4 Students' Goals Influence Their Learning

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Research on learning occupies a prominent place in both psychology and education. Psychological research on learning usually focuses on specific learning processes: analogical reasoning, causal inference, discrimination, encoding, retrieval, formation of mental representations, strategy formation, and problem solving (Bransford, Brown, & Cocking, 1999; Brown, Bransford, Ferrara, & Campione, 1983; Siegler, 2006). Methods such as expert–novice comparisons and microgenetic designs have yielded valuable lessons regarding the differences produced by deep mastery of specific content and the variability of learning processes both within and between learners (Chase & Simon, 1973; Kuhn & Franklin, 2006; Siegler, 2006; Staszewski, 1988).

Research on learning has also been conducted by researchers primarily interested in education. Educationally oriented studies of learning often emphasize how to promote deeper learning and reflection through instructional scaffolds, such as designing instructional methods and technologies and comparing the quantity and quality of learning that they elicit (Bransford et al., 1999). The rapid growth of technology in recent years, particularly the connectivity of the Internet and television, has prompted educational researchers to focus on dynamic relations among learners, instructors, instructional content, and instructional media (Cognition & Technology Group at Vanderbilt, 1997; Lin, 2001; Lin & Lehman, 1997).

A general assumption underlying most studies of learning in both psychology and education is that the primary goal of learners is to master the material. Although this assumption might seem obvious, our research indicates that it probably is not valid. Learners' primary goals, at least in the school context, are highly variable, and deep understanding of the material is not always a high priority (Lin, Schwartz, & Hatano, 2005). Instead, learners' goals vary with their social and cultural contexts, including the school context. Instructional techniques and environments that recognize this diversity of goals and that address it can increase learning.

In this chapter, we first describe several studies showing that not all students view learning as their primary goal in school and that students' goals vary between and within cultures. Next, we discuss the effects on students' understanding of how an instructor's background influenced her goals and values, on students' attitudes toward the instructor, and on the quality of collaborative teacher–student problem solving. Finally, we explore how educational approaches that encourage students to adopt the goal of explaining the behavior of other people and of physical devices can improve learning. The overarching message is that the optimization of students' learning requires attention to learner's goals and values, and that instruction which leads students to adopt the goal of deeply understanding the material that is being taught can produce superior learning.

IS LEARNING THE PRIMARY GOAL FOR ALL STUDENTS?

To examine whether learning is students' primary goal in school, Lin and Schwartz (2007) asked 371 fifth-grade students and their 12 teachers to design an ideal student. That is, each fifth grader and teacher was asked to select the five properties that they thought were most important for an ideal student. The students and teachers came from 12 classes in three schools in New York City (four classes per school). School A was in a neighborhood of Harlem that served a predominantly low-income African American population. School B was in a neighborhood in Chinatown that served a predominately low-income East Asian population. School C was in a neighborhood in midtown that served a population of mixed socioeconomic and ethnic backgrounds. As shown in Figure 4.1, school A had the lowest average achievement test scores on both the ELA (a measure of reading skills in English) and a math achievement test, school B had the highest average achievement on both tests, and school C was between on both.

We coded and analyzed the ideal-student properties generated by each student and teacher in this free-response format. The properties that were generated fell into four major categories: learning well, behaving well, performing well, and socializing well. In the present discussion, we mainly focus on the learning and behavior categories, because these are the areas where the mismatches between teachers' and students' goals were most pronounced. Responses that emphasized learning included "being able to understand what is taught," "knowing when he/she makes mistakes," "asking good questions," "explaining ideas clearly," and so on. Responses that emphasized behavior included "not fighting in class," "sitting still when the teacher is lecturing," "raising hands before answering questions," "following class rules," and so on.

Almost all children at all schools generated at least one aspect of good behavior as an important characteristic of an ideal student. However, as shown in Figure 4.2, the percentage of students from the three schools who chose at least one aspect of good learning as an important goal for their ideal student was far more variable. The school with the highest academic achievement (school B) had almost twice as high a percentage of students who considered high-quality learning as an important characteristic of an ideal student as compared to the school with

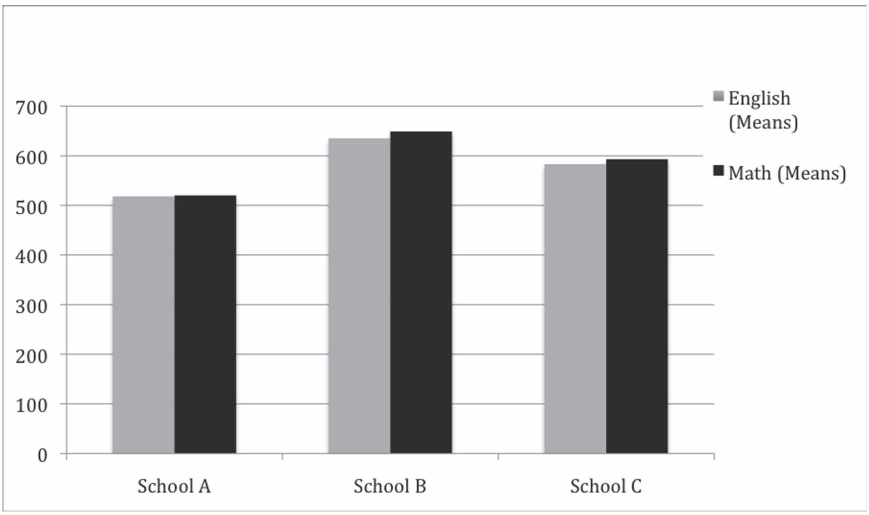

Figure 4.1 Mean english and mathematics achievement test scores for three schools.

the lowest academic achievement (school A)—61% versus 32%. The school with an intermediate level of academic achievement also had an intermediate level of students citing at least one learning goal for their ideal student (45%).

Analyses at the level of individual classrooms yielded converging evidence for this analysis. As shown in Figure 4.3, the highest-achieving class had a much higher percentage of students citing learning goals than the lowest achieving class: 62% versus 26%. Regardless of ethnicity, school types, and socioeconomic status (SES), students with higher academic achievement tended to assign more learning-related properties to their ideal student than did low-achieving students.

