Enhancing the Academic Performance of At-Risk College Students via Self-Explanations

Gerald J. Calais
McNeese State University

Research suggests that student enrollment in developmental level courses at the postsecondary education level increases annually. This is occurring because underprepared and/or nontraditional students' reading, writing, or math skills are inadequate to meet the challenges of college-level work. This article focuses on self-explanations as an instructionally effective approach designed to enhance the academic performance of at-risk college students. Implications regarding these findings are discussed.

Developmental education focuses on the needs of students who are classified as underprepared and/or nontraditional and whose reading, writing, or math skills are inadequate to meet the demands of college-level work (U.S. Department of Education, National Center for Education Statistics, 2003). These at-risk students' needs, moreover, are more conspicuous than ever because student enrollment in developmental level courses at the postsecondary education level increases annually (U.S. Department of Education, National Center for Education Statistics, 2004). Central to this article is the assertion that Siegler's (2002) studies on learner generated self-explanations can be employed to enhance the academic performance of at-risk college students in reading, writing, and math.

According to Siegler (2002), a major challenge facing educational establishments centers on the need to design pedagogical procedures that are instructionally effective. In meeting this challenge, designing effective instructional procedures, Siegler and his colleagues employed studies specifically to analyze the encouragement of learners to develop self-explanations. In the next sections, first, the focus is on Siegler and his colleagues' examination of why the encouragement to produce explanations is a desirable instructional technique. Second, what research (Siegler, 1995) has to say regarding self-explanations' effectiveness is discussed. Third, scenarios with sample problems demonstrating the utility of Siegler's learner generated self-explanations for the academic performance of at-risk college students are provided. Fourth, implications for developmental education instructors at the college level are discussed.

Evidence for the Significance of Self-Explanations

Self-explanations, according to Siegler (2002), may be described as inferences that we make relative to causal connections that exist amongst objects or events. These inferences we indulge in, furthermore, have immense applications in real life (e.g., how procedures' causes are related to their effects, how systems' structural features impact their functioning, how our reasoning and conclusions are related, or how characters' motivations within a narrative affect their behavior).

Three Types of Evidence Supporting Self-Explanations

Siegler (2002) and his colleagues focus on three major types of evidence suggesting that self-explanations play a vital role in educational contexts.

Causal connections and problematic math and science instruction. Although learners, ranging from very young children to adults, are capable of generating causal connections, they frequently fail to execute them, even though they are capable of doing so. According to Van Lehn (1983), these occurrences reflect learners' failures of self-explanation.

Individual differences in learning. Gauging the extent to which learners attempt to explain their learning experiences reflects a critical difference between capable and less capable learners. According to Chi, Bassok, Lewis, Reimann, and Glaser (1989), students are able to learn textbook material across a wide range of disciplines more successfully when they are able to logically explain statements read in textbooks.

Math teaching practices in Japan. According to Stigler and Hiebert (1999), Japanese students' levels of learning in math are consistently higher than those of American students because Japanese educators invest more time and energy providing students with explanations, as well as encouraging students to provide their own explanations, stating why mathematical algorithms produce sought after results.

What Does Research Have to Say Regarding the Effectiveness of Self-explanations?

Siegler (2002) and his colleagues were cognizant of the correlation between degree of learning and amount of self explanation; however, only randomized experiments (Siegler, 1995) in which subjects were assigned to conditions encouraging them, or not encouraging them, to utilize self-explanations could establish a link between the two. Hence, subjects in this experiment, who were assigned to a condition encouraging self-explanation, focused on a specific form of self-explanation that required them to explain another person's reasoning. More specifically, subjects were provided with a problem, asked to generate an answer, furnished with feedback that focused on the correct answer, and asked how they thought the experimenter knew that the procedure was correct. This instructional technique has distinct advantages: it is versatile because it can be applied to virtually any task or range of age groups, and it can be easily executed.

Six Critical Issues Regarding the Effectiveness of Self-Explanations

These investigations (Siegler, 1995, 2002) focused on six critical questions regarding the effectiveness of self-explanations, the results of which are summarized below.

