Mathematics Education Research Journal 2002, Vol. 14, No. 2, 87-98

Young Children Posing Problems: The Influence of Teacher Intervention on the Type of Problems Children Pose

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This paper describes the type of problems young children (Grade 1 and Grade 3) generated in problem-posing situations as they worked, on a one-to-one basis, with a student teacher. In the initial stages of the investigation, the children posed one- and two-step problems that reflected the type of experiences the children encountered at school. With guidance, the children began to solve increasingly sophisticated problems that became more open ended and novel. The problem-solving situations provided opportunities for the children to pose problems they enjoyed solving and promoted both a more complex and motivating learning environment. The results indicate that the problem-posing actions of students can be nurtured by teachers' actions.

Problem posing is an important companion to problem solving and lies at the heart of mathematical activity (Kilpatrick, 1987). Problem posing has been used to refer both to the generation of new problems and to the reformulation of given problems (Silver, 1994). In the first instance, "the goal is not the solution of a given problem but the creation of a new problem from a situation or experience" (Silver, Mammona-Downs, Leung, & Kenney, 1996, p. 294). In such situations the problem poser would usually need to consider the nature of the context (including an awareness of who might be asked to solve the problem), and possible solution paths. Several researchers (English & Halford, 1995; Leung, 1996; Lowrie, 1998; Silver, 1995) have found that students usually think about solution paths to problems they have posed, thus establishing another powerful opportunity for learning. Importantly, the problem poser does not need to be able to solve the problem in order for positive educational outcomes to occur.

Literature Review

There are many benefits gained from fostering a problem-posing classroom. English (1997a) argued that problem posing allowed students to generate more diverse and flexible thinking in ways that not only enhanced problem solving but also reinforced and enriched basic mathematics concepts. From a teaching perspective, problem-posing activities reveal much about the understandings, skills, and attitudes the problem poser brings to a given situation and thus become powerful assessment tools (English, 1997a; Lowrie, 1999). Not surprisingly, reports such as those produced by the National Council of Teachers of Mathematics (NCTM, 1989, 1991, 2000) have called for an increased emphasis on problem-posing activities in the mathematics classroom.

Problem posing and problem solving are closely related. As Silver (1995) suggested, problem posing could occur both *prior* to problem solving when problems were being generated from a particular situation or *after* solving a problem when experiences from the problem-solving context are modified or applied to new situations. In addition, problem posing could occur *during* problem solving when the individual intentionally changes their goals while in the process of solving the problem. Such metacognitive processes underlie mathematical power and autonomy.

Since an ability to pose problems is linked to metacognitive thought, it is not surprising that more able students are more successful in generating problems (Ellerton, 1986; Lowrie, 1998). Lowrie (1999), for example, found that talented Grade 3 students were able to modify two-step word problems into problems that were open-ended in nature. English (1997b) suggested that children with strong number sense were more likely to be able to pose appropriate problems than children with limited number sense because they had a better understanding of problem structure.

Interestingly, there are conflicting findings from the research literature concerning a student's capacity to generate problems and their problem-solving ability. Silver and Cai (1993) concluded that students who were able to generate effective problems were not always the most efficient problem solvers. By contrast, several studies (English, 1997a, 1997b; Leung, 1996) have found that broadening children's perceptions of mathematical situations enhances problem-posing development. In these studies, the children who had conceptually sound mathematical ideas tended to pose problems that were well structured and had clear goals. Perhaps the more mathematically able students design better problems as they become more accustomed to essential components of problem structure. English (1997b, p. 188) developed a problem-posing programme that focused on three components: "children's recognition and utilisation of problem structures; their perceptions of, and preferences for, different problem types; and their development of diverse mathematical thinking". The second component of the framework drew attention to children's perception of different problems, including problems they liked and disliked within both routine and nonroutine contexts. When children first pose problems they invariably generate traditional word problems (Lowrie, 1999). Understandably, they are creating the type of problems that they have been exposed to at school. As they become more proficient problem posers they begin to consider other types of problems. English (1997b) found that as Grade 5 children modified traditional problems, they tended to pose more sophisticated problems that required deductive reasoning in order to be solved.