Another question of considerable interest was whether students and teachers have different goals for their ideal student. Teachers at all of the schools were far more likely than their students to emphasize learning goals. Almost all teachers—75% of those from school A and 100% of those from schools B and C–included learning goals among the properties of their ideal student. Thus the teachers' goals were not well aligned with the students' goals in that the teachers put far more emphasis on learning goals, even at the school with the highest achievement.

At the level of individual classrooms, 9 of the 12 classes had a significant mismatch between how the teacher and his or her students

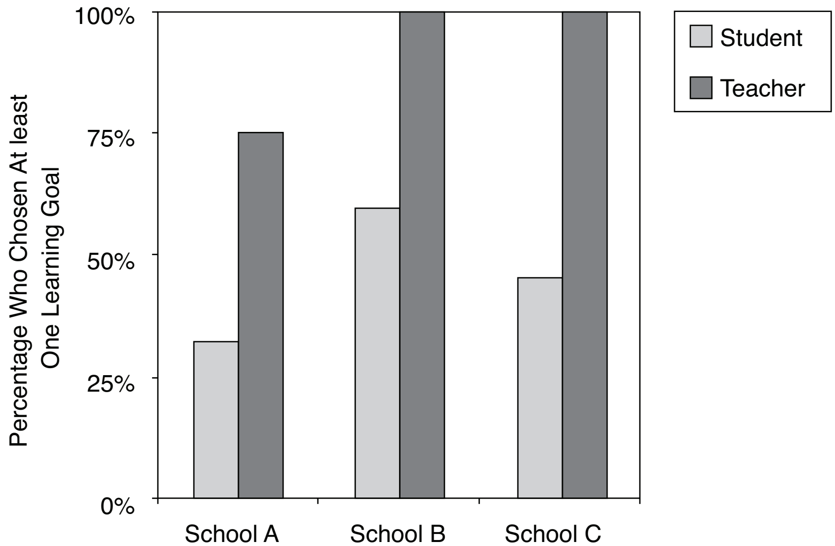

Figure 4.2 Percentage of students and teachers from the three schools who chose at least one aspect of good learning as an important goal for their ideal student.

envisioned an ideal student. The teachers generated almost twice as many learning-oriented qualities for their ideal student as the students. In contrast, the students generated far more qualities relevant to good classroom behaviors and attractive personalities.

We compared the degree of mismatch between students' and teachers' ideal-student characteristics of the two classes that had the highest achievement scores with those of the two classes that had the lowest achievement scores. The mismatch was larger for the low-achieving classes than for the higher-achieving classes (Figure 4.4). Teachers in all four classrooms cited one or more learning goals. The same was true for almost all students in the highest-achieving classrooms (almost 90%). In contrast, only about half of the students in the lowest-achieving classrooms cited any learning goals.

Mismatches between teachers' and students' goals may be one reason why innovative materials and instruction have not fostered the learning of all students (Cuevas, Lee, Hart, & Deaktor, 2005; Lee, 2003; 2004; Lin & Schwartz, 2003). Based on our results to date, many teachers believe that students' major goal is to learn academic content and acquire skills. However, the present data indicate that many students in urban communities do not share this goal or at least do not view it as a high priority. Instructional programs may be more effective if students assign learning goals a higher priority, so that their goals, those of

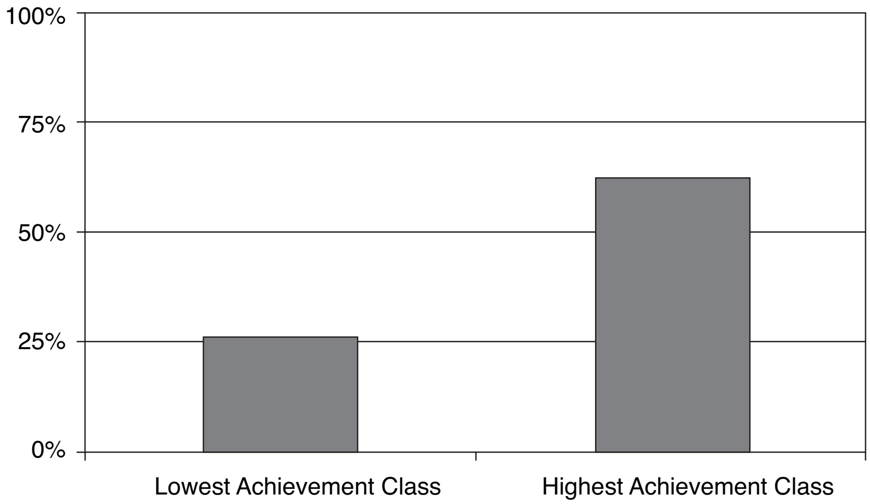

Figure 4.3 Comparison of percentage of students in the highest and the lowest achieving classes who generated learning goals for their ideal student.

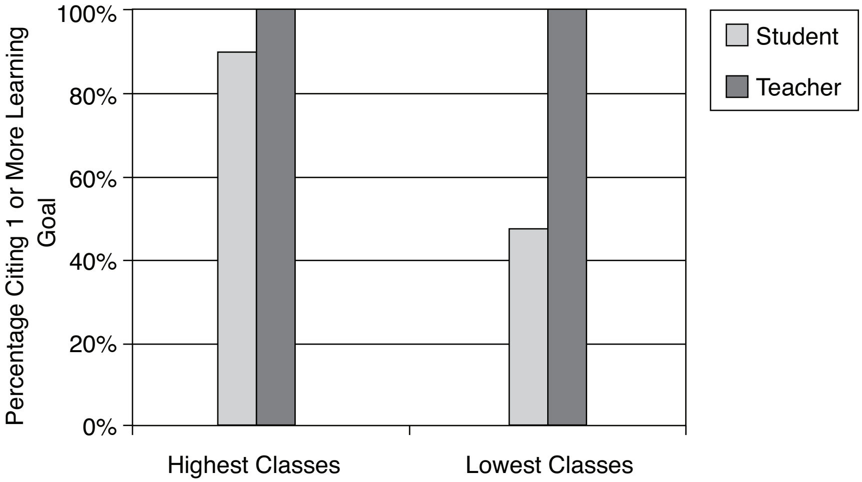

Figure 4.4 Comparison of students and teachers in the highest and lowest discipline and achieving classes who cited one or more learning goals.

teachers, and those implicitly valued in the entire academic system are more closely aligned. Perhaps because educators have assumed that everyone knows that the goal of school is to build knowledge and that everyone adheres to this goal, schools have failed to inculcate this goal in all of their students.

