K'NEX® Education

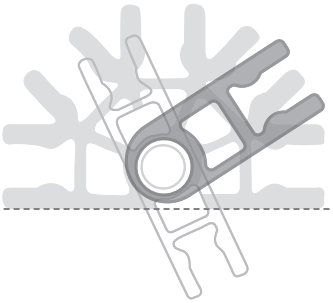
TEACHER'S GUIDE™

EXPLORING MACHINES™

TOW TRUCK

PADDLEBOAT

Exploring Machines



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Teaching Strategies:

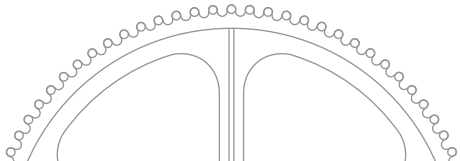
The best way to administer the investigations provided in this Teacher's Guide will be determined by the teacher, the nature of the classes, the curriculum goals, and national, state, and local standards. As teachers review their science standards they may gain additional insight into how to further enrich the experiences with simple machines. The following suggestions may also be helpful:

• Use the building portion of each investigation as an introduction for new topics or concepts.

• Use building and investigation portions together as culminating laboratory activities for each simple machine.

• Set aside two or three days to be used as investigation days at the end of a section on a specific type of machine, such as levers. Have students rotate through stations and investigations that illustrate different types of levers. Include one or several stations that have models **without** investigations (from Booklet #2) and have students use their newly gained knowledge and understanding to identify the simple machine. For example, a series of lever investigations might include a balance station and a hammer station. Additional stations without investigations might also include the rowboat (first-class lever) station, a nutcracker (second-class lever) station, and a fishing pole (third-class lever) station.

• If students keep a record of their observations and investigations in a science journal, use this as a means of assessment. Alternatively, have students keep student sheets in a designated lab folder for assessment and note keeping purposes.



The Balance

student inquiry sheet

Objectives

- To determine experimentally the relationships between effort force, load force, and fulcrum in a first-class lever system.
- To compare the mechanical advantage of different first-class lever systems.
- To design a first-class lever system that uses minimal effort force to balance the greatest load.

Materials

- K'NEX Exploring Machines: Balance model

The following items are not included in the set:

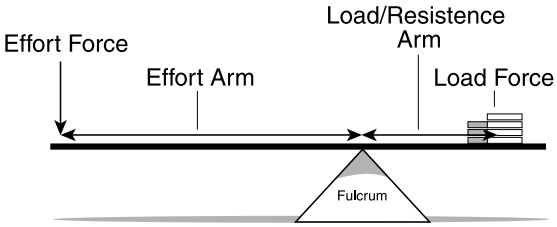
- Pennies minted after 1982 (approx. 20 - 30)
- 2 paper squares (7.5 cm x 7.5 cm), or weighing boats
- Ruler
- Small paper cup to store the pennies
- Dot stickers or masking tape
- Pen/marker

What's the Story?

Machines allow you to do work faster or more easily. In other words, a machine helps you to do work. Machines can transfer energy, magnify force, multiply speed, or change the direction of a force. They cannot, however, increase work or energy. In most cases, the amount of work put ***into*** the machine is more than the amount of work produced ***by*** the machine. Because friction is present in most systems, some energy is changed to heat or sound.

Different types of machines offer different levels of mechanical advantages. Mechanical advantage is the ratio of the **output force**, or force exerted by the machine, to the **input force**, or force applied to the machine. A nail is difficult to pull out of wood with your hand because you cannot apply enough force to the nail to overcome friction. The same small force, however, applied to the end of a claw hammer handle, produces a larger force, applied over a small distance, at the hammer head. The output force of the hammer is large enough to overcome friction, allowing you to pull out the nail.

A hammer is just one example of a lever. A lever is one of six simple machines. There are three classes of **levers**, classified by the arrangement of forces and pivot point. In the investigation below, you will explore a first-class lever. First-class levers are those in which a pivot point, or fulcrum, separates the input force, or effort force, from the output force, or load force.