Although some studies have investigated the extent to which children as young as ten years of age design and generate problems (Lowrie, 1999; Lowrie & Whitland, 2000; Silver, Leung, & Cai, 1995), most studies have focused on children in upper-primary or secondary school settings. In general, these studies have provided children with either specific strategies or mathematics content to manipulate as a way of scaffolding their problem posing. English (1997a), for example, encouraged children to focus on key ideas and how these related to problems that were teacher generated before considering situations that might arise from extending these ideas. Then, before posing new problems, the grade 5 children were given a series of generative questions that were intended to help the children design their problems. These questions provided the children with a set of ideas or examples that could be used when they began to pose problems. In other studies (Lowrie & Whitland, 2000; van den Heuvel-Panhuizen, Middleton, & Streefland, 1995), children have been encouraged to verbalise their thinking and consider problems associated with a particular content area (for example, percentages) before posing problems.

It seems to be the case that young children are more likely to be able to pose appropriate problems when they have a meaningful context in which to situate the problem. Providing opportunities for children to scaffold their ideas and understandings is one way of ensuring that the problem-posing contexts are meaningful. Writing problems for friends to solve (Ellerton, 1986; Lowrie, 1998; Stoyanova, 1998) is another way of contextualising problems. The very fact that a student must consider the mathematical ability of another person when engaged in free problem-solving situations requires reflection and careful planning. In order to complete the task successfully, the problem poser might not only focus on the underlying structures of the problem, but also the extent to which the problem solver will be able to interpret the components of the problem. It could also be the case that children need to understand important elements of the problem-solving process (including the way mathematical ideas are related within the context) if they are to generate problems that have a sound structure.

In order to establish problem-solving environments that are motivating for students it is beneficial to consider the type of problems they like to solve. Students' likes and dislikes may differ considerably within a regular classroom. Examining the type of problems individuals pose for themselves and others to solve may provide valuable insights into their mathematical development and help guide future instruction (English, 1997b). Furthermore, problem-posing contexts should encourage students to look beyond the mathematical content they typically focus on—and consider, with increased sophistication, problem representation and strategy selection.

The present study adds to the research literature on problem posing in a number of ways. First, it investigates the problem posing capabilities of children who are only six years of age—with most studies in the past focusing on children aged ten or older. Second, the children had not previously been exposed to teaching-learning situations that encouraged problem posing. As a result, the influence of a scaffolded teaching-learning programme—where individuals worked on a one-to-one basis with a student teacher for a five-week period—could be evaluated critically. Third, the children realised that they were expected to solve the problems they had posed. Consequently, the study established strong links between problem solving and problem posing.

Method

Participants

The investigation involved Grade 1 (n = 25) and Grade 3 (n = 28) children from a school in a large rural city in Australia. These children worked with a cohort of fourth-year undergraduate students (n = 53), on a one-to-one basis, in their final semester of a Bachelor of Education course.

Most of the teaching-learning experiences associated with mathematics in these two grades were derived from the N.S.W Department of Education (1989) *Mathematics K-6* syllabus. Mathematics textbooks were used in each class but the children did not work from one textbook in particular. Although the children were accustomed to working in cooperative-group contexts, only the Grade 3 children were taught explicit cooperative-learning skills. For the Grade 1 children, most problem-solving activities were taken from traditional mathematics textbooks and were almost entirely in a word-problem format. The problem-solving activities presented to the Grade 3 children were selected from more diverse sources and were represented in a variety of visual and verbal forms. Nevertheless, most of the problem-solving activities were entirely teacher generated. Both classroom teachers had indicated that problem-posing environments had not been established in classroom contexts and thus they considered these activities to be relatively novel.

The Problem-posing Sessions

Each student teacher worked with one of the children for one hour per week for five weeks. In most instances, a strong rapport was developed over this period of time. The student teachers developed an understanding of the children's mathematical ability and preference for investigating particular types of problems in addition to a range of affective factors including confidence and task persistence. The teaching-learning sessions were based on the notion that the student teacher would serve both as a role model for designing the problems and as an expert who would provide appropriate "mathematics-knowledge" support. The Brown et al. (1993) notion of an *intentional learning environment* was adapted with the student teacher promoting guided discovery and a model of active inquiry throughout the five sessions. Thus, the children were encouraged to be researchers, teachers, and monitors of their own progress. At all times the children were encouraged to verbalise their thinking as they attempted to make meaning of the knowledge and understandings required to pose and then solve the problems they had designed.