Is there both a correlational and a causal relationship between self-explanations and learning? Students in Siegler (1995) and his colleagues' study were assigned to one of three training procedures (feedback-only condition, explain-own-reasoning condition, and explain-correct-reasoning condition), in addressing this issue by using number conservation problems that closely resembled Piaget's classic procedure. The results clearly indicated that the third condition, having students explain the reasoning underpinning the experimenter's answer, was significantly better than providing them with feedback alone or having them explain their own reasoning. This study revealed that students' learning excelled in the third group because of the variability of their thinking prior to the training exercises. According to Chi, de Leeuw, Chiu, and LaVancher (1994) and Bielaczyc, Pirolli, and Brown (1995), motivating children and adults to explain the reasoning typically encountered while reading textbooks bears similar benefits.

Does encouragement to generate explanations benefit both young children and older individuals? Siegler's (1995) findings demonstrated in the affirmative that encouraging one to explain someone else's reasoning benefits five-year-olds, older children, and adults.

Does one derive greater benefits from explaining other peoples' reasoning or from explaining one's own reasoning? Siegler's (1995) findings also demonstrated in the affirmative that learners in varying age groups who are encouraged to explain someone else's correct reasoning derive greater benefits than learners who are asked to explain their own reasoning which may be correct or incorrect.

Our ability to benefit from self-explanations is influenced by what individual difference variables? Siegler's (1995) study also provided an answer to the fourth question: Students' variability of initial reasoning was positively related to individual differences in learning styles.

Do learners derive greater benefits by explaining correct and incorrect reasoning than by explaining only correct reasoning? In order to test this fifth question, Siegler, (2002) employed a task designed by Perry, Church, and Goldin-Meadow (1988) to test students' grasp of mathematical equality. The task itself entailed problems of the form A + B + C = ____ + C and was selected because the problems could be solved by using various types of strategies (e.g., 3 + 4 + 5 = ____ + 5 may have been solved with "12" as the answer or with "17" as the answer. The former strategy is called an add-to-equal-sign strategy, and the latter answer is called an add-all-numbers strategy.) The students, in this study, received one of three training conditions: explain-own-reasoning condition, explain-correct-reasoning condition, and explain-correct-and-incorrect-reasoning condition. Results confirmed that subjects in the "explain-correct-and-incorrect-reasoning condition" significantly outperformed all other subjects because they spent less time switching over to new, more advanced reliable strategies while relinquishing old, less reliable ones. These advantageous results enabled subjects to acquire a deeper understanding of the problems and to successfully transfer this performance throughout the posttest phase.

How does encouraging learners to self-explain produce its effects? In responding to the sixth question, Siegler (2002) asserted that at least four distinct mechanisms enable self-explanations to generate their effects. Increasing the probability that a learner will even search for an explanation or that a learner will be encouraged to attempt an explanation of observed outcomes is one way that encouraging self-explanation generates its effects. Increasing the depth of learners' search for an explanation or the depth of their explanatory endeavors is a second way to accomplish the same ends. Changing learners' access to both effective and ineffective ways of thinking is a third likely mechanism. In essence, instructional techniques that strengthen efficient approaches and simultaneously weaken inefficient ones increase the probability that learners will retrieve efficient techniques and decrease the probability that they will retrieve inefficient techniques. The fourth mechanism entails three general processes associated with the degree of task engagement. One process involves motivational effects because learning that makes sense tends also to be more enjoyable. A second process revolves around depth of processing: learners who are encouraged to self-explain process information more deeply than if self-explanation were not involved. Increased time spent actively thinking about the task constitutes the third benefit. Learning, in other words, is likely to be more successful if learners engage in more time seeking to grasp why correct answers are correct and why incorrect answers are incorrect.

