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Program Introduction

*Hands-On Problem Solving* focuses on developing students’ knowledge, skills, attitudes, and strategic thinking related to mathematics through active inquiry, problem solving, and decision making. Throughout all activities presented in the book, students are encouraged to explore, investigate, and ask questions in order to heighten their own curiosity about and understanding of the world of mathematics.

Program Principles

1. Effective problem-solving programs involve students actively building new knowledge from experience and prior knowledge.

2. Development of students’ understanding of concepts, flexibility in thinking, reasoning, and problem-solving skills/strategies form the foundation of the problem-solving program.

3. From a young age, children are interested in mathematical ideas. This interest must be maintained, fostered, and enhanced through active learning.

4. Problem-solving activities must be worthwhile and relate to real-life experiences. Problems should be rooted in context so that students can make sense of the numbers with which they are being asked to work in a meaningful way.

5. The teacher’s role in the problem-solving process is to actively engage students in tasks and experiences designed to deepen and connect their knowledge. Children learn best by doing, rather than by just listening. The teacher, therefore, should focus on creating opportunities for students to interact in order to propose mathematical ideas and conjectures, to evaluate their own thinking and that of others, and to develop mathematical problem-solving skills.

6. Problem solving should be taught in correlation with the mathematics program and with other school subjects. Themes and topics of study in problem solving should integrate ideas and skills from mathematics, as well as from other areas of study, whenever possible.

7. The problem-solving program should encompass and draw on a range of educational resources including literature and technology as well as people and places in the local community.

8. Assessment of student learning in problem solving should be designed to focus on performance and understanding and should be conducted through meaningful and varied assessment techniques carried on throughout the modules of study.

Big Ideas in Mathematics

In order to achieve the goals of mathematics education and to support lifelong learning in mathematics, students must be provided with opportunities to encounter and practise critical mathematical processes. Problem solving is one of these processes, but since they are all inter-related, it is important to recognize the characteristics of each mathematical process, and the related learning experiences for students. These processes are as follows:

Communication

Students need opportunities to share their mathematical ideas and thinking through oral language, reading and writing, diagrams, charts, tables, and illustrations. Communicating mathematically, aloud or on paper, helps students clarify their thinking for themselves and others.
For example:
There are 12 goldfish.
The goldfish are in fishbowls.
Each bowl has the same number of goldfish in it.
Show different ways the goldfish could be put into fishbowls.

The process of communication is essential to the learning process during problem-solving investigations. Students should be encouraged to share their ideas, listen to others, and write about their problem-solving experiences, strategies, and solutions. In addition, students should be encouraged to write their own problems.

Connections
When doing problem-solving activities in the classroom, teachers should ensure that links are made between the various strands of the mathematics curriculum. It is also important to make connections between concrete, pictorial, and symbolic representations, so students should be encouraged to explore the use of manipulatives, illustrations, and symbols to solve problems. Further, concepts and skills should be connected to everyday life and to other curricular areas.

The Hands-On Problem-Solving program offers suggestions for connecting problem solving to other subject areas and to children's literature through use of storybooks in lessons. The books suggested are generally well known and are usually available in school or public libraries. Before beginning the Hands-On Problem-Solving program, teachers are encouraged to review the lessons for references to various related children's books (please see the references at the back of the book for full details), and acquire the recommended books before presenting the given problems/lessons to students.

Mental Math
Mental math is more than just knowing the facts—it is about strategic thinking and number sense. Mental math is a process necessary to many everyday experiences, and students need extensive exposure to activities that encourage them to solve problems mentally. Strong mental math skills enable students to respond quickly to questions or required tasks phrased in a variety of ways. For example:

- Double 4
- Half of 6
- Two 5s
- You roll double 3. What’s your score?
- How many shoes in 2 pairs?

Estimation
Students should be encouraged regularly to estimate quantities and measurements. Being able to make an educated guess allows students to independently check the validity of their calculations. It is also an essential skill in everyday life. Estimation encourages students to take risks, use background knowledge, and learn from the process. For example:

Estimate whether there are enough dog houses for the dogs.
Now, check. Are there too many or too few dog houses?