The first session consisted of four distinct components that involved the child 1) posing a problem, 2) discussing approaches that would be required to solve the problem, 3) solving the problem, and 4) reflecting upon the manner in which they solved the problem. In the first instance the children were asked to "write (or tell me about) a mathematics problem you would like to solve". The children appreciated that they were able to seek assistance from the student teacher, but were encouraged to pose the problem on their own. After the child had posed the problem the student teachers posed questions that encouraged the children to a) describe the types of understandings and strategies they would need to consider in order to solve the problem, and b) ascertain why they liked solving the particular problems they had posed. Although the specific questions were influenced by the nature of problem posed, the questions followed a similar structure. The interview protocol included the following questions:

- What do you have to think about to solve this problem?
- What things will you need to help you finish the problem?
- What is going to be the hardest thing to do?
- Will we need to use numbers (maths)?
- When do you think you will need help from me?
- Where should we begin?
- Could we solve the problem another way?

It could be argued that these guided questions not only allowed the children to consider the knowledge and strategies required to solve the problem but also allowed them to consider the extent to which the problem evoked interest. Individuals were then encouraged to solve the problem they had posed.

A second session provided the student teacher with the opportunity to gain insights into the children's overall perception of problem solving. In particular, the extent to which the pupil enjoyed solving the problem, their likes and dislikes with regard to the structure of this type of problem, and how they may be able to make their problem more interesting were considered. The format of this session allowed the children to consider relationships between problem posing and problem solving as discussion moved between the problem they had posed and possible solutions to the problem.

In the following sessions the student teacher had a more active role in the problem-posing process. This role included assisting the pupil to formulate problems that were solvable and encouraging individuals to compose problems they enjoyed solving. Once the team was happy with the task, the student teacher attempted to establish whether the child was able to determine the type of understandings and strategies that would be required to complete the task. Importantly, the children knew that they were able to seek assistance from their "teacher" to solve the task. This added another dimension to the study because the children were not inhibited by their inability to complete computations or solve multi-step problems. Thus, the children were challenged to consider the types of strategies and methods they would need to use in order to complete the task without being restricted by a lack of content-specific knowledge.

It is quite difficult for young children to design appropriate problems without a substantial amount of practice (Ellerton, 1986), specific instruction (Leung, 1996), or guided questioning (Lowrie, 1999). The rationale behind matching a student teacher with each child was to provide support with problem construction. Further, some children required assistance in constructing problems that were challenging but still "solvable" in the given time period. On occasions the student teachers had to use their professional judgement with respect to the degree of input they had in the problem-posing process. As Brown et al. (1993) argued, teachers should be encouraged to invite children to arrive at a mature understanding of a particular problem-solving situation, including as a last resort, explicit instruction. In the present investigation explicit instruction was not required.

Results and Discussion

First Problems: Nature of Problems Posed

It is not surprising that most of the children generated traditional word problems when first asked to "write (or tell me about) a mathematics problem you would like to solve". In total, 83% of children generated traditional one- or two-step word problems with the Grade 3 children posing more two-step problems than those children in Grade 1 (36% and 12%, respectively). The following problems are examples of those that were classified as traditional one- or two-step problems.

> I had 9 Pokemon cards and but I lost 4 of them. How many did I have left? (Year 1, traditional one-step problem).

> I got $4 in pocket money, then $5 then $6 then $7. I bought clothes for my doll that cost $8. How much money did I have left? (Year 1, traditional two-step problem).

A non-typical word problem was classified as a task that involved more than the manipulation of operations. A number of appropriate strategies could be used to solve these problems and there could be more than one solution to the problem. In most cases, the problem solver was required to undertake an activity (usually physically) in order to solve the problem. The following problem, constructed by a Grade 3 pupil, was categorised as a non-typical word problem.

> How many sheets of newspaper would you need to cover the classroom floor? (Grade 3)

It was found that 12% of Grade 1 children and 14% of Grade 3 children posed such problems. One pupil in each class posed a problem that could be classified as open ended—a problem that required the problem solver to go beyond the given information in order to generate a solution. A Grade 1 pupil constructed the following novel problem.

