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Scientific Reasoning and Achievement in a High School English Course

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The hypothetical-deductive pattern of reasoning, an advanced reasoning model common to science, can be effectively transferred to the study of English and improve both English usage and reasoning skills.

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Though educators in the United States say that they already are teaching thinking and that the physical sciences and mathematics offer opportunities for learning higher-order reasoning skills, most observers agree that the goal of teaching students how to think has not been fulfilled.

The reasons are varied. Perhaps the most serious deficiency is that teachers have never had a clear notion of just what advanced reasoning is—and just what to do to stimulate its development in students.

My own search for effective ways to promote critical thinking during thirty years as a high school English teacher grew out of dissatisfaction with what was offered by various

authors representing the humanities and behavioral and social sciences. Guided by my study of the paranormal and my association with college professors experimenting with various theories of intellectual development, including those of Swiss psychologist Jean Piaget (known for his research of thought processes in children), I turned to the physical sciences for answers.

Emphasizing the *hypothetical-deductive* pattern of reasoning in teaching critical thinking appeared feasible. So by means of a Piagetian-based, systematic instructional theory developed by Anton E. Lawson of Arizona State University, I used this reasoning model in my twelfth-grade English course at Grand Island Senior High in Grand Island, Nebraska, from 1982 to 1991.

This reasoning model, common to science, can be effectively transferred to the field of English (and likely to other curriculum areas, as well as to everyday life); an academic discipline such as English can be used to help students develop higher-order thinking skills of a hypothetical-deductive nature.

Patterns of Advanced Reasoning

Some psychologists have characterized human intellectual development in terms of four major levels or "stages" of thought processes. Piaget called the stages *sensorimotor, preoperational, concrete operational,* and *formal operational.* For this article, the last of these, called by Lawson the *hypothetical-deductive stage,* is of interest. The thinking patterns at this stage are advanced reasoning patterns used in testing alternative hypotheses and are characterized in five ways. Examples in this article are taken from the discipline of English and include language, literature, and composition.

Combinatorial thinking enables the individual to systematically consider all possible relations of experimental or theoretical conditions, even though some may not be realized in nature. For example, one could generate all possible combinations of the several probable causes of Hamlet's depression in Shakespeare's *Hamlet.* One could systematically list the options a novelist has for the outcome of a story given the meaning of the novel, the traits of the characters, and the author's intent. Once generated, these possibilities can then be tested.

In the *identification and control of variables,* the individual recognizes the need to consider all the known variables and to design a test that controls all variables except the one being investigated. One could determine in John Knowles's novel *A Separate Peace* that the differences in the responses to hardship of prep school students Leper and Gene were due to their differences in assertiveness and abilities to communicate. The boys were alike in all other identifiable variables: both were the same age and were sensitive, intellectual, serious students; and both participated in the same activities. Leper dropped out of school to join the military but was discharged during basic training for mental illness. Gene finished school despite a trauma with his roommate, Finny.

Proportional thinking enables the individual to recognize and interpret relationships between relationships in situations described by observable or theoretical variables. While qualitative functional relationships are found in some literary works, seldom if ever are these relationships quantified. For example, one would recognize in Shelley's poem "Ozymandias" (the character Ozymandias calls himself a "king of kings") that a functional relationship exists between the esteem of the dictator's followers and the vast size and quality of the stone statue sculpted as a tribute to him.

Probabilistic thinking enables the individual to recognize that natural phenomena themselves are probabilistic in character and that any conclusions or explanations must involve probabilistic considerations. For example, one may predict that if eight out of ten of fictional character Michael Henchard's interactions with other people in Thomas Hardy's *Mayor of Casterbridge* resulted in a negative impact on the character's life, then his next personal interaction will most likely (a probability of 8 out of 10) have a negative impact as well.

In *correlational thinking,* the individual is able to recognize causes or relations in phenomena under study by comparing the number of confirming and disconfirming cases of hypothesized relations with the total number of cases. In *A Separate Peace,* a chapter analysis of the emotional and physical strengths of roommates Finny and Gene reveals that an inverse correlation exists. At the onset of the novel, Finny is strong and Gene weak, while near the conclusion the opposite is true.