The Key Parts of a First-Class Lever

Fig. 1

What To Do
Part I: All Things Being Equal

1. Build the K'NEX balance model. NOTE: You will want to modify the base of the 2 hanging pans in Step 15 so that they can hold a load of pennies. To reduce the spaces in the base, replace the blue Rods with pale gray Connectors and small black Rods. ***(Fig. 2)***

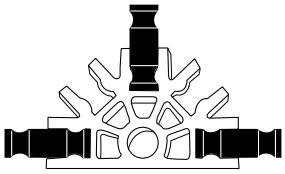


Fig. 2

2. Using masking tape, or dot stickers, label one hanging pan as the **effort** force pan (E) and one as the **load** force pan (L).

3. Slide the load force pan (L) into position approximately 3 cm from the end of the balance arm, as shown in ***Fig. 3.***

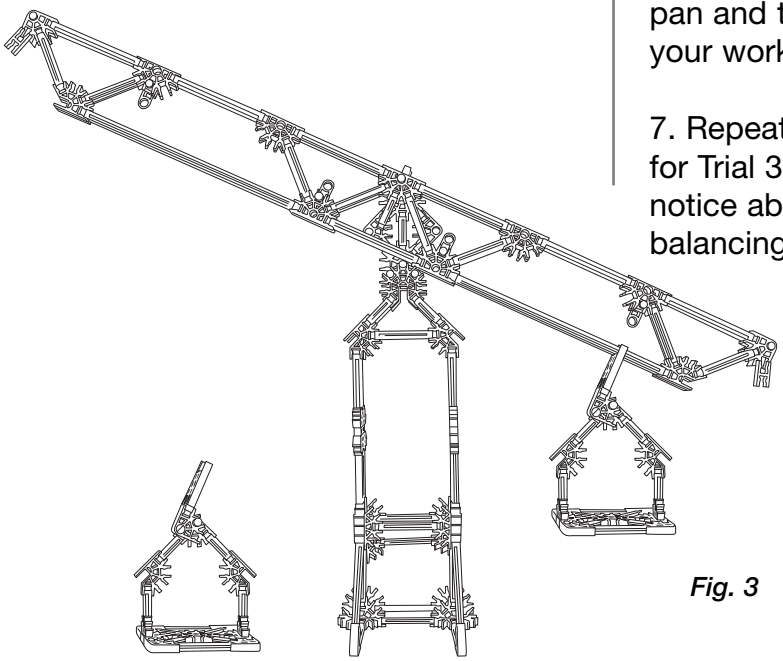


Fig. 3

4. On the other side of the fulcrum, attach and then slide the effort pan (E) along the lever until the system is balanced.

5. Measure the distances from the load pan to the fulcrum and from the effort pan to the fulcrum. ***(Fig. 4)*** Record these distances as Trial 1 in Table 1, Balance Worksheet.

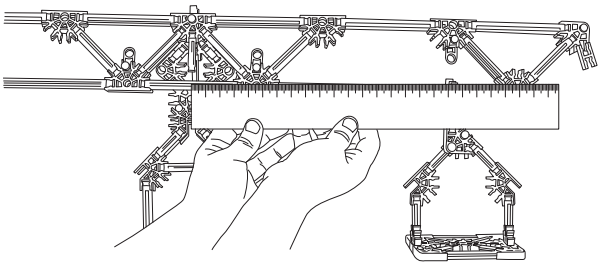


Fig. 4

6. Slide the load pan to a new position along the lever. Slide the effort pan along the lever until the system is balanced again. Measure and record distances between each pan and the fulcrum for Trial 2 on your worksheet.

7. Repeat Step 6, recording distances for Trial 3 in Table 1. What do you notice about your measurements for balancing the system?

8. Calculate and record the mechanical advantage (MA) for each trial. (The formula for MA, provided in Table 1, is the ratio of effort distance to load distance. In ideal circumstances this is the same as the ratio of output force to input force discussed earlier.)