Scenarios with Sample Problems

In this section, four scenarios with sample problems are employed to explain and demonstrate the utility of self-explanations. More specifically, two sample problems (one correctly solved and one incorrectly solved) will be applied to each of two core content areas (math and English) to explain and demonstrate the utility of this approach. In the first math example to be presented, the instructor walks up to the blackboard and writes the correct solution to an exponential problem: $10^2 \times 10^3 = 10^5$, and the following conversation takes place. Instructor: "Why is the answer to this problem a correct solution?" Student: "Well, as I remember, when you multiply any two numbers that have an exponent, the first thing is to be sure that the two numbers that have an exponent must also have the same base. In the example we are looking at, both numbers have base ten, which makes it easy to work with." Instructor: "What else can you tell me?" Student: "Since both numbers do have the same base in your example, I leave that alone and simply add both exponents." Instructor: "Do you remember the general form that we discussed in class to help us remember how to solve this type of problem?" Student: "I believe that when you choose to multiply two numbers that have the same base, you let n^y be one of your numbers with 'y' as its exponent, and you let n^z be your other number with 'z' as its exponent. Then you put it together like this: $n^y \times n^z = n^{y+z}$ Since both numbers have the same base, when you multiply them together, you keep the same base (n), and then you are now able to add both of the exponents (y and z) together." Instructor: "That's pretty good. So how would you rewrite my sample problem above?" Student: "I would rewrite your sample problem like this: $10^2 \times 10^3 = 10^{2+3} = 10^5$." Instructor: "That was excellent. In the past, what did you do that caused you to get the wrong answer to this type of problem?" Student: "Well, in the past, I would remember to make sure that each number with an exponent had the same base, and then I would set up the problem as follows: $10^2 \times 10^3 = 10^{2 \times 3} = 10^6$ My biggest mistake was that I thought that I had to multiply both of the exponents because this type of problem involved multiplication. At that time, this made a lot of sense to me."

At this point, it might be advantageous for the instructor to check for transfer of learning by posing a different exponential problem that, nonetheless, shares some similarities with the original problem. For example, the instructor might write out the correct solution to the following exponential problem: $(X^2)^6=X^{12}$ and conduct the following conversation. Instructor: "Why is the solution to this exponential problem correct?" Student: "Hmmmm. This is somewhat of a different type of problem to me." Instructor: "O.K. Can you tell me how this new problem is like the preceding problem?" Student: "Well, each problem has exponents, and I guess that each problem also uses multiplication." Instructor: "Good. Now can you tell me how each problem is different?" Student: "In the first example, since both numbers already had the same base, all I had to do was add both of the exponents. But, the second problem is different because there is a number that has an exponent, but this same exponent itself is then raised to a power, too." Instructor: "So, would you simply add both exponents in the second example?" Student: "I feel like adding both exponents, but if I did, my answer would be X^8 which is wrong because your answer is X^{12}." Instructor: "So what do you think is happening here in the second example?" Student: "Well, the only way that I am going to get X^{12} is by multiplying 2 x 6." Instructor: "So what can you tell me about this type of problem?" Student: "I suppose that when a number with an exponent is included inside parentheses, and everything inside those parentheses also is raised to an exponent, that you have to multiply both exponents in this type of a problem. In other words, you don't simply add both numbers." Instructor: "So what do you have to do to get the right answer?" Student: "I had to multiply both exponents to get the right answer: 2 x 6 = 12." Instructor: "That's right."

In the second math example, the instructor provides an incorrect solution to the following logarithmic problem by stating that the exponential function $4^{3} = 64$ may be expressed as the following logarithmic function: $\log_3 (64) = 4$. The following conversation occurs. Instructor: "Why is this solution incorrect?" Student: "You told us that problems that have exponents in them and problems that have logarithms in them have a lot in common." Instructor: "Can you be more specific?" Student: "Each type of problem is kind of like the opposite of each other."

Instructor: "O.K. What does that mean?" Student: "Well, for example, if I have the following equation that has an exponent in it, like say $y = a^x$, then I can say that this equation's exponent $x = \log_a(y)$, which is the same thing as saying log to base 'a' of 'y'". Instructor: "And what does that mean?" Student: "In other words, $\log_a(y)$ is the exponent I must raise 'a' (my base) to so that I can come out with 'y.' Now this means, I think, that if $\log_a(y)=x$, then 'x' is the exponent that I must raise 'a' to so that I come out with 'y.'" Instructor: "Correct. And that is the same thing as saying what?" Student: "It means, I guess, that this is the same thing as saying that $a^x=y$. " Instructor: "So how would you correctly express my equation that has an exponent as an equation in logarithmic form?" Student: "I would say that your equation with an exponent in it, $4^3 = 64$ can be written as the following equation that deals with logarithms, $\log_4 (64) = 3$." Instructor: "Good. Why?" Student: "Because I know that $4^3=64$." Instructor: "So why was my solution to this problem wrong? What was I doing wrong?" Student: "If I say that $\log_3(64)=4$, what I'm really saying is that $3^4=64$, which is wrong because $3^4=81$." Instructor: "Good."