In general, an individual at the hypothetical-deductive stage will have the capabilities to: initiate reasoning with concepts, relationships, abstract properties, axioms, and theories; use symbols to express ideas; apply class inclusion, conservation, serial ordering, and all five characterizations of the hypothetical-deductive stage; plan a lengthy procedure to attain given goals; and be aware and critical of his or her own reasoning process and actively check the validity of his or her conclusions by appeal to other information.

Since we attempt to survive in this world by discovering cause-and-effect relationships, we can examine the existence of such relationships by using the hypothetical-deductive thinking pattern. As shown in Figure 1, this pattern involves the formation of a causal question and subsequent hypotheses, experiments, predictions, results, and conclusions that follow the *if... and... then* pattern of thinking.

Outside the physical sciences, where controlled experiments are set and conducted in a laboratory and where replication is likely, all phases of the hypothetical-deductive pattern, including setting up a "test" or gathering instances with

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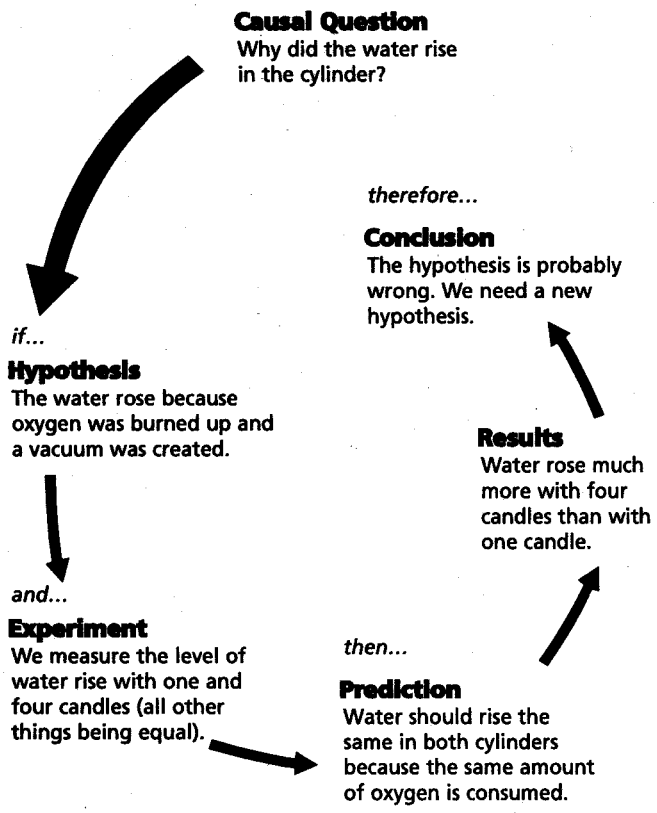

Figure 1. The Hypothetical-Deductive Thinking Pattern. This *if ... and ... then* pattern of thinking requires students to isolate and control independent variables when comparing water rise with one and four candles in a familiar candle-burning experiment. As shown, the initial hypothesis leads to a contradicted prediction and thus should be rejected. Students must now create an alternative hypothesis or hypotheses and start over again until they have a hypothesis that is consistent with the data. (Adapted from *Science Teaching and the Development of Thinking* by A. E. Lawson, ©1995 by Wadsworth, p. 145, permission granted.)

and without the hypothesized cause, are often intuitively used. But with instruction and experience, the phases can be systematically applied to the discipline of English. In Knowles's novel, for example, students can "observe" the interactions of Gene and Finny and explore human relationship issues such as the struggle for self-identity and the development of maturity. The students often note that despite Gene's traumatic involvement in his roommate's death, he successfully matures by the end of prep school and emerges with several positive traits, including independence.

During class discussion, a causal question arises: Why did Gene become more independent? A hypothesis is formulated: Ending his relationship with Finny caused Gene to become more independent. One possible "test" can be designed: Record Gene's behavior before and after the "breakup" with Finny. The prediction is that Gene should show more evidence of independent behavior during and after the breakup than before. The results are: of the twelve observable instances of Gene's behavior before the breakup, nine show dependent behavior; and of the five instances after the breakup, all five show independent behavior. When the interaction and behavior variables are charted in a matrix, we find that fourteen instances fit the predicted pattern; only three do not. The conclusion is that a correlation exists between the two variables. Although a cause-and-effect relationship cannot be shown, a correlation does suggest the hypothesis is supported.