Part II(a): Unbalanced Forces

1. Slide the **load** pan (L) to the far right of the fulcrum.

2. Measure the distance from the load pan to the fulcrum and record this measurement on your worksheet.

3. Slide the **effort** pan (E) to a position, to the left of the fulcrum, which is **one half the distance** you measured for the load pan in # 2 above. Record this distance on your worksheet.

4. Add enough pennies to the **effort** pan to balance the system. See ***Fig. 5*** below.

5. Now place four pennies on the **load** pan and observe what happens to the system.

6. Predict the number of pennies that, when added to the effort pan, will return balance to the system. Record your prediction on your worksheet.

7. Add pennies, one at a time, to the **effort** pan until the system is balanced. How many pennies must be added to the effort pan to return balance to the system? Record your result. Do not include the pennies you first added in Step 4 (above) to balance the system.

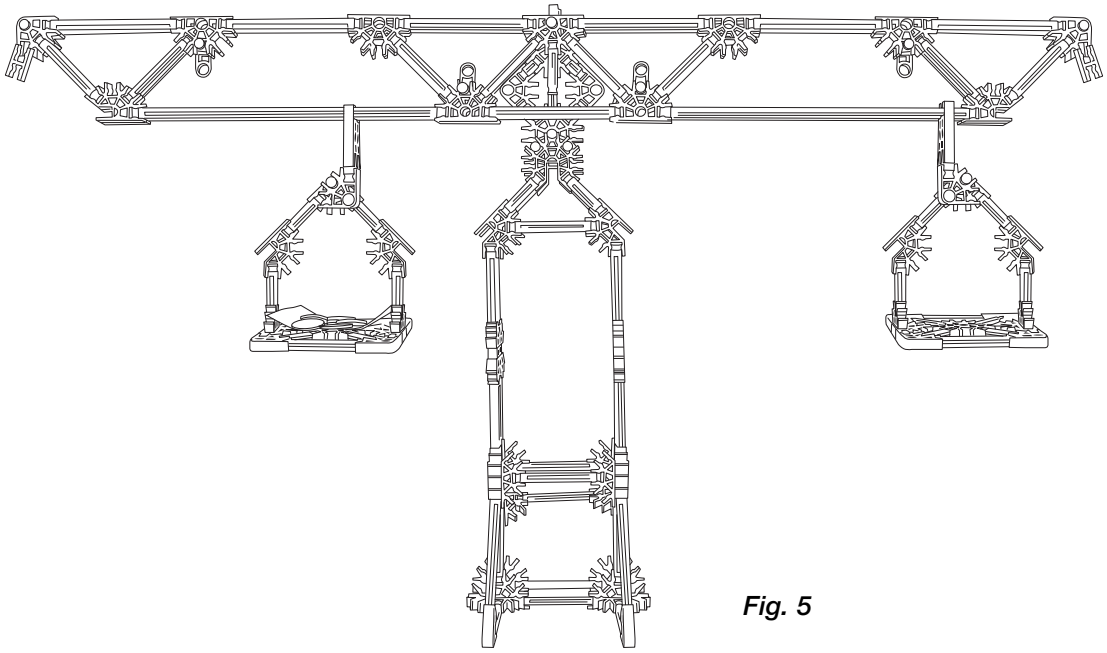


Fig. 5

Part II(b): Unbalanced Forces

1. Remove all the pennies from the effort and load pans.

2. Slide the **effort** pan to the far left of the fulcrum. Measure the distance from the effort pan to the fulcrum and record this measurement on your worksheet.

3. Slide the **load** pan to a position, to the right of the fulcrum, which is **one half the distance** you measured for the effort pan in # 2 above. Record this distance on your worksheet. Add enough pennies to the **load** pan to balance the system. See ***Fig. 6*** below.