> What would a seesaw look like if you sat on one end and I sat on the other end? (Grade 1)

The pupil who constructed this problem provided a quite elaborate description of how the problems should be solved.

> I know you (the student teacher) weigh more than me so I will be up and you will be down on the seesaw but I need to know how much higher I will be…I will have to draw a picture to get the answer.

Table 1 lists frequencies for the type of problems posed by the children.

Table 1
Initial Problem Posed by the Children

Grade	One-step Word	Two-step Word	Non-typical Word	Novel Problem
Grade 1 (n = 25)	18 (72%)	3 (12%)	3 (12%)	1 (4%)
Grade 3 (n = 28)	13 (46%)	10 (36%)	4 (14%)	1 (4%)
Total (n = 53)	31 (59%)	13 (24%)	7 (13%)	2 (4%)

All of the participants involved in the study were able to generate problems that contained mathematics content. Most of these problems involved the manipulation of computational facts in order to generate a solution. Most teacher-generated problem-solving activities involve such examples, with textbook examples reinforcing this format and structure. Before intervention from the student teacher, it could be argued that there was a strong relationship between the types of problems the children were posing and the problems they were accustomed to solving in the classroom context.

Identification of Knowledge and Processes Required to Solve the Problem

All of the children were able to identify the type of mathematical understandings that would be required to solve the problem they had posed. On occasions the student teacher needed to probe deeply in order to get a response, and in some instances individuals had to start solving the problem before they could identify the appropriate content or processes. This did not mean that all children were able to solve the problem successfully—but that they knew how to complete the task. It could be argued that Silver's (1995) notion of problem solving *prior* to problem posing taking place occurred as children considered the elements or structure of the problem as they posed it. The children who did not solve their problem successfully often lacked the procedural knowledge to solve the problem.

In all, 83% of the children correctly solved the first problem they had posed. Of the nine incorrect responses, most errors occurred with children who had posed one- or two-step problems. The errors were solely calculation errors with children not able to accurately complete basic operations. Interestingly, eight of the nine children who posed non-typical word problems or novel problems were able to solve their task. Table 2 provides a description of the key elements of the problem posed by the children. Most of the Grade 1 children (72%) who designed a one-step word problem needed to apply knowledge associated with addition facts or addition operations in order to solve the problem. On the other hand, one of the Grade 1 pupils (John) designed a two-step problem that required the problem solver to add two numbers then subtract the sum from another number.

> 1 chips cost 60c and 1 drink cost 60c. I gave the tuckshop $2. How much money did I get back? (John, Grade 1, two-step problem)

This type of problem was not given to John in class. When asked where he had seen such problems John responded "my big cousin does these problems." John correctly solved this problem after posing it. Six Grade 3 children used a combination of the four operations to construct their two-step problems. Five of these problems required addition and subtraction algorithms—the other a combination of multiplication and subtraction algorithms.

> Alicia bought 2 drinks for $1.20 each. How much change would she get from $5.00? (Alicia, Grade 3, two-step problem).

Alicia suggested that she would need to "times $1.20 by two then take it away from $5.00." Alicia successfully solved her problem.

Table 2
The Mathematical Content/Processes Identified by the Children as Necessary to Solve the Problem Posed

Content	One-step Word		Two-step Word		Non-typical Word		Novel	
	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3
+ facts/operations	13	5	2	4				
- facts/operations	4	4						
x facts/operations	1	2						
÷ facts/operations		2						
combination (+, -, x, ÷)			1	6		1		
Measurement concepts					3	3	1	1
Space concepts								
Total	18	13	3	10	3	4	1	1

Most of the children posed problems that they were confident they would be able to solve correctly—with incorrect responses involving careless errors on most occasions. This is to be expected when children first engage in problem posing as a classroom task—students are less likely to venture into unfamiliar terrain. Importantly, this makes the instances of non-typical and novel problem solving even more compelling because that is the kind of problem posing we would like children to develop.