Theory of Reasoning Development

But how does one stimulate the development of hypothetical-deductive thinking? For an in-depth treatment, see Anton E. Lawson's *Science Teaching and the Development of Thinking* (1995). Briefly stated, it can be done through *self-regulation*, a process in which a person actively searches for relationships and patterns to resolve contradictions and bring coherence to a new set of experiences. Implicit in this notion is the image of a relatively autonomous person, one who is neither under the constant guidance of a teacher nor strictly bound to a rigid set of precedents.

Self-regulation begins with *assimilation*, a phase in which an individual's reasoning assimilates a problem situation and gives it a meaning by present reasoning. This meaning may or may not be appropriate. Inappropriateness produces "disequilibrium," a state that, according to Piaget, is the prime mover of initiating a second phase—*accommodation*. This second phase involves an analysis of the situation to locate the source of difficulty and to form new hypotheses and plans of attack. The results of these reflective and experimenting activities are new reasoning patterns that may include new understandings. In short, self-correcting activities (accommodation) are constantly being tested (assimilation) until this alternation of phases produces successful behavior, or *equilibration* as Piaget called it. For example, in Knowles's novel, Gene is on a high tree limb and his roommate Finny is at the other end, preparing to jump into the river. Finny loses his balance, falls to the ground instead, and breaks his leg, which ruins his athletic career. Some students at first declare it an accident. Later, they see the connection between Gene's prior anger and jealousy toward Finny and his jouncing the limb. Students move from wanting to believe that it was an accident toward realizing the relationship between facts and consequences and responsibility.

Experience with the physical world plays an essential role in self-regulation. Argumentation with others over beliefs and the reasons for these beliefs is also a crucial element in self-regulation.

The Learning Cycle and Methods of Instruction

Systematic instruction based on the above theories includes various teaching behaviors and procedures, inquiry-oriented methods, and the learning cycle, all thoroughly described in Lawson's 1995 text. An important model of instruction is the *learning cycle*. Comprising the phases of *exploration*, *term introduction*, and *concept application*, it is designed to encourage students' self-regulation and intellectual development.

Learning cycles in the discipline of English center around the forms of argument and use of the hypothetical-deductive thinking pattern. The *exploration phase* involves students in initial experiences with readings in which they look for exam-

ples of argument used by characters and the author in literary works. Activities are designed in which students raise questions, generate and test hypotheses, attempt to argue in favor of their own hypotheses and against hypotheses of others in the class, and discover weaknesses in arguments. In the *term-introduction phase*, the teacher introduces a new concept or reasoning pattern, such as arguments using method of differences or concomitant variation, or more typical subject-matter concepts such as tone, style, and character. The teacher introduces a new way of thinking about the experiences of the exploration phase.

The *concept-application phase* involves further student experiences of the same concept or reasoning pattern via others' written examples, presenting science activities as extra experiences in forms of argument, and writing their own examples of forms of argument. During this phase, students are able to self-regulate and come to new understandings.

As an example, one learning cycle developed by Lawson involves reasoning used in argumentation by the method of differences and agreement. It incorporates the novel by Knowles, a board game, and a science experiment. In the exploration phase, students play a board game called "Mastermind" in which the discovery of the colors of some hidden pegs requires use of the method of differences and agreement. The method of differences and agreement is basically a control-of-variables strategy in which, in this case, only one peg color or position is varied at a time. In the term-introduction phase, the teacher introduces the testing of hypotheses via controlled experimentation, independent and dependent variables, and relevant forms of argument. In the concept-application phase, students engage in readings and laboratory activities, including a science experiment that requires use of the separation and control of variables just introduced, a discussion of the inability of fictional prep school student Leper to cope, and a one-page position paper in which arguments by differences and/or agreement are used to defend some hypothesized cause-and-effect relationship in the novel, the game, or the science experiment.

A valuable teaching procedure in the exploration phase and often in the concept-application phase is the division of students into groups of three to five to facilitate peer teaching and cooperative learning. (The teacher dominates the term-introduction phase during large group discussion and circulates from group to group during the other phases to dispense questions and assistance.) At the start of the school year, students are tested to determine their level of reasoning ability; based on the results, groups are formed so that each group contains a mix of those who are and who are not hypothetical-deductive thinkers. (For examples of reasoning tests, see Lawson 1995.) These test results are followed over the semester with daily observations and informal discussions to obtain a more accurate measure of reasoning competence. Grouping of students on this basis insures that each group has its own "teacher," the hypothetical-deductive thinker who increases teacher-to-student communication, intragroup discussion, and learning by all group members.