4. Place four more pennies on the **load** pan. Observe what happens to the system.

5. Predict the number of pennies that, when added to the effort pan, will return balance to the system. Record your prediction on the worksheet.

6. Add pennies, one at a time, to the **effort** pan until the system is balanced. Record your result on the worksheet.

7. Using your data from Part II, develop a conclusion that describes the mechanical advantage of a first class lever system. Include evidence from your experimental results and calculations to support your answer. Remember, mechanical advantage is a calculation that indicates how many times the machine multiplies the effort force. Write your conclusion.

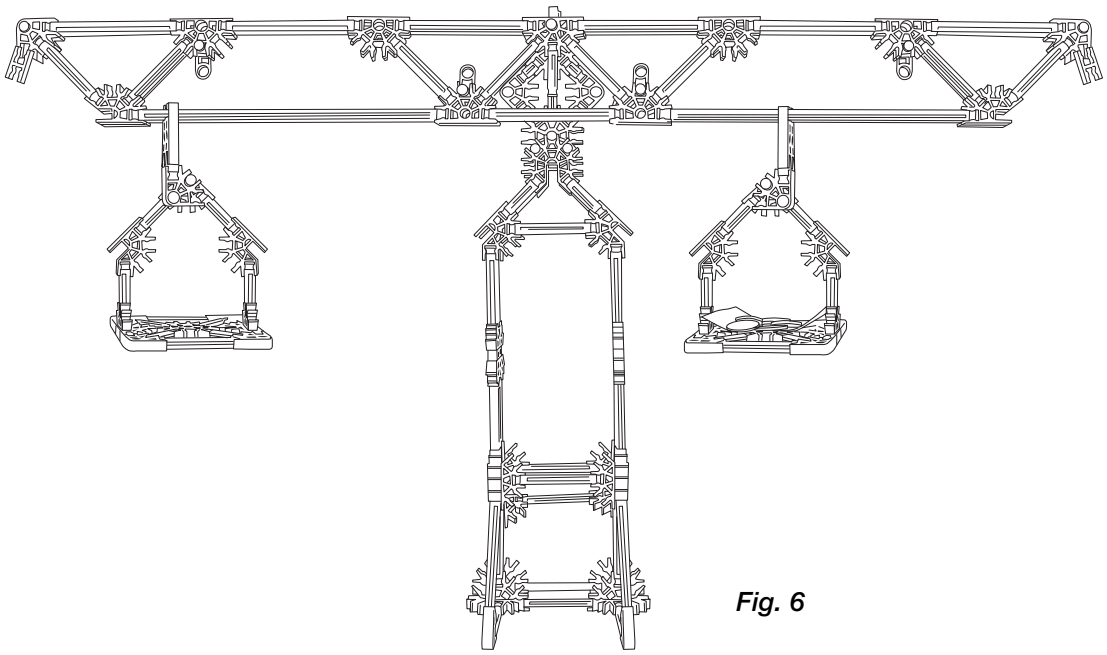


Fig. 6

name date

student worksheet

Balance Worksheet

Observations

Part I: All Things Being Equal
Table 1

Trial	Load distance (cm)	Effort distance (cm)	Mechanical Advantage: $\frac{\text{Effort distance}}{\text{Load distance}}$
1			
2			
3			

Part II(a): Unbalanced Forces

1. Distance from load pan to fulcrum:_____cm.

2. Distance from effort pan to fulcrum:_____cm.

3. Prediction: _____ pennies will return balance to the system.

4. How many pennies were actually used to balance the load force of 4 pennies? ____

5. Calculate the mechanical advantage of this system in the space below.
Show all work. (Use the other side of the paper if you need more space.)

Part II(b): Unbalanced Forces

1. Effort distance:_____cm.

2. Load distance: _____cm.

3. Prediction: _____pennies will return balance to the system.

4. How many pennies were actually used to balance the load force of 4 pennies? ____

5. Calculate the mechanical advantage of this system in the space below.
Show all work. (Use the other side of the paper if you need more space.)