CROSS-NATIONAL DIFFERENCES IN LEARNING GOALS

The findings summarized above indicate that students' goals and values vary greatly among classes and individual students in the United States. We have also examined whether students' and teachers' ideal students vary between cultures. In this study, we asked 280 fifth-grade students and their teachers in both public and private schools in China and in the United States to specify the five most important characteristics of an ideal student (Lin & Schwartz, 2003). The methodology was very similar to that used in the study that contrasted the three schools in New York City.

Figure 4.5 presents the percentage of students and teachers in the United States and China who generated one or more learning characteristics and one or more aspect of good behavior for their ideal student. As in the study of New York City schools, virtually all teachers cited learning goals. The Chinese students in both public and private schools and

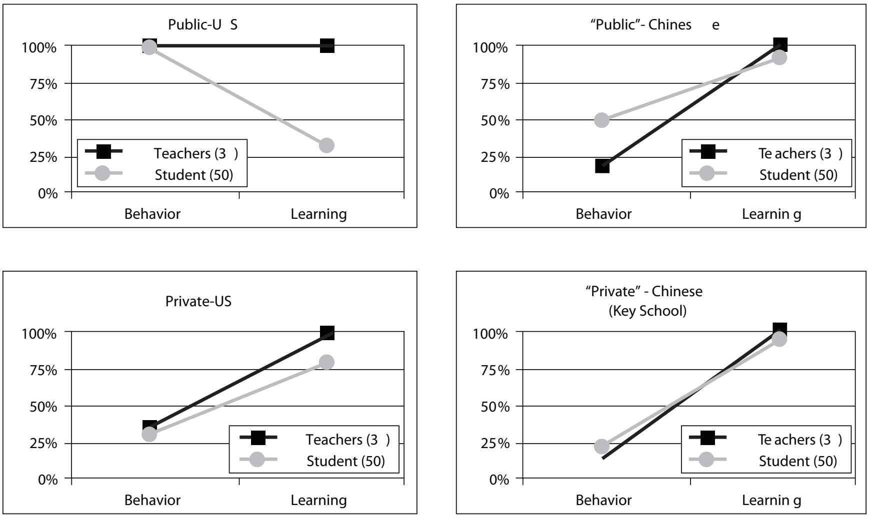

Figure 4.5 Comparisons of ideal student characteristics generated by the U.S. and Chinese public and private schools teachers and students.

the American students in private schools also emphasized learning goals (e.g., "the ideal student explains and understands deeply and tries hard to correct mistakes when they occur"). In contrast, the American public school students were concerned mostly with good classroom behavior (e.g., "does not fight, sits still during lectures"). Apparently, students' goals differ both within cultures (U.S. public and private schools) and between cultures (U.S. and Chinese public schools). It seems clear from Figure 4.5 that some parents, teachers, and schools in the United States as well as in China had communicated successfully to their students that learning well was essential to being a good student.

Significant for this discussion, the American public school teachers, like their students, emphasized good behavior in their choices of properties of ideal students far more than the other groups of teachers. Good behavior is far more of an issue in the American public schools than in the Chinese public schools or in the private schools in both countries. The effect on both students and teachers is to lead them to cite good behavior more often as a characteristic of the ideal student. However, the American public school teachers also cite learning goals as essential, while this goal seems to be lost on many students.

We showed these results to teachers in the U.S. public schools who had filled out the questionnaires regarding the ideal student. The teachers initially expressed surprise at their students' emphasis on good behavior at the expense of learning well. Then they noticed that they, too, were emphasizing behavior more than did the teachers from other schools. The teachers then began to reflect on their own assumptions about teaching, their actions in the classroom, how they could improve their practices, and how they could communicate the centrality of learning to their students.

These findings suggest that the common assumption that all students view learning as their primary goal in attending school is false. Students' goals and values vary greatly depending on the families, teachers, schools, and local cultures within which they live and interact. The results suggest that learning research should include examination of students' goals and values regarding schooling, how teachers can be made aware of their own and their students' values, and how teachers can modify their behaviors so that their students adopt the learning of academic material as an essential goal for themselves.

DOES UNDERSTANDING PEOPLE'S GOALS AND VALUES IMPROVE CROSS-CULTURAL UNDERSTANDING?

If we take seriously the proposition that culture greatly influences goals and values, then the culture of the classroom should influence students' goals and values for learning (Cole, 2002; Nisbett, Peng, Choi, & Norenzayan, 2001; Rogoff, 2003). For example, Rosenthal and Jacobson (1968) concluded that students' performance reflects teachers' expectations; when teachers set more ambitious goals for their students, students learn more than when teachers present them with less ambitious goals. Yet teachers are often unaware of their own values and beliefs (Cohen, 1991; Darling-Hammond, 1997; Lampert, 1990; Staub & Stern, 2002; Thompson, 1992) and find it difficult to describe them (Jacobs, Yoshida, Stigler, & Fernandez, 1997; Jacobs & Morita, 2002). As the saying goes, "Fish will be the last to discover water." This may be one of the reasons why teachers find it difficult to revamp their traditional methods of instruction (Darling-Hammond, 1997; Prawat, 1992; Thompson, 1992). When teachers do not have an explicit understanding of their own goals, it is difficult for them to see how those goals can best be implemented, much less how to change these goals and practices.

In this section, we address the question of whether gaining insight into other people's goals and cultural backgrounds improves our ability to solve problems involving intercultural working relationships. To answer this question, we examined how two types of video-based stories that contained personal background knowledge (PBK) and general cultural background knowledge (GCBK) affected people's understanding of an educational problem and proposed ways of solving it. The problem-solving situation involved a poor relationship between a foreign-born college professor and her students (Lin & Bransford, in press).

The GCBK video included general information about the culture in which the professor grew up: its customs, history, and political and social systems. This video is representative of the ways in which past research has tried to bridge cultural gaps in understanding (for example, see Eini, 2006).

The PBK video represents a very different genre of communication: one that focuses on the individual teacher's goals, values, and formative experiences. Because of this emphasis, it was hypothesized to offer more powerful ways of helping students understand and empathize with the professor and thus motivate them to perform better in her class. The PBK included detailed information regarding the professor's personal experiences and upbringing, the goals and values that she and her family viewed as most important, and why she and her family viewed those goals and values as most important. It also linked this background to her approach to teaching in order to help students understand why she taught the way she did.