**Reasoning**
Mathematical reasoning involves informal thinking, conjecturing, and validating. Students should be encouraged to justify their solutions, thinking processes, and hypotheses. Good reasoning is as important as finding correct answers, so students need many opportunities to think about, describe orally, and record their mathematical activities and ideas. For example:

I am a two-digit number.
My tens digit is 2 greater than 3.
My ones digit is 3 less than my tens digit.
What number am I?

**Technology**
The use of calculators is recommended, to facilitate and enhance problem-solving skills and to encourage discovery of number patterns. However, calculators must not replace development of students’ number concepts and skills. Other technologies such as interactive whiteboards, computer software, and websites can provide valuable resources for students and teachers as well.

**Visualization**
This is the process of creating mental images needed to develop concepts and understand procedures. Visualizations help students clarify their understanding of mathematical ideas.
For example:

- Show all you know about the number 17.
  Use pictures, diagrams, and words in your answer.

**Problem Solving**
Problem solving is another of the “big ideas” in mathematics—the mathematical processes students need in order to achieve the goals of mathematics education and to support lifelong learning in mathematics. Students are exposed to a wide variety of problems in all areas of mathematics in *Hands on Problem Solving*. They also explore a variety of methods for solving and confirming their solutions to a variety
of different types of problems. They should also be encouraged to find multiple solutions for problems and to create their own problems.

**What is Problem Solving?**

Problem solving refers to “mathematical tasks that have the potential to provide intellectual challenges for enhancing students’ mathematical understanding and development” (Cai and Lester, NCTM). Problem solving is the application of a variety of mathematical knowledge, tools, and strategies to a wide range of math problems in order to solve them.

**Problem solving**
- Is a life skill;
- Creates a purpose for learning skills and concepts;
- Motivates students by developing a sense of inquiry;
- Allows students to demonstrate their understanding of mathematical concepts and skills in meaningful contexts;
- Teaches perseverance.

Problem solving should be the main focus of mathematics instruction. The ability to apply their knowledge to solve problems is the goal for all students.

**Best Practices in Teaching Problem Solving**

Problem solving is often not viewed positively by students. In order to change this perception teachers should
- Use a problem-solving approach when introducing and teaching concepts and skills;
- Begin with simple problems so students can experience success;
- Include a balance of routine, non-routine, and extended exploration problems;
- Encourage the use of multiple strategies for solving problems;
- Provide opportunities for students to write their own problems;
- Use modelling (think aloud) to demonstrate the thinking processes involved in solving a problem. Students will be reluctant to attempt a problem if they do not know where or how to begin;
- Provide time for reflection (journaling, summarizing, and so on) in order to clarify mathematical ideas and relationships;
- Encourage discussion (turn-and-talk, whole class, and so on) to develop and reinforce critical and creative thinking skills.

**Routine Problems**

These are problems in which the way to a solution is generally straightforward. The solution usually involves one or two arithmetic operations.

**Problem Types**

Efforts are made to offer a variety of types of routine problems for students to solve in *Hands on Problem Solving*. As such, those problems focusing on number concepts include the following operations and problem types:
- Addition and subtraction: Beginning unknown, middle unknown, and end result unknown
- Multiplication: Product unknown
- Division: Quotitive and partitive division

These problem types are described in detail in the Implementation of Routine Problems section (see page 26).
Non-Routine Problems

These problems are more challenging for students. Upon first reading, the path to a solution is not immediately evident. Students draw on a bank of strategies (teacher-presented and student-developed) to solve the problem. Possible strategies include the following:

1. Act it out/use materials.
2. Draw a picture/diagram.
3. Look for a pattern.
4. Use logical reasoning.
5. Guess and check.
6. Make an organized list.
7. Make a table.
8. Work backwards.
9. Use an equation.
10. Use simpler numbers.

Some non-routine problem-solving strategies are more appropriate for use at specific grades than others. The chart below provides details for when each strategy is addressed in the Hands-On Problem-Solving program:

Descriptions of these strategies are provided in detail in the Implementation of Non-Routine Problems section (see page 120).