Balance Worksheet

Conclusion

Challenge

Each penny minted after 1982 has a mass equal to 2.5 grams. Design a first class lever system to balance the greatest load (number of pennies). Your design must stay within the following guidelines:

- Your system *cannot* include adding pennies to increase effort force.
- Both effort and load pans must be able to swing freely without contacting anything else.

Draw your design in the space below.

Make these measurements:

Effort distance:_____ cm.

Load distance:_____ cm.

Mechanical advantage:_____

Total mass of load: _____

NSES Content Standards Alignments

National Science Education Standards (Grades 5 - 8) *Students will develop an understanding of:*
UNIFYING CONCEPTS AND PROCESSES
• *Systems, order, and organization*
• *Evidence, models, and explanation*
• *Change and measurement*
• *Form and function*
SCIENCE AS INQUIRY
• *Abilities necessary to do scientific inquiry*
• *Understanding about scientific inquiry*
PHYSICAL SCIENCE
• *Motions and Forces*
• *Transfer of Energy*
SCIENCE AND TECHNOLOGY
• *Abilities of technological design*
• *Understanding about science and technology*

Standards for Technological Literacy: Content for the Study of Technology

Standards for Technological Literacy: Content for the Study of Technology (Grades 3-5) *Students will develop an understanding of:*
THE NATURE OF TECHNOLOGY
The Core Concepts of Technology
• *Systems*
• *Processes*
• *Requirements*
DESIGN
Engineering Design
• *Creativity and considering all ideas*
• *Models*
The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving.
• *Troubleshooting*
• *Experimentation*

Standards for Technological Literacy: Content for the Study of Technology (Grades 6-8) *Students will develop an understanding of:*
THE NATURE OF TECHNOLOGY
The Core Concepts of Technology
• *Systems*
• *Processes*
• *Requirements*
Relationships among technologies and the connections between technology and other fields.
• *Interaction of systems*
• *Knowledge from other fields of study and technology*
DESIGN
Engineering Design
• *Brainstorming*
• *Modeling, testing, evaluating, and modifying*
The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving.
• *Troubleshooting*
• *Invention and innovation*
• *Experimentation*
ABILITIES OF A TECHNOLOGICAL WORLD
Apply Design Process
• *Identify criteria and constraints*
• *Test and evaluate*
• *Make a product or system*

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NCTM Standards Alignments

National Council of Teachers of Mathematics Education Standards and Expectations for Grades 6 - 8
NUMBER AND OPERATIONS
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand numbers, ways of representing numbers, relationships among numbers, and number systems.*
• *Understand meanings of operations and how they relate to one another.*
• *Compute fluently and make reasonable estimates.*
GRADES 3 - 5 **NUMBERS AND OPERATIONS**
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand numbers, ways of representing numbers, relationships among numbers, and number systems.*
• *Understand meanings of operations and how they relate to one another.*
• *Compute fluently and make reasonable estimates.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
• *Understand the place-value structure of the base-ten number system and be able to represent and compare whole numbers and decimals.*
• *Develop understanding of fractions as parts of unit wholes, as parts of a collection, as locations on number lines, and as divisions of whole numbers.*
• *Use models, benchmarks, and equivalent forms to judge the size of fractions.*
• *Recognize and generate equivalent forms of commonly used fractions, decimals, and percents.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Understand meanings of operations and how they relate to one another.
• *Understand various meanings of multiplication and division.*
• *Understand the effects of multiplying and dividing whole numbers.*
• *Identify and use relationships between operations, such as division as the inverse of multiplication, to solve problems.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Compute fluently and make reasonable estimates.
• *Develop fluency with basic number combinations for multiplication and division and use these combinations to mentally compute related problems, such as 30 × 50.*
• *Develop fluency in adding, subtracting, multiplying, and dividing whole numbers.*
• *Develop and use strategies to estimate computations involving fractions and decimals in situations relevant to students' experience.*
• *Select appropriate methods and tools for computing with whole numbers from among mental computation, estimation, calculators, and paper and pencil according to the context and nature of the computation and use the selected method or tools.*