At this time, it may be appropriate to check for transfer of learning by posing another logarithmic problem that shares some features with the first sample logarithmic problem. For example, the instructor provides an incorrect solution to the following logarithmic problem by stating that the exponential function $2^6=64$

may be expressed as the following logarithmic function: $\log_6 64=2$. From here, the following conversation takes place. Instructor: "In telling me why the solution to this logarithmic problem is incorrect, please tell me first what this sample problem has in common with the previous sample problem?" Student: "This second sample problem also has the value 64 as a part of the equation to start with." Instructor: "O.K. Now tell me how they differ." Student: "I think what you mean is that this second sample problem has 2 for its base instead of 4, and the exponent here is 6, not 3." Instructor: "So, what do you do from here?" Student: "If I am to do a good job, I need to rewrite the equation that has an exponent, $2^6=64$, into an equation that has a logarithm in it, $\log_2 64=6$." Instructor: "How do you know that this is correct?" Student: "Because $2^6=64$." Instructor: "Correct."

In English grammar, periods and commas are to be placed inside closing quotation marks, and colons and semicolons are to be placed outside closing quotation marks. However, question marks and exclamation marks may be placed inside or outside closing quotation marks. Actually, both question marks and exclamation marks are to be placed inside closing quotation marks only if they actually are a part of the passage being quoted. Otherwise, question marks and exclamation marks must remain outside of the quotation marks. Due to their dual roles, the following scenarios will focus on question marks and exclamation marks being used in quotations. Hence, in the first English grammar problem, a question mark that is part of the passage being quoted is correctly used by being placed inside the quotation marks: Nancy asked Mrs. Smith, "Is it still raining?" The following conversation occurs. Instructor: "Why must this question mark be placed inside the quotation marks?" Student: "In your sample sentence, Mary is the one who actually asks Mrs. Smith if it was still raining. That tells me that her question is actually a part of the passage that is being quoted. So that's why the question mark must be placed inside the quotation marks." Instructor: "That is correct." Note: The instructor decides to check for transfer of learning by providing the student with an example of the correct usage of an exclamation mark inside quotation marks: The soldier shouted, “Halt or I’ll shoot!” (The example with the proper use of exclamation marks inside quotation marks is employed because both exclamation marks and question marks must be used inside quotation marks only when they are part of the quoted passage.) Another conversation occurs. Instructor: “Now, can you tell me why the exclamation mark is used correctly in this sentence?” Student: “In this sentence, the soldier actually tells someone to halt or the soldier will shoot. That tells me that the soldier’s strong way of saying what he had to say is actually a part of the passage that is being quoted. So that’s why the the exclamation mark must be placed inside the quotation marks.” Instructor: “Good.”

In the second English grammar problem, the focus is on the use of question marks and exclamation marks when they are not a part of the quoted passage. Here the instructor provides the student with a sentence that incorrectly places a question mark inside quotation marks, when it should have been placed outside the quotation marks: Did I just hear you say, “Food is expensive?” Another conversation follows. Instructor: “Why is this sentence incorrect?” Student: “Hmmm. I noticed that in this sample sentence that the subject of the sentence is not the one who is actually talking about food. Actually, someone else is talking about food.” Instructor: “Very good. What else can you tell me?” Student: “Well, I guess that since the subject is not the person talking about food, that the question mark needs be placed outside the quoted material because the question mark is not part of the passage that is being quoted.” Instructor: “How, then, would you rewrite this sentence?” Student: “I guess that I would write it this way: Did I just hear you say, ‘Food is expensive’?” Instructor: “Good analysis.” Note: The instructor decides to check for transfer of learning by providing an example with an incorrect usage of an exclamation mark outside quotation marks: Stop saying “no!” (The example with the improper use of exclamation marks outside quotation marks is employed because both exclamation marks and question marks must be used outside quotation marks when they are not part of the quoted passage.) The following conversation takes place. Instructor: "Can you tell me why the exclamation mark is used incorrectly in this sentence?" Student: "This one is tricky." Instructor: "Why?" Student: "Well, in all of the other sentences, you knew from the beginning who was the subject of the sentence and who said what." Instructor: "Go on." Student: "I guess someone is saying no over and over. But that person is not the subject of this sentence because someone is tired of hearing the person who uses the word yes again and again." Instructor: "And therefore." Student: "Just like in the preceding sample sentence, since the subject is not saying yes over and over, then I guess you would have to place the exclamation mark outside the quotation marks because the exclamation mark is not part of the quoted passage." Instructor: "So how would you rewrite this sentence?" Student: "As follows: Stop saying 'no'!" Instructor: "Job well done."