The participants were 43 preservice teachers (25 women and 18 men) enrolled in a general educational psychology course. The problem case used in the study was inspired by a real classroom experience that evolved into a highly uncomfortable conflict between a foreign-born college professor and her U.S. college students. As the conflict intensified, many students began to complain to fellow students and other professors that they had been stuck with a foreign-born professor with an accent who assigned too many readings, graded too strictly, and even took attendance. The professor, a new PhD, was trying her best to give the students the highest-quality education she could provide. Over the course of the semester, the sense of disconnection between the professor and her students worsened, and the professor began to search for ways to start afresh and reverse the downward spiral in her students' morale.

A review of the literature, as well as discussions with other foreign-born professors, suggested that this problem was not unique to this particular professor (Alberts, 2008; Ngwainmbi, 2006). One sign of the pervasiveness of the problem is that many university teaching centers have programs to address exactly this kind of issue. The programs that we found were focused primarily on helping new professors adjust to American culture. This approach seemed likely to be helpful but also limited, because it placed little emphasis on helping university students rethink their attitudes about professors (and other people) who were different from them and who came from foreign cultures.

Lin and Bransford (in press) created an experimental version of the student–teacher "disconnect" phenomenon described above. The first step was to build a multimedia casebook that described the behaviors of "Professor X." She was said to assign too much homework and demand too much detail in papers. Included in the casebook was a wide-ranging set of negative statements from students; these mirrored many that had been expressed in the actual case that motivated this study. The casebook, which included video recordings, set the stage for exploring how different treatment conditions might affect participants' subsequent attitudes and questions about Professor X as well as their strategies for resolving the conflict.

The study combined a within-and-between-subjects design. The participants first heard, read, and voiced their opinions about Professor X and her students without having access to any information about either the personal or impersonal cultural background of the professor (baseline measure). Then, the participants were assigned randomly to one of two conditions that differed in the video the students were shown: Personal Background Knowledge (PBK) or General Cultural Background Knowledge (GCBK). The PBK video started with a narrative about how Professor X and her family were affected by the Cultural Revolution in China. Students learned that the entire family was sent from the large city in which they had previously lived a privileged existence to a poor, remote rural area where they lived in a cave, were deprived of books, and had no teachers, formal classes, or other educational opportunities. Because of this experience, Professor X particularly valued educational opportunities, and she adopted learning as her primary goal when, after the Cultural Revolution had ended, she was given the opportunity to attend a university. The video also described the great efforts that Professor X, her family, and the other people who had been exiled made to educate themselves and each other during those hard times. This experience led her to value education strongly and to react negatively when her students seemed to take college education for granted and refused to apply themselves to learning. Her view was that students should make learning their primary goal, relegating parties and other social activities to the background.

Participants in the study who were assigned to the GCBK condition were given general, impersonal information about China. They were told about Chinese history; how Mao copied the first emperor of China to start the Chinese Cultural Revolution; how the ancient Chinese developed their language, political systems, and food; and how modern Chinese celebrate various holidays. There was no information in the GCBK condition about individual Chinese, how they and their families lived through the Cultural Revolution, or how it affected their goals and values. After the students read and watched the PBK or the GCBK video, the researchers collected and analyzed the participants' assessment of Professor X's personality, their explanations of the causes of the conflict between Professor X and her students, and their proposed solutions for resolving the conflict.

The PBK video had strong positive effects on students' understanding and interpretation of the problem situation and on their strategies for solving it. In contrast, the GCBK video tended to worsen negative stereotypes and opinions of both Professor X and Chinese society. This latter outcome was surprising, given the frequent reliance on such videos and the background assumption that general cultural knowledge makes people more empathetic for those from dissimilar backgrounds. If these negative effects prove to be general, the usual general information videos that are used in efforts to build cultural understanding will need to be seriously reconsidered.

Prior to viewing the videotapes, almost all of the students saw the problem as being caused by Professor X and her unrealistic expectations. Students who watched the GCBK video did not change their perceptions. For example, one student wrote, "The professor is a typical Chinese who is rigid, critical, and boring." Another student wrote, "Like most Chinese, she is hard-working and values education but is boring and strict and has few social skills." In contrast, students who watched the PBK—which told about the experiences that influenced Professor X's personal goals and values—altered their thinking. In particular, they integrated Professor X's cultural experiences into their understanding. One student wrote, "The professor realizes what life can be like without education because of her personal cultural experiences. She is a responsible professor, values education, and wants to provide her students with a good education."

To assess the degree to which the two videos influenced the students' understanding of the problems posed by the teacher–student interactions, we asked participants from both conditions to rate the change in their understanding of the problem situation. Our assumption was that if they discerned changes, they would be in a better position to reflect on those changes. At the end of the study, students rated their level of understanding before and after the videotape on a scale of 1 to 5. Both groups of students rated their initial understanding at an average level of 2.1. However, students who were given the personal background information rated their subsequent understanding at an average of 4.2, whereas the students who were given the general cultural background information provided an average rating of 2.4, barely different from the baseline.

Viewing the PBK video also improved the quality of solutions that the students offered to deal with the conflict between Professor X and her students. Relative to both their own baseline performance and the posttest performance of students who watched the GCBK video, students in the PBK condition generated better solutions after watching the video. Their solutions were more detailed and included more specific ideas that could be adopted, such as having both the teacher and the students discuss their backgrounds to improve their understanding of why they emphasized particular educational values and goals. The solutions offered by those who had watched the PBK video were also more likely to include components that would please both the professor and the students rather than being based entirely on the perspective of one side or the other.

The results of viewing the PBK video suggest that knowledge about goals and values can offer teachers and students new explanations for phenomena that are difficult to understand without such knowledge. For instance, in the ideal-student project, the U.S. public school teachers from classrooms with low achievement test scores told us that they did not understand why their implementation of innovative science activities, such as problem-based learning, did not interest their students nearly as much as expected. These innovative science curricula also did not lead to the same increases in learning in their classrooms as in other classrooms described in the literature. These teachers thought that good learning programs should interest and engage all students and that the students who were not engaged must just be dumb, lazy, or both. After participating in the ideal-student study, they realized that neither of these explanations might be right. Instead, they understood that many of their students might not have viewed learning as being among the primary goals of going to school. This knowledge gave the teachers opportunities to revise their instruction in ways that would influence students' goals, with the aim of improving their learning.