ALGEBRA
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand patterns, relations, and functions.*
• *Represent and analyze mathematical situations and structures using algebraic symbols.*
• *Use mathematical models to represent and understand quantitative relationships.*
• *Analyze change in various contexts.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Understand patterns, relations, and functions.
• *Represent and analyze patterns and functions, using words, tables, and graphs.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Represent and analyze mathematical situations and structures using algebraic symbols.
• *Represent the idea of a variable as an unknown quantity using a letter or a symbol.*
• *Express mathematical relationships using equations.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Use mathematical models to represent and understand quantitative relationships.
• *Model problem situations with objects and use representations such as graphs, tables, and equations to draw conclusions.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Analyze change in various contexts.
• *Investigate how a change in one variable relates to a change in a second variable.*
• *Identify and describe situations with constant or varying rates of change and compare them.*
MEASUREMENT STANDARD
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand measurable attributes of objects and the units, systems, and processes of measurement.*
• *Apply appropriate techniques, tools, and formulas to determine measurements.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Understand measurable attributes of objects and the units, systems, and processes of measurement.
• *Understand such attributes as length, and select the appropriate type of unit for measuring each attribute.*
• *Understand the need for measuring with standard units and become familiar with standard units in the customary and metric systems.*
• *Carry out simple unit conversions, such as from centimeters to meters, within a system of measurement.*
• *Understand that measurements are approximations and how differences in units affect precision.*
DATA ANALYSIS AND PROBABILITY
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.*
• *Select and use appropriate statistical methods to analyze data.*
• *Develop and evaluate inferences and predictions that are based on data.*
• *Understand and apply basic concepts of probability.*

Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
• *Collect data using observations, surveys, and experiments.*
• *Represent data using tables and graphs such as line plots, bar graphs, and line graphs.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Select and use appropriate statistical methods to analyze data
• *Describe the shape and important features of a set of data and compare related data sets, with an emphasis on how the data are distributed.*
Grades 3 - 5 Expectations: In grades 3 - 5 all students should: Develop and evaluate inferences and predictions that are based on data.
• *Propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions.*
GRADE 6 **NUMBERS AND OPERATIONS**
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
• *Work flexibly with fractions, decimals, and percents to solve problems.*
• *Understand and use ratios and proportions to represent quantitative relationships.*
• *Develop meaning for integers and represent and compare quantities with them.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Understand meanings of operations and how they relate to one another.
• *Understand the meaning and effects of arithmetic operations with fractions, decimals, and integers.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Compute fluently and make reasonable estimates.
• *Select appropriate methods and tools for computing with fractions and decimals from among mental computation, estimation, calculators or computers, and paper and pencil, depending on the situation, and apply the selected methods.*
ALGEBRA
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand patterns, relations, and functions.*
• *Represent and analyze mathematical situations and structures using algebraic symbols.*
• *Use mathematical models to represent and understand quantitative relationships.*
• *Analyze change in various contexts.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Understand patterns, relations, and functions.
• *Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and symbolic rules when possible.*
• *Relate and compare different forms of representation for a relationship.*

Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Represent and analyze mathematical situations and structures using algebraic symbols.
• *Develop an initial conceptual understanding of different uses of variables.*
• *Use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships.*
• *Recognize and generate equivalent forms for simple algebraic expressions and solve linear equations.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Use mathematical models to represent and understand quantitative relationships.
• *Model and solve contextualized problems using various representations, such as graphs, tables, and equations.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Analyze change in various contexts.
• *Use graphs to analyze the nature of changes in quantities in linear relationships.*
MEASUREMENT STANDARD
Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Understand measurable attributes of objects and the units, systems, and processes of measurement.*
• *Apply appropriate techniques, tools, and formulas to determine measurements.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Understand measurable attributes of objects and the units, systems, and processes of measurement.
• *Understand both metric and customary systems of measurement.*
• *Understand relationships among units and convert from one unit to another within the same system.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Apply appropriate techniques, tools, and formulas to determine measurements.
• *Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision.*
DATA ANALYSIS AND PROBABILITY
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.*
• *Select and use appropriate statistical methods to analyze data.*
Grades 6 - 8 Expectations: In grades 6 - 8 all students should: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
• *Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population.*