Eight of the nine problems posed in this manner contained mathematics content associated with measurement concepts. It could be argued that such problems are among the most difficult for young children to solve, yet the children were capable of posing and solving these problems. Interestingly, these problems were distributed evenly between the two grades. The problems included:

> How long would it take for me to tie your shoes up? (Emily, Grade 1, measurement problem)

> How many more steps would it take for me to walk around the playground equipment and back than it would take you? (Ralph, Grade 3, measurement problem)

When asked to describe how she would solve this problem, Emily suggested "you should close your eyes and pretend that you are doing up your shoe lace and count slowly as you go…You also have to remember that you have two shoes not one." Ralph indicated that he would need to calculate "how many steps it would take for me to go around the equipment and back and then decide how many less steps it would take Jane [his student teacher]…She will take less than me because she has bigger steps".

Later Problems: The Intentional Problem-Solving Environment

There were quite distinct differences between the type of problems the children posed in the first session and the problems they posed in subsequent sessions. It was apparent that the teaching-learning experiences that occurred in these sessions had an immediate impact on the type of problems the children posed—particularly their ability to formulate non-typical word problems or open-ended tasks. Table 3 categorises the first three problems posed by the children. By the time the children had posed their third problem, 12 of the Grade 1 children (48%) and 16 of the Grade 3 children (57%) had posed non-typical or novel problems. Similarly, the number of one-step problems posed by the children decreased markedly over this period of time (Grade 1 one-step problems were reduced from 18 to 5, and Grade 3 one-step problems from 13 to 0). The open-ended tasks exposed the children to a more diverse range of problem structures that encouraged them to talk about mathematics in more sophisticated ways. For example, the following two novel problems were posed by Grade 3 children.

> How much higher would a tennis ball bounce if I dropped it off the second stor[ey] than the first storey? (Grade 3, novel problem)

> If I had $400 what could I do on holiday in Queensland for a week? (Grade 3, novel problem)

In both Grades, as the children became more willing to pose elaborate problems they were less likely to be able to outline the types of understandings and strategies they would need to consider in order to solve the problem (see Table 4).

Table 3
Types of Problems Posed by the Children over the Five Week Period

Problem Posed (sequence)	One-step Word		Two-step Word		Non-typical Word		Novel	
	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3
Problem 1	18	13	3	10	3	4	1	1
Problem 2	9	5	9	14	6	7	1	2
Problem 3	5	0	8	12	10	13	2	3

Table 4
The Type of Problems Posed over the Course of the Program, Number of Children Who Were Able to Identify Key Processes and Count of Appropriate Responses by Grade and Problem Type.

Problem Posed	One-step Word		Two-step Word		Non-typical Word		Novel	
	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3	Gr. 1	Gr. 3
Problem 1	18	13	3	10	3	4	1	1
Identify key processes	18	13	3	10	3	4	1	1
Appropriate solution	15	12	2	7	2	4	1	1
Problem 2	9	5	9	14	6	7	1	2
Identify key processes	9	5	7	12	4	6	1	2
Appropriate solution	8	5	6	10	4	5	1	2
Problem 3	5	0	8	12	10	13	2	3
Identify key processes	5		6	9	7	11	2	2
Appropriate solution	5		5	8	5	9	2	2

Of the 33 two-step or non-traditional problems solved by the Grade 1 children in the collaborative sessions only 20 children (60%) were able to generate a correct solution without assistance. With respect to the Grade 3 children, the proportion correct increased to almost 70%.

Figure 1 illustrates the relationship between the type of problem posed, the children's ability to identify key understandings and processes involved in the problem, and the ability to generate an appropriate solution without assistance. The proportion of children who were able to demonstrate that they were aware of the knowledge and processes required to solve the problem was similar across the grades (72% and 74%, respectively).

The children were less likely to outline and describe potential solution strategies as the problems they posed became more sophisticated. This was probably because the concepts and ideas embedded in the problems were too complex for the children to outline without a considerable degree of reflection. Although the children moved toward solving more sophisticated problems with exposure to the *intentional* problem-solving environment, the proportion of problems that were geometric or measurement based in nature remained quite high throughout the sessions. Of the 28 problems that were classified as either a non-typical word problem or a novel problem, 19 (approximately 66%) contained