From the aforementioned scenarios with sample problems, students demonstrated a breadth of understanding that enabled them to more deeply process information and to successfully transfer their performance to other sample problems within the same discipline. All of this was possible because they explained why someone else's correct solutions to problems were correct and why someone else's incorrect solutions to problems were incorrect. In essence, these instructional/pedagogical approaches strengthen the students' efficient approaches and simultaneously weaken inefficient ones, which in turn increase the probability that learners will retrieve efficient techniques and decrease the probability that they will retrieve inefficient techniques.

Implications

At-risk students, underprepared and/or nontraditional, enrolled in college level courses must confront and conquer a variety of challenges—both academic and nonacademic—if they are to have a decent opportunity to succeed in academia. Based on Siegler's (1995, 2002) studies, the education community has at its disposal a powerful approach for helping these students meet these academic challenges: self-explanations. This approach succeeds because it centers on the need to design pedagogical procedures that are instructionally effective.

Hence, for instructors of developmental courses, the previously mentioned approach specifically implies that it should provide students with problems that are correctly solved as well as problems that are incorrectly solved. Then the students should be asked to explain why the approaches employed to solve the correctly solved problems are indeed correct and why the approaches selected to solve the incorrectly solved problems are inappropriate. Application of these pedagogical approaches are significantly effective because they increase the degree to which at-risk college students understand what they read or write by enhancing their ability to logically explain textbook information.

References

Bielaczyc, K., Pirolli, P. L., & Brown, A.L. (1995). Training in self-explanation and self-regulation strategies: Investigating the effects of knowledge acquisition activities on problem solving. *Cognition and Instruction*, *13*, 221-252.

Chi, M.T.H., Bassok, M., Lewis, M., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, *13*, 145-182.

Chi, M.T.H., de Leeuw, N., Chiu, M.H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, *18*, 439-477.

Perry, M., Church, R.B., & Goldin-Meadow, S. (1988). Transitional knowledge in the acquisition of concepts. *Cognitive Development*, *3*, 359-400.

Siegler, R. S. (1995). How does change occur: A microgenetic study of number conservation. *Cognitive Psychology*, *28*, 225-273.

Siegler, R. S. (2002). Microgenetic studies of self-explanations. In N. Granott & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning* (pp. 31-58). New York: Cambridge University.

Stigler, J.W., & Hiebert, J. (1999). *The teaching gap.* New York: The Free Press.

U.S. Department of Education, National Center for Education Statistics. (2003). *Remedial Education at Degree-Granting Postsecondary Institutions in Fall 2000,* (NCES 2004-010) Washington, DC. Basmat Parsad and Laurie Lewis. Project Officer: Bernard Greene.

U.S. Department of Education, National Center for Education Statistics. (2004). *The Condition of Education 2004* (NCES 2004-077). Washington, DC: U.S. Government Printing Office.

Van Lehn, K. (1983). On the representation of procedures in repair theory. In H.P. Ginsburg (Ed.), *The development of mathematical thinking.* New York: Academic Press.

Dr. Gerald J. Calais is an Associate Professor at McNeese State University. He received his Ph.D. at UW-Madison in 1985. He has taught both undergraduate and graduate level courses in reading for 22 years at the university level: four years at Fort Hays State University and 18 years at McNeese State University.