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<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
<th>Grade 6</th>
<th>Grade 7</th>
<th>Grade 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act it out/use materials</td>
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<td>Draw a picture/diagram</td>
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<td>Look for a pattern</td>
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<tr>
<td>Use logical reasoning</td>
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<td>Guess and check</td>
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<tr>
<td>Work backwards</td>
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<tr>
<td>Use an equation</td>
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<td>Use simpler numbers</td>
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Extended Exploration Problems

Extended problems are meant to provide a thought-provoking challenge for students. These problems may present mathematical situations that are slightly beyond the grade-level curricular outcomes, may take the form of an investigation, or may require an extended period of time to solve. In all cases, students are encouraged to use their own strategies to arrive at a solution(s).

Extended problems are open ended, can be investigative in nature, and have multiple entry points to allow for differentiation. They often

- Have more than one solution/answer;
- Can be solved using a variety of strategies;
- Require students to gather their own data;
- Require creative and critical thinking;
- Require more/extended time to solve;
- Make connections to the real world.

Extended problems support the other six “big idea” mathematical processes: communication, connections, mental math, estimation, reasoning, technology, and visualization. The engaging nature of these problems helps students develop perseverance.

Examples and procedures for extended explorations are described in detail in the Implementation of Extended Exploration Problems section (see page 218).

Implementing the Hands-On Problem-Solving Program

*Hands-On Problem Solving* is arranged in a format that makes it easy for teachers to plan and implement, with tasks that relate to specific outcomes/learning expectations established in Canadian curriculum documents.

Program Format

Problem-solving tasks are presented as daily mathematics activities and are organized according to the approximate number of weeks in the school year. As such, there are 40 weeks-worth of problem-solving tasks, consisting of

- 40 routine problems that focus on math topics including number, patterns, measurement, and geometry. These problems are identified as problems 1A through 40A.
- 40 non-routine problems that focus on specific strategies for the grade level. These problems are identified as problems 1B through 40B.
- 10 extended explorations that offer in depth, real-life contexts as the basis for problem solving. These problems are identified as problems 1C through 10C.

Planning your Year of Problem Solving

The three types of problems (routine, non-routine, and extended explorations) are presented in three separate sections of this book, each with its own detailed introduction on implementation. However, it is essential that students focus on all three types of problems throughout the school year. Therefore, it is recommended that teachers do one routine and one non-routine routine problem with students each week, and one extended exploration each month.

In the following section of *Hands-On Problem Solving* a correlation chart identifies the math concepts presented in each lesson of the book. Teachers can refer to this chart to plan problem-solving activities that correspond with other math activities occurring in the classroom. For example, if students are focusing on 2-D shapes in math, the correlation chart will show which problems herein connect to that topic.
Curricular Connections
Efforts have been made to correlate Hands-On Problem-Solving problems with other curricular areas, such as language arts, science, and social studies. For example, children’s literature is referenced in some problems to provide a context. Other problems connect specifically to a science or social studies topic or to a general area of emphasis such as social justice. As teachers become familiar with the problems, they will find opportunities to connect these problems to specific units or topics of study.

Supporting Literacy During Problem Solving
It is important that all students, regardless of reading ability, have the opportunity to participate and succeed in problem solving. As such, some will require additional supports to read and understand the problems presented. To help support students’ literacy skills, consider the following options:

- Read the problem aloud, and have students follow along.
- Read the problem as a class.
- Have students work with partners or in small groups to read and discuss the problem.
- Introduce, discuss, and review related math vocabulary, and display pictorial representations in the classroom (for example, display labelled illustrations of triangles, squares, and rectangles during a lesson in which students must draw on their knowledge of 2-D shapes).

The Questioning Process
During the problem-solving process, it is important for teachers and students to pose questions and to consider various strategies for solving the problem. To encourage these processes, blackline masters of guiding questions have been included for teacher and student use (see page 10). These two templates (one for teacher use and the other for student use) provide suggested questions that can be asked during the problem-solving process.

The blackline masters can be photocopied onto sturdy tag board and laminated for long-term use. Teachers may choose to use these resources during lessons, as they support students in their problem solving. Students can glue their cards into problem-solving file folders or notebooks, or the cards can be placed on desks or tables for use during problem-solving activities.

Additional Resources
For some problem-solving tasks, students might use strategies requiring specific materials, such as hundred charts, number lines, graph paper, dot paper, and so on. These materials can be found in the Appendix at the back of the Hands-On Problem-Solving book (see page 253); teachers are encouraged to photocopy these resources and distribute them to students as needed.