PROCESS STANDARDS
Problem Solving Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Build new mathematical knowledge through problem solving.*
• *Solve problems that arise in mathematics and in other contexts.*
• *Apply and adapt a variety of appropriate strategies to solve problems.*
• *Monitor and reflect on the process of mathematical problem solving.*
Reasoning and Proof Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Recognize reasoning and proof as fundamental aspects of mathematics.*
• *Select and use various types of reasoning and methods of proof.*
Communication Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Organize and consolidate their mathematical thinking through communication.*
• *Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.*
• *Analyze and evaluate the mathematical thinking and strategies of others.*
• *Use the language of mathematics to express mathematical ideas precisely.*
Connections Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Recognize and use connections among mathematical ideas.*
• *Recognize and apply mathematics in contexts outside of mathematics.*
Representation Instructional programs from pre-kindergarten through grade 12 should enable all students to:
• *Create and use representations to organize, record, and communicate mathematical ideas.*
• *Select, apply, and translate among mathematical representations to solve problems.*
• *Use representations to model and interpret physical, social, and mathematical phenomena.*

Common Core Standards Alignments

Common Core State Standards for Mathematics in Grades 5 - 8
MATHEMATICAL PRACTICES - ASSOCIATED WITH MATHEMATICS AT ALL GRADE LEVELS
1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.
GRADE 5
Operations and Algebraic Thinking
• *Write and interpret numerical expressions.*
• *Analyze patterns and relationships.*
Number and Operations in Base Ten
• *Perform operations with multi-digit whole numbers and with decimals to hundredths.*
Measurement and Data
• *Convert like measurement units within a given measurement system.*
• *Represent and interpret data.*
Geometry
• *Graph points on the coordinate plane to solve real-world and mathematical problems.*
MATHEMATICS GRADE 6
In Grade 6, instructional time should focus on four critical areas:
• *Connecting ratio and rate to whole number multiplication and division and using concepts of ratio and rate to solve problems.*
• *Writing, interpreting, and using expressions and equations.*
• *Developing understanding of statistical thinking.*
GRADE 6
Ratios and Proportional Relationships
• *Understand ratio concepts and use ratio reasoning to solve problems.*
The Number System
• *Compute fluently with multi-digit numbers and find common factors and multiples.*
Expressions and Equations
• *Apply and extend previous understandings of arithmetic to algebraic expressions.*
• *Reason about and solve one-variable equations.*
• *Represent and analyze quantitative relationships between dependent and independent variables.*

Statistics and Probability
• *Develop understanding of statistical variability.*
MATHEMATICS GRADE 7
In Grade 7, instructional time should focus on four critical areas:
• *Developing understanding of and applying proportional relationships.*
• *Developing understanding of operations with rational numbers and working with expressions and linear equations.*
• *Drawing inferences about populations based on samples.*
GRADE 7
Ratios and Proportional Relationships
• *Analyze proportional relationships and use them to solve real-world and mathematical problems.*
The Number System
• *Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.*
Expressions and Equations
• *Use properties of operations to generate equivalent expressions.*
• *Solve real-life and mathematical problems using numerical and algebraic expressions and equations.*
MATHEMATICS GRADE 8
In Grade 8, instructional time should focus on three critical areas:
• *Grasping the concept of a function and using functions to describe quantitative relationships.*
GRADE 8
Expressions and Equations
• *Analyze and solve linear equations.*
Functions
• *Define, evaluate, and compare functions.*
• *Use functions to model relationships between quantities.*
Statistics and Probability
• *Investigate patterns of association in bivariate data.*

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