Course Content and One-Year Curriculum

An academic discipline such as English offers experiences that can help students develop higher-order thinking skills or patterns. It seems the triad of language, literature, and composition offers a fertile field for the application of the hypothetical-deductive thinking pattern. In language and composition, myriads of editing problems face any student. A common editing problem, for example, is determining the completeness or incompleteness of a sentence. A student must know that an independent clause is a group of words that contains both a subject and a verb and can stand alone and make sense, while a subordinate clause has a subject and verb but cannot stand alone and make sense. If a sentence happens to be simple, compound, complex, or compound-complex, then the abilities to identify and control variables, possess knowledge of main and subordinate clauses and their various components, and test hypotheses enable the student to answer the question, "Is my sentence complete or is it a fragment?"

Students need considerable practice in clearly stating the questions, hypotheses, experiments, predictions, evidence, and conclusions drawn. To help them think through all the steps in the hypothetical-deductive thinking pattern, the teacher provides questions to elicit questions, hypothesis generation, and hypothesis testing. The classroom environment must encourage discussion and debate about the appropriateness or correctness of language choices, the meaning of literature being read, and the presentation of arguments in composition projects.

The presentation of two major subject-matter variables can be analyzed and sequenced to encourage hypothetical-deductive thinking along the concrete-to-abstract continuum. The first is the type of discourse students read, analyze, and create. The second is the form of argumentation they read, discuss, and generate in support of major assertions in readings, classroom discussions, speeches, and essays.

The curriculum of my two-semester twelfth-grade English course contained literature and composition activities normally expected in a traditional course. These activities were restructured in the form of eighteen learning cycles that included selected modules and hands-on tasks from Lawson's *Biology: A Critical Thinking Approach.* Emphasis was on the introduction of nine forms of argumentation (see Ziegelmueller and Dause 1975), application of the hypothetical-deductive thinking pattern, and the writing of twelve to fourteen persuasive papers, ranging from a one-page letter and a two-page speech to a ten-page research or position paper, the majority of which were based on literary works by British authors. For a more complete course description, see Lawson and Kral's "Developing Formal Reasoning Through the Study of English" in the Winter 1985 issue of *Educational Forum.*

Results of Evaluation

What were the results of embedding hypothetical-deductive thinking patterns in an English course for nine years? Test data suggest that student achievement improved. A former twelfth-

grade student, Tracy L. Wit, with the help of a statistician at the University of Nebraska-Lincoln, conducted a three-year study (1984 to 1987) of control and experimental groups using a pretest and post-test design that included results of the American College Test (ACT) Assessments, taken on nationally scheduled test dates, and a specially designed questionnaire.[1] I then continued this study through 1991.

Selection of the ACT for evaluation purposes blended well with the course content—reasoning and subject-matter knowledge. Students generally took the ACT on nationally scheduled test dates, assuring test security and integrity as well as a measurement educators cared about. The students considered the college admissions test seriously because they perceived it as a step toward reaching an important goal. Raising their scores also offered immediate rewards for their classwork. Moreover, the English portion of the ACT tested a student's ability to reason out answers in multiple-choice form, and it measured knowledge in the areas of punctuation, grammar and usage, sentence structure, rhetorical strategy, organization, and style that called for the application of reasoning as well as memory, the same kinds of skills needed during the editing stage of their composition projects. An unexpected bonus in 1989 was the addition of the science reasoning test to the ACT.

Significant correlations existed between the English ACT gain/loss score and the math, natural science, and composite ACT gain/loss scores. Questionnaires completed by the 206 participants revealed that a factor important to higher scores was application of hypothetical-deductive reasoning. The use of practice English ACT exams in class, or coaching for the test, was another factor in higher scores, though familiarization with the test was a small part of the thirty days of language instruction during the first semester. Our interpretation was that coaching for the test resulted in only a one-point gain, which corroborated an independent finding in a 1987–1988 study conducted by a Rock Island, Illinois, high school. Three other factors inferred as important were related to the variables of test anxiety and motivation: a positive attitude, confidence, and a degree of concern.