These findings are consistent with results from the previously described ideal-student studies. In both cases, students' goals and values differed from expectations, and the goals influenced the students' learning and problem solving. Also in both cases, as a result of experiences that led teachers and students to reflect on their goals, classroom interactions were influenced in positive ways.

Knowledge about students' and teachers' goals also can help us identify new areas of research and new variables for investigation. For instance, the realization that not all students view learning as their primary goal at school led us to investigate variables that we would otherwise not have considered, such as the roles of personal background knowledge in bridging classroom cultural gaps. Currently, we are exploring how explicit instruction in negotiating and handling diverse goal orientations in a science classroom can improve teacher training and whether this has consequences for student learning. We will compare classes where no information about students' and teachers' goals is provided with classes in which the teachers and students discuss each other's goals in the context of solving specific classroom problems (e.g., failure to engage in science projects; poor quality project reports, etc.). We will test how such interventions affect classroom discourse, engagement in learning, and learning outcomes. In addition, we are exploring the benefits of having teachers and students choose attributes for computer agents that participate in learning situations and observe how their ideal agents perform in various situations. A focus on learners' goals and values led us to examine the effects of these and other manipulations that may lead students to revise their goals and learn more effectively.

ENCOURAGING STUDENTS TO ADOPT EXPLANATORY GOALS

Perhaps the prototypical learning goal is striving to explain for oneself how and why events occur. As with learning goals in general, however, such explanatory goals turn out to be assigned a relatively low priority by many U.S. students. The reasonable expectation that students would consistently try to explain unexpected statements found in textbooks and heard from teachers, and unexpected observations of physical events, turns out not to be true. Yet when they do occur, such *self-explanations* enhance learning.

Self-explanations are inferences about causal connections among objects and events. The inferences can concern how procedures cause their effects, how structural aspects of a system influence its functioning, how people's reasoning leads to their conclusions, how characters' motivations within a story lead to their behavior, and so on.

The ability to infer such causal connections is present very early in life. Infants in their first year sometimes infer connections between physical causes and their effects (Leslie, 1982; Oakes & Cohen, 1995). Infants and toddlers also remember events that reflect a coherent causal sequence better than ones in which the causality is unclear (Bauer & Mandler, 1989). Thus the ability to explain the causes of events seems to be a basic property of human beings and influences many aspects of cognition, including memory, problem solving, and conceptual understanding.

Although very young children can generate causal connections, older children and adults often fail to do so. This poses a particular problem in math and science learning. Math and science teachers frequently lament the fact that their students can execute procedures but have no idea why the procedures work. Consistent with the teachers' view that such conceptual understanding is crucial, better and worse learners differ in the frequency with which they try to explain what they are learning. In a wide range of areas—including physics, biology, algebra, and computer programming—the frequency with which learners try to explain the logic underlying statements in a textbook is positively related to their ability to learn the material covered in the textbook (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, DeLeeuw, Chiu, & LaVancher, 1994; Ferguson-Hessler & de Jong, 1990; Nathan, Mertz, & Ryan, 1994; Pirolli & Recker, 1994).

Explaining Observations

In recent years, a number of researchers have attempted to supplement these correlational studies with experimental evidence. That is, they have examined whether encouraging randomly selected students to adopt the learning goal of explaining their observations would increase their learning. These studies have consistently shown that being asked to explain why events occur promotes the more rapid and more frequent discovery of superior rules and strategies than does making the same observations but not explaining them (Calin-Jageman & Ratner, 2005; Chi et al., 1994; Pine & Messer, 2000; Renkl, 2002; Renkl, Atkinson, Maier, & Staley, 2002; Siegler & Chen, 1998).

Requests to explain observations have positive effects even on the learning of children who are just starting school. For example, Siegler

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(1995) examined whether requests to explain why other people reached the conclusions they did would increase 5-year-olds' learning of number conservation. Children were shown two parallel rows, each with the same number of objects (7, 8, or 9) arranged in 1:1 correspondence. At the beginning of each trial, children readily agreed that the two rows had the same number of objects. Then, one of the rows was lengthened, shortened, or left spatially unchanged and had an object added, subtracted, or neither. The experimenter called attention to both spatial and numerical transformations, by saying, for example, "Now I'm spreading this row out and I'm taking an object away from it." Children in all groups were then asked whether they thought the transformed row had more objects, fewer objects, or the same number of objects as the untransformed row.

At the outset of the experiment, children in all groups were given a pretest. Those whose performance indicated that they did not yet know how to solve number conservation problems were randomly assigned to one of three experimental conditions. One group of children received feedback alone; they advanced their answer and were immediately told whether it was correct or incorrect (*feedback-only condition*). A second group of children advanced their answers and were asked, "Why do you think that?" Then they were given feedback on their answers (*explain-own-reasoning condition*). Examining this condition allowed us to determine whether describing one's own reasoning was causally related to learning.

A third group of children advanced their answers, received feedback from the experimenter concerning which answer was correct, and were then asked by the experimenter "How do you think I knew that?" (*explain-correct-reasoning condition*). This last condition, in which the child was asked to explain the experimenter's reasoning, was of greatest interest. Having children explain another person's correct reasoning combines advantages of discovery and didactic approaches to instruction. It is like discovery-oriented approaches in that it requires the child to generate a relatively deep analysis of a phenomenon without being told how to do so. It is like didactic approaches in that it focuses the child's attention on correct reasoning. Thus it combines some of the efficiency of didactic instruction with some of the motivating properties of discovery.