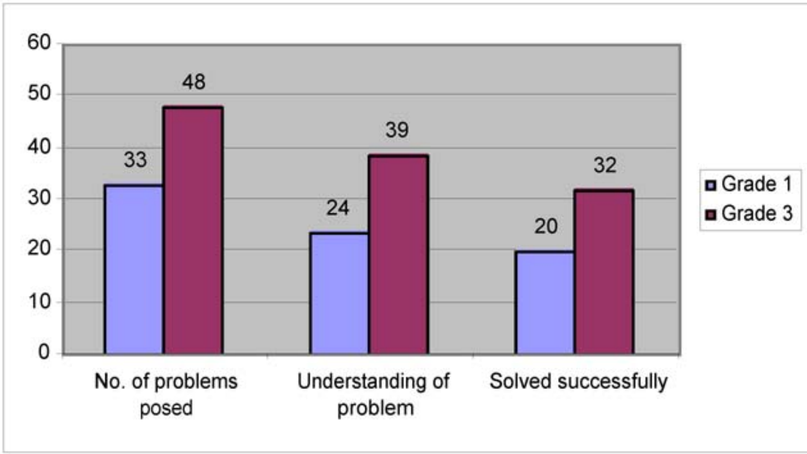

Figure 1. Children's understanding of, and success in solving, problems posed in the interactive situations.

measurement concepts. In contrast, only one of these problems had a strong spatial focus. Thus, the children were more inclined to pose problems that contained concepts associated with length, perimeter, area, or capacity rather than concepts associated with position or orientation. This is an important finding when you consider that measurement and spatial concepts are likely to be integrated in the early years of school.

It was evident that the teaching-learning sessions provided opportunities for the children to pose problems that were more challenging and enjoyable to solve than tasks usually presented in classroom contexts. Some of these children may have felt comfortable solving difficult problems because they appreciated that they were able to seek assistance from the teacher working with them. Importantly, with limited guidance and support, many of these children were able to solve the problems they had posed. Even for the children who could not solve the problems by themselves, the problem-posing environments constructed in this study broadened the children's perceptions of mathematical situations and enhanced their problem-solving development.

Conclusions

All of the children who participated in this study were able to pose problems and consider the type of mathematics content that would be required to complete the task successfully. Although the children were quite young they were able to identify important components of the problem and suggest which mathematical operations would be required to solve the problem. This is consistent with the findings of recent studies with children in Grade 1 (Lowrie, 2000) and Grade 3 (Lowrie & Whitland, 2000). The present study adds to this research by documenting both the structure and content of problems they pose.

When first asked to construct a problem, the children were more likely to pose problems that could be classified as word problems. They were, in fact, posing problems that reflected the type of instructional practice presented in the classroom (van den Heuvel-Panhuizen, Middleton, & Streefland, 1995). Generally, the children appeared to hold narrow views of what constitutes problem solving, although the design of the non-typical word problems and novel problems tended to be more sophisticated than problems posed by Grade 5 children in other studies (see English, 1997b). The older children were more likely to pose complex two-step word problems. This may have been a result of the type of instruction they had been exposed to but also may be an indication of their more sophisticated understanding of the problem-solving process.

In the initial stages of the investigation, it was apparent that the children were able to outline the types of understandings and strategies they would need to consider in order to solve the problems they had posed. All of the children involved in the study were convincing in their description of what they would need to do in order to solve the problem they posed in the first week of the study. However, as the children began to pose problems that were more novel in nature, they were less successful in identifying the types of understandings or processes that would be required to develop a solution. This was particularly the case with the Grade 1 children. Because the more open-ended problems did not have straightforward solutions some of the children were not able to focus their attention on solution paths. As Silver (1994, p. 26) commented, "when one poses a problem, one may not know whether or not the problem will have a simple solution, or a solution at all." On the other hand, these less traditional problems allowed the children to explore, conjecture and investigate in ways not possible in more routine situations. Many of the children who could not identify understandings or processes necessary to complete the task were still able to generate an appropriate solution for their problem—though this development took time. The children's evolving awareness of problem posing was facilitated by the teachers' pedagogical actions in the scaffolded environment.

The movement toward young children generating more sophisticated problems occurred in the *intentional* problem-posing environments that challenged individuals to pose problems they enjoyed solving. Within a short period of time, children began posing problems that were quite different from those they usually solved in the classroom. Although the one-on-one learning environments reported in this study cannot be replicated in typical classroom situations, the study shows how quickly young children begin posing problems that are more complex in nature, and are challenging to solve, than the type of problems presented in textbooks and typical classroom discussions.

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