A Note About Pennies
The Government of Canada, in its 2012 Budget, has announced its intention to withdraw the Canadian penny from circulation; as of fall 2012 the Royal Canadian Mint will no longer distribute pennies. However, the Government of Canada has also indicated that

- The penny will remain Canada’s smallest unit for pricing of goods and services.
- The penny will retain its value indefinitely, and consumers can continue to use it in payments for goods and services.

Pennies are included in some problems in the *Hands-On Problem Solving* program. The rationale for this is that using pennies in a problem-solving context

- Supports counting skills;
- Builds familiarity with money;
- Lends itself to grouping and place-value structure of base ten;
- Prepares students for global citizenship. Many monetary systems still include a penny or other coin with a value of 1;
- Can extend to opportunities to explore other Canadian coins that are in circulation but may not be used on a regular basis (for example the 50 cent coin).
The **Hands-On Problem-Solving** series has been designed to complement the mathematics program at any given grade level, with lessons (problems) that address the various mathematics topics and concepts focused on in grade 3. The following chart indicates how lessons (problems) in the program connect to these math topics and concepts.

### Grade 3 Correlation Chart

<table>
<thead>
<tr>
<th>MATHEMATICS TOPIC</th>
<th>LESSON (PROBLEM) NUMBER</th>
</tr>
</thead>
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<tr>
<td><strong>Number</strong></td>
<td></td>
</tr>
<tr>
<td>Skip counting by 3s</td>
<td>11A, 29A, 33A, 1B, 26B</td>
</tr>
<tr>
<td>Skip counting by 4s</td>
<td>24A, 27A, 30A, 1B, 34B, 39B</td>
</tr>
<tr>
<td>Skip counting by 5</td>
<td>15A, 18A, 13B, 26B, 7C</td>
</tr>
<tr>
<td>Skip counting by 10s and 100s</td>
<td>1A, 15A, 32A, 13B, 39B, 7C</td>
</tr>
<tr>
<td>Skip counting by 25s</td>
<td>25A, 28A, 7C</td>
</tr>
<tr>
<td>Representing numbers to 1 000</td>
<td>1C, 6C</td>
</tr>
<tr>
<td>Comparing and ordering numbers to 1 000</td>
<td>26B, 34B</td>
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<tr>
<td>Estimation</td>
<td>4A, 28A</td>
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<td>Place value</td>
<td>12A, 31B, 34B</td>
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<tr>
<td>Fractions</td>
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<td>Mental math</td>
<td>4A, 13A, 30A, 36A, 13B</td>
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<td><strong>Operations</strong></td>
<td></td>
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<tr>
<td>Addition to 50</td>
<td>14A, 18A, 21A, 24A, 33A, 4B, 15B, 16B,</td>
</tr>
<tr>
<td>Addition to 100</td>
<td>7A, 9A, 13A, 32A, 3B, 5B, 20B, 28B, 29B</td>
</tr>
<tr>
<td><strong>Patterns and Relations</strong></td>
<td></td>
</tr>
<tr>
<td>Decreasing patterns</td>
<td>26A, 23B, 25B, 40B</td>
</tr>
<tr>
<td>Unknown variables</td>
<td>8A, 9A, 9B</td>
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These correlations are based on an in-depth review of mathematics curriculum documents from across Canada, including the Western/ Northern Canadian Protocol (WNCP), Ontario, and Atlantic Canada.
### Measurement

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<table>
<thead>
<tr>
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<tr>
<td>Time</td>
<td>32A</td>
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<tr>
<td>Length</td>
<td>30A, 31A, 33A, 34A, 3B, 37B</td>
</tr>
<tr>
<td>Mass</td>
<td>29A, 22B</td>
</tr>
<tr>
<td>Perimeter</td>
<td>33A, 1C, 3C</td>
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</table>

### Geometry

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<tr>
<td>3-D objects</td>
<td>36A, 37A</td>
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### Data

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<tr>
<td>Data collection</td>
<td>40A, 2C, 4C</td>
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<tr>
<td>Bar graphs</td>
<td>38A, 39A, 40A, 2C</td>
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Routine Problems
1A Jamie Counts his Money

Math Topic
Number

Math Concepts
- Number sequences
- Skip counting
- Addition to three digits
- Addition of money

Problem Type
Addition: End result unknown (a + b = ?)

