friction, amount of traction, weight, elasticity of the rubber bands, and many other small uncontrollable factors. Friction most likely played the biggest key role in this project because it was in direct contact with the car the entire time. It is what cause the car to stop moving once the rubber bands ran out and stopped turning the axel of the car. The elasticity changes also as we had to rotate the stretched out bands for new ones to keep it consistent. During this project we discovered that the acceleration of the car was the greatest right at the start of the track. We tested many different gears to see which one would benefit the car the most. We found out that the smaller gears were best for a great initial burst off the line with great acceleration. The bigger gears would give the car more distance but it would not accelerate very fast and once the bands ran out it wouldn't glide anymore. The small gears allowed for the velocity of the car to constantly increase until it ran out of rubber band and it than had so much momentum pushing it that it continued to glide for many more feet until friction stopped the car.

During the project my ideas didn't change much about energy efficiency because from the start I believed that the car that used the least amount of energy but at the same time increased the amount of energy going out. The types of strategies that helped my group out the most were testing all of the different designs that we could think of. We test tested three different gears separate and some at the same time working together. We tested different dimensions of the car and different amounts of rubber bands used. We tried front wheel and back wheel drive cars and different designs for the tires. Next time to improve the lab we could use strategies like looking up some different designs for the car and doing more research for it.

I learned many things when designing this vehicle like how traction can affect the distance the car travels. Also how the different size of the gears play a factor in speed and distance the car goes. I helped contribute to the team by helping come up with the design of the gears. I also helped be recording all the data from the test runs. The strengths of the team were that we all worked together but at the same time we all worked on separate tasks to make the process go faster. If anyone were to get stuck we would all come together to figure it out.

Interactions that could be improved are making sure we all listen to each other's ideas and let one another share them.