The results indicated that, as hypothesized, encouraging children to explain the reasoning underlying the experimenter's answer resulted in their learning more than feedback alone or feedback in combination

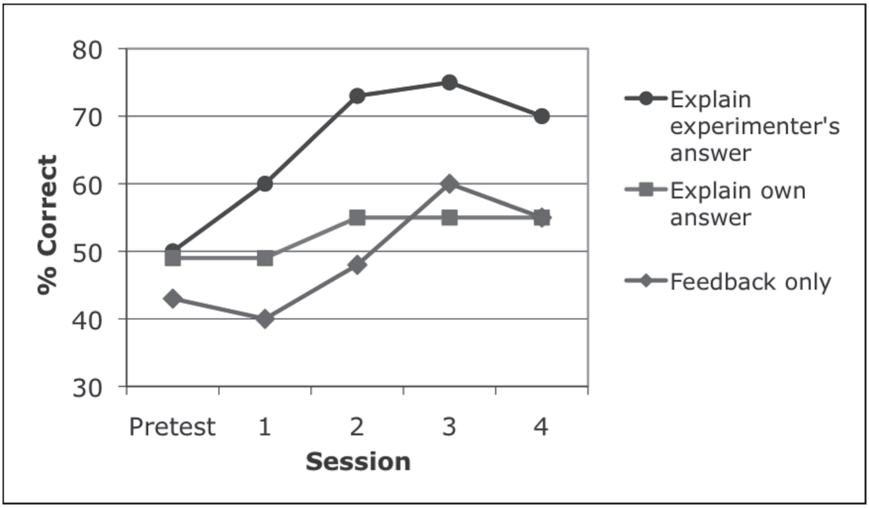

Figure 4.6 Percentage of being correct on pretest and training sessions of number conservation task.

with requests to explain their own reasoning (Figure 4.6). The differential gains were largest on the most difficult problems—those in which relying on the length cue led to the wrong answer. Those children who explained the experimenter's judgment in terms of the numerical transformation that had been performed learned far more than children who generated other types of explanations or those who could not generate any explanation for the experimenter's judgment.

Explaining Both Correct and Incorrect Answers

Other studies have examined the effects of encouraging learners to explain why wrong answers are wrong as well as why right answers are right. Within recent computer simulation models of strategy choice, such as ASCM and SCADS (Shrager & Siegler, 1998; Siegler & Shipley, 1995), the likelihood of a strategy being used on a problem is a positive function of its own effectiveness and a negative function of the effectiveness of competing approaches. For example, although children can solve 2 + 2 very quickly and accurately by counting from 1, they rarely use that approach because they can solve 2 + 2 even more quickly and just as accurately by retrieving the answer from memory. Similarly, a strategy that is not particularly fast and accurate will be used often if alternative approaches are even less effective. Thus the likelihood of using a given strategy can be increased in two ways: increasing its own strength or decreasing the strength of alternative strategies.

The computer simulations suggest that the best way to increase the use of the new, more advanced approaches should be to increase their strength and also to decrease the strength of less advanced approaches. In the context of self-explanation, having children explain both why correct approaches are correct and why incorrect approaches are incorrect should be more effective than explaining only why correct approaches are correct. Explaining how correct answers were generated and why they are correct should increase the strength of correct procedures; explaining how incorrect answers were generated and why they are wrong should decrease the strength of incorrect procedures.

Siegler (2002) tested this prediction on the mathematical equality task developed by Perry, Church, and Goldin-Meadow (1988). This task involves problems of the form A + B + C = ____ + C. Third- and fourth-graders find such problems surprisingly difficult. For example, they usually answer 3 + 4 + 5 = ____ + 5 by writing "12." This answer reflects an add-to-equal-sign strategy, in which the children add all numbers to the left of the equal sign. The next most common answer to the problem is 17, which reflects an add-all-numbers strategy. Both approaches reflect limited understanding of what the equal sign means. The third and fourth graders seem to interpret it either as meaningless or as a signal to add the relevant numbers rather than as an indication that the values on the two sides of the equals sign must be made equivalent.

In Siegler (2002), 87 third- and fourth-graders were presented a procedure that included three phases: pretest, training, and posttest. The pretest and posttest included three types of problems: A + B + C = ____ + C (*C problems*), A + B + C = ____ + B (*B problems*), and A + B + C = ____ + D (*D problems*). These problems differed in the relation of the number after the equals sign to the numbers before it. On C problems, the number after the equals sign was identical to the rightmost number before it (e.g., 3 + 4 + 5 = ___ + 5). On B problems, the number after the equals sign was identical to the middle number before it (e.g., 3 + 4 + 5 = ____ + 4). On D problems, the number after the equals sign did not match any of the numbers before it (e.g., 3 + 4 + 5 = ____ + 6).

The reason for including these three kinds of problems was that they were solvable by different types of strategies that children might induce from the feedback. The strategy of just adding the first two numbers worked on C problems but not on B or D problems. The strategy of locating a number present on both sides of the equals sign and adding the other two numbers works on B and C problems but not on D problems. Two other strategies worked on all types of problems as well as implying conceptual understanding of the equals sign. One of these optimal strategies was to create equivalent values on the two sides of the equals sign (e.g., on 3 + 4 + 5 = ___ + 5, add the numbers on the left and solve 12 = ___ + 5). The other optimal strategy was to subtract from both sides the number on the right side of the equation (e.g., on 3 + 4 + 5 = ___ + 5, subtract 5 from both sides and solve 3 + 4 = ___). These two strategies would be effective on any mathematical equality problem. Thus, presenting these three types of problems made it possible to assess children's use of strategy before and after training.

The training procedure included 10 problems. Those of greatest interest were the 6 C problems, such as 3 + 4 + 5 = ____ + 5. The other 4 items were standard 3-term addition problems with no numbers on the right side of the equals sign, such as 5 + 6 + 7 = ____. These four problems were included to prevent children from developing the approach of blindly adding the first two numbers on all problems. Performance on these foils was virtually perfect in all conditions and is not described further.

Children received the 10 problems under one of three training conditions. Children in the *explain-own-reasoning condition* were asked to answer a problem and then asked to explain why they thought their answer was correct; they were then given feedback (either "You're right, the answer is N" or "Actually, the correct answer is N"). Children in the *explain-correct-reasoning condition* also were presented a problem, asked to answer it, and given feedback as to the correct answer. However, they were then told that a child at another school had answered N (the right answer), asked how they thought the child at the other school had done so, and asked why they thought that was the right answer. Finally, children in the *explain-correct-and-incorrect-reasoning condition* were presented the same procedure except that they were asked to explain not only the reasoning of a hypothetical child who had generated the right answer but also the reasoning of a hypothetical child who had generated a wrong answer. The wrong answer that children in this condition needed to explain matched the answer that would have been generated by the strategy that that child had used most often on the pretest.