Problem
Jamie has 33¢ in his piggy bank.
His grandparents give him 6 loonies to add to his bank.
Every week after that, Jamie adds 10¢ more to his bank.
How much money does Jamie have in his piggy bank after 5 weeks?

Background Information for Teachers
This problem focuses on addition of money. It will benefit students to have previous exposure to identifying dollars and cents and to understanding their value in representing numbers to 100.

Students may use a variety of strategies to solve this problem, such as the following:
- Use manipulatives, such as play money.
- Draw a picture or diagram.
- Write a number sentence:
  \[ 33 + 600 + 10 + 10 + 10 + 10 + 10 = ? \]
- Add 600 + 33, and then skip count by 10s five times.

To scaffold this problem, consider the following sequence:
- Display various combinations of coins. Have students record the values.
- Display a combination of coins. Add one more coin. Have students create a number sentence and solve.

Think
Provide time for students to read, think, and formulate ideas about the problem.

Talk
Discuss the problem. Pose questions (as outlined on the support cards—see page 10), and encourage students to ask questions as well. Discuss the problem as a class, in small groups, or in pairs.

Solve
\[ 33 + 600 + 10 + 10 + 10 + 10 + 10 = 683 \]
Jamie has $6.83 in his piggy bank.

Share
Have students share their strategies and solutions.

Extend
Present the following extension problem to students:
Jamie earns some money doing chores.
For helping his Dad rake leaves, he gets 3 loonies.
Then he finds a dime and a nickel in the leaf pile!
If he adds this money to his piggy bank, how much will Jamie have altogether?
Jamie Counts his Money

Jamie has 33¢ in his piggy bank.

His grandparents give him 6 loonies to add to his bank.

Every week after that, Jamie adds 10¢ more to his bank.

How much money does Jamie have in his piggy bank after 5 weeks?
Mohammed and Andy Watch a Movie

Math Topic
Number

Math Concepts
- Fraction of a whole
- Comparing fractions

Note: The Problem-Type section is not included with this problem, as students are not expected to use operations to solve the problem.

Problem
Mohammed and Andy are watching a movie. Mohammed watches 7/10 of the movie before falling asleep. Andy watches 5/10 of the movie before falling asleep.

Who watches more of the movie? How much more of the movie does he watch?

Background Information for Teachers
Students may use a variety of strategies to solve this problem, such as the following:
- Use manipulatives, such as fraction pieces.
- Use the visual provided, or draw another picture: draw 2 circles, and divide each one into 10 equal parts. Shade the circles to represent 7/10 and 5/10.
- Use ten frames to show fractions, as in the example below:

Think

Talk

Solve
Mohammed watches more of the movie. He watches 2/10 more of the movie than Andy does.

Share

Extend
Provide students with the following two extension problems:
- The movie is 100 minutes long.
  Mohammed watches for 70 minutes. Andy watches for 50 minutes.
  How many minutes of the movie does each boy miss?
- While they are watching the movie, the boys are eating blueberries.
  Mohammed eats 5/6 of a bag of blueberries. Ali eats a whole bag of blueberries.
  Draw pictures to show how much blueberries each boy eats.
Mohammed and Andy
Watch a Movie

Mohammed and Andy are watching a movie.
Mohammed watches 7/10 of the movie before falling asleep.

Andy watches 5/10 of the movie before falling asleep.

Who watches more of the movie?
How much more of the movie does he watch?
About the Authors

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Lara Jensen, BEd, BA, BPHE, has been a classroom teacher, specialist teacher, ICT integrator, curriculum coordinator, and librarian for the past 18 years at K–8 schools in Canada, Germany, and Switzerland. She holds a certificate in Outdoor and Experiential Education and has worked to incorporate inquiry-based teaching and learning into every classroom. Lara has conducted teacher’s workshops on such topics as mathematics, literacy, international-mindedness, and inquiry.

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Pat Steuart, BEd, is an elementary school teacher who has taught all subjects in primary grades 1 to 4. She currently teaches a multi-age/grades 1–3 classroom. Pat believes in an activity-based approach to teaching and providing opportunities for students to share and discuss their solutions and ideas. She has taught courses in the Faculty of Education at the University of Manitoba and she resides in Winnipeg, Manitoba.