As shown in Figure 4.7, children in all conditions learned a considerable amount during training. However, those who were asked to explain both why correct reasoning was correct and why incorrect reasoning was

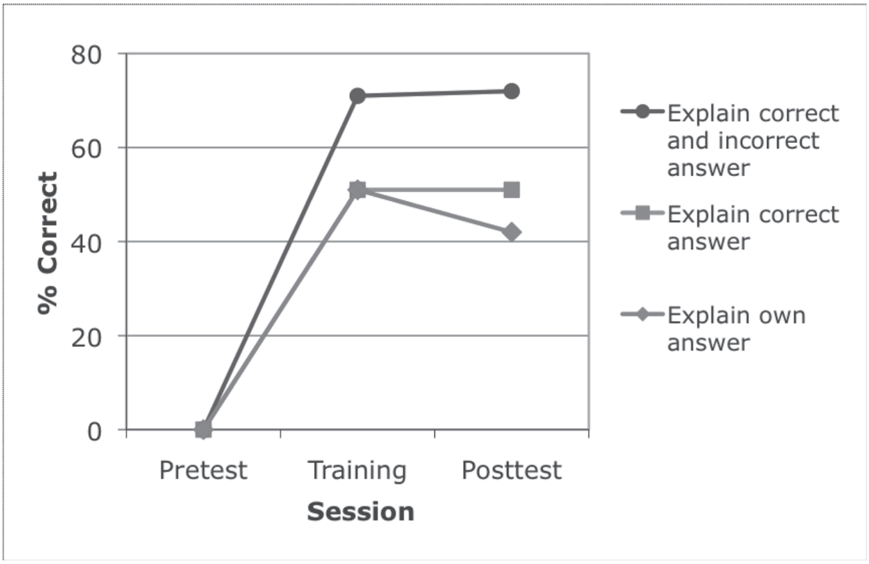

Figure 4.7 Percentage of being correct on pretest, training, and posttest problems on mathematical equality task.

incorrect learned more than those in the other two groups. These differences were maintained on the posttest.

As shown in Figure 4.8, the superior posttest performance of children who explained both correct and incorrect answers during training was due largely to their being better able to solve the problems that required relatively deep understanding (B and D problems). Analysis of changes in explanations during the training phase made clear the source of this effect. Children in all groups greatly decreased their use of the add-to-equal-sign strategy, which had predominated on the pretest. The decrease occurred more quickly in the group in which children needed to explain why that strategy was wrong; but over the six trials, it occurred in all the groups to large extents. However, the groups differed considerably in the new strategies that children adopted. Children who received only feedback and explained their own reasoning largely adopted the simplest strategy, that of adding A + B. In contrast, children who explained both why correct answers were correct and why incorrect ones were incorrect were more likely to use the advanced strategies of equalizing the two sides or eliminating the constant on the right side of the equal sign by subtracting its value from both sides.

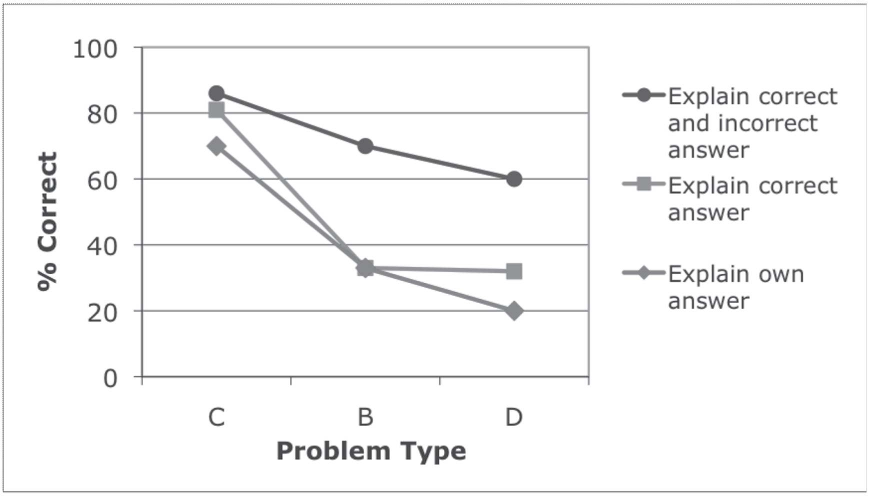

Figure 4.8 Percentage of being correct on posttestof mathematical equality task on three types of problems: Trained (C); near generation (B) and far generalization (D).

The strategies that children adopted to explain correct answers during the training period proved to be very predictive of their own posttest performance. Frequency of adopting one of the two advanced strategies correlated r = .77 with percent correct on the B problems and r = .86 with percent correct on the D problems on the posttest. In contrast, percent use of the A + B explanations during training was strongly negatively correlated with performance on these problems: r = –.70 with percent correct on the B problems and r = –.76 with percent correct on the D problems on the posttest. Thus asking children to explain why correct answers were correct and why incorrect answers were incorrect led to deeper understanding of the problems, as indicated by the adoption of strategies that would solve a broader range of problems rather than just the problems in the initial training set.

These findings suggest that explaining incorrect as well as correct answers improves learning. However, the findings may have stemmed from an idiosyncrasy of the data in this study. Unlike the case in numerous other studies, the group that was asked to explain only why correct answers were correct did not learn more than the group that was given only feedback. Thus the greater effectiveness of explaining both correct and incorrect answers than of explaining only correct answers in that study may have been produced by the idiosyncratically low level of performance of the group that explained only correct answers. This

S___
E___
L___

concern, as well as the desire to replicate the results and extend them to scientific as well as mathematical reasoning, motivated a study by Siegler and Chen (2008) on children's learning about water displacement.

The task was modeled after Inhelder and Piaget's (1958) water displacement problem. On each trial, first- through fourth-graders were shown two identical beakers containing equal amounts of water. Then the children were shown two objects, told their relative sizes and weights, and informed that either both would float or both would sink. They were then asked which object would cause the water to rise higher if one object were placed in each beaker. The problem's complexity stems from the fact that one variable (weight) determines water displacement when objects float, whereas a different variable (volume) determines displacement when they sink. To state the principle more formally: sunken objects displace a quantity of water equal to their volume; floating objects displace a quantity of water equal to their weight.

This problem was of interest for several reasons. First, it requires differentiation of weight and volume, two quantitative dimensions that are highly correlated in the everyday environment and that even adolescents often confuse (Piaget, 1952). It was also of interest because it addresses the concept of interactions among variables in a particularly direct way. In water displacement, the relevance of all variables depends on the states of other variables. Weight matters when the objects float; volume matters when the objects sink; no variable matters across all displacement problems. A third source of interest was that the task is related to a milestone in the history of science: Archimedes' principle of buoyancy. This principle states that a body immersed in a fluid, either wholly or partially, is buoyed up by a force equal to the weight of the displaced fluid. A floating object displaces an amount of fluid equal to its weight, whereas an object that is totally immersed displaces an amount of fluid equal to its volume (as illustrated in the proverbial tale of Archimedes' insight in the bathtub, in which the mathematician realized that he could determine whether the king's crown was made of pure gold by examining the amount of water it displaced).

The study followed the same type of pretest-training-posttest design as the previously described studies of number conservation and mathematical equality. On each trial in all phases of the study, children were shown two identical transparent glasses filled with water to equivalent points and also a pair of cubes, one for each glass. The cubes varied in weight, volume, and type of material (metal, wood, stone). Depending on the type of material, some cubes floated and others sank. On each trial, children heard descriptions of the cubes' relative sizes and weights (e.g., "this block is bigger than the other one, but they weigh the same") and were encouraged to pick them up. Next, children were told, "Imagine that I put this block into this container and that block into that container, and that both float (or sink). Which container will have a higher water level—or will they be the same?"

Children were randomly assigned to three conditions that paralleled the conditions in the Siegler (2002) study of mathematical equality. In all conditions, immediately after children predicted the effects of putting the blocks in the water, they observed the rise in water levels when the blocks were placed in the glasses and were told by the experimenter "You were right" or "No, that wasn't right."

The three experimental conditions differed in what happened after the children received this feedback. Children in the explain-correct-and-incorrect-answers condition were asked, after the feedback, to explain why the correct answer was correct and then why the answer suggested by the status of the variable that was irrelevant on the trial (weight when the object sank, volume when it floated) was incorrect. The exact question regarding why the correct answer was correct depended on whether the child's prediction on the trial was accurate. If the child's prediction was accurate, the experimenter said: "You were right. Now look carefully at what happened and see if you can figure out why." If the child's prediction was inaccurate, the experimenter said: "No, that's not right. Look carefully and see if you can figure out why that wasn't right. Now tell me why the water level in this container is higher than in that one."

Having explained the correct answer, children in this condition were then presented with the wrong answer and asked to explain why it was wrong. They were told, "A child from another school thought that the water level in this container would be higher than in that one after we put these two blocks into the containers. Why do you think she thought this container would have a higher water level? Do you know why she was wrong?" The experimenter responded with a noncontingent "very good" after the children's explanations in this and the other two conditions.

Children in the explain-correct-answers condition were presented with a procedure that was identical to the first part of the procedure presented to children in the explain-correct-and-incorrect-answers condition. Children in the explain-own-answers condition received only the feedback that children in all groups received; they were not asked to explain the outcome after seeing it.

The number of children who used the correct rule on the pretest (defined as at least 15 of 18 correct answers on the three-choice questions) was zero in all three conditions. The number of children who used the correct rule on the posttest was influenced by both the type of explanatory activity in which they engaged and their age/prior knowledge. Children were divided into an older half (third- and fourth-graders) and a younger half (first- and second-graders); not surprisingly, the pretest knowledge of the older children surpassed that of the younger children. Among the older (and more knowledgeable) children, those who were asked to explain both correct and incorrect answers were more likely to use the correct rule on the posttest than were children who were asked to explain correct answers (67% vs. 37%), and children who were asked to explain correct answers adopted the correct rule more often than children who received only feedback (37% vs. 5%). Among the younger (and less knowledgeable) children, frequency of correct rule use on the posttest showed the same trend (33% vs. 20% vs. 6%), but the differences among the three conditions were not significant. Analyses of the relation between the sophistication of the rules children used on the pretest and their likelihood of learning yielded a similar pattern. Those with the most advanced pretest rules were more likely to use the correct rule on the posttest than those whose pretest rules were less advanced. Age and knowledge on the pretest were sufficiently highly correlated that it was impossible to determine which was the better predictor of pretest performance.

Thus, as predicted by Shrager and Siegler's (1998) and Siegler and Araya's (2005) computer simulations of strategy choice, explaining both why correct answers were correct and why incorrect answers were incorrect resulted in greater learning than only explaining why correct answers were correct, which in turn led to greater learning than receiving feedback but not being asked to explain why the outcome turned out as it did. Stated slightly differently, learning is increased by questions that encourage children to adopt the learning goal of understanding why observed outcomes occur and why other plausible outcomes do not occur.

CONCLUSIONS

The research reviewed in this chapter shows that learning goals cannot be taken for granted. Fifth-grade students in public schools often did not mention even one general learning goal among the five characteristics that they chose for their ideal student. Similarly, students ranging from 5-year-olds to those of college age did not appear to spontaneously adopt the learning goal of explaining their observations regarding number conservation, mathematical equality, and water-displacement problems. If they had, the self-explanation manipulations would have been redundant with the students' spontaneous processing and therefore would have had no effect. After all, the encouragement to explain conveyed no content information whatsoever about any of the three problems—only a suggestion that students adopt the goal of explaining why the observed event occurred.

The research reviewed in this chapter also showed that the adoption of learning goals increases learning. Students who were given information about a teacher's background generated better and more balanced solutions to an interpersonal cross-cultural conflict problem than did students who received only general cultural information. Exposure to the personal information led to superior solutions that took into account and addressed both the teacher's and the students' perspectives. Similarly, students who were encouraged to explain both why correct answers are correct and why incorrect answers are incorrect generated deeper and more general solutions to mathematical equality problems than did students who were encouraged only to explain the correct answers or who received feedback only regarding the correct answer.

Both types of findings argue for both educators and researchers to pay greater attention to learners' goals. Educators cannot assume that students have the same learning goals as they do, nor can they assume that students are trying to explain for themselves observations of physical phenomena, statements of teachers, or passages in textbooks. Although the limited adoption of learning and explanatory goals by many students presents a challenge, it also provides an opportunity; that is, the identification of methods for encouraging students to adopt learning goals seems to have considerable potential for improving education. Further research on learning goals and on ways in which teachers can inculcate them can contribute to this effort.

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