Results of the ACT over a seven-year period (1984 to 1991) reveal that, for the English portion of the test, 171 students in the experimental group had an average pretest score of 20.61 and a mean gain of 3.31; while 295 students in the control group had an average pretest score of 19.82 and a mean gain of 1.93. (The number of students in both groups was much greater but not all were willing to take the ACT on the nationally scheduled test dates in the summer and again the following fall or winter. The average number of students per class in both groups was about 25, the norm for almost any class at Grand Island Senior High.)

For the 1990–1991 school year, the first year for which both pretest and post-test scores for the science reasoning portion of the ACT were available, the 15 students in the experimental group had an average pretest score of 20.62 in science reasoning, and a mean gain of 2.00; while the 60 students in the control group had an average pretest score of 22.25, and a mean gain of 0.36. For more comparative test data, refer to Tables I to IV.

Table I

Difference in mean gain on English ACT for seven-year study at Grand Island [NE] Senior High School.

School Year	Group	Number	Pretest Mean	Post-test Mean	Mean Gain
1984-91	**Males**				
	Experimental	62	20.71	24.10	3.39
	Control	124	19.05	21.03	1.98
	Females				
	Experimental	109	20.51	23.74	3.23
	Control	171	20.59	22.48	1.93
	Totals				
	Experimental	171	20.61	23.92	3.31
	Control	295	19.82	21.75	1.93

Note: Scores reported in this study were recorded only for those twelfth-grade college prep students who voluntarily took the ACT exam on nationally scheduled test dates twice—once in June (pretest) and again in either October or December (post-test).

Table II

Comparative average scores on English ACT test for each of the seven years in the study.

School Year	Grand Island [NE] English ACT Avg.	Nebraska English ACT Avg.	National English ACT Avg.
1984-85	18.7	18.8	18.1
1985-86	19.9	19.1	18.5
1986-87	20.3	19.1	18.4
1987-88	20.2	19.3	18.5
1988-89	20.6	19.0	18.4
1989-90*	22.5	21.0	20.5
1990-91	21.3	20.7	20.3

Note: The ACT was revised in 1989. The state and national test scores were provided courtesy of American College Testing, Iowa City, Iowa.

Discussion

The results were significant. Although various intervening factors could have affected the equivalency of the experimental and control groups, thereby skewing the results, the evidence suggests they can be ruled out.

Members of both groups were randomly assigned by school counselors to the eight to ten sections of the same course annually taught by four different teachers without regard to any student variables other than scheduling availability. Nearly all had previously taken a similar number of "core" courses, and the vast majority scholastically ranked in the top half of their graduating class.

Analysis of membership for the seven years reveals no gender or high-achiever bias between the groups. In the experimental group, 36 percent of the students were male, 64 percent female; in the control group 42 percent were male, 58 percent female. In the experimental group, 38 percent of the males and 48 percent of the females ranked in the top 15 per-

Table III

Difference in mean gain on Science Reasoning ACT for the one year in the study that both pretest and post-test scores were available.

School Year	Group	Number	Pretest Mean	Post-test Mean	Mean Gain
1990-91	**Males**				
	Experimental	7	22.00	24.00	2.00
	Control	35	22.11	22.54	0.43
	Females				
	Experimental	8	19.25	21.25	2.00
	Control	25	22.40	22.68	0.28
	Totals				
	Experimental	15	20.62	22.62	2.00
	Control	60	22.25	22.61	0.36

Note: The science reasoning portion of the ACT was first instituted in the 1989-90 school year. Thus the June 1989 ACT did not yet have a science reasoning portion, making 1990-91 the first year in which both science reasoning pretest and post-test scores were available.

Table IV

Comparative average scores on Science Reasoning ACT test for one year in the study.

School Year	Grand Island [NE] Sci. Reason ACT Avg.	Nebraska Sci. Reason ACT Avg.	National Sci. Reason ACT Avg.
1990-91	21.4	21.3	20.7

cent of their graduating class; in the control group, similar ranking was achieved by 30 percent of the males and 40 percent of the females.

Although a Hawthorne effect may have operated in the experimental classes during the first year or two of the change to new methods and materials, such an effect surely could not account for the differences between the experimental and control group classes sustained over several years.

One cannot rule out the possibility that the greater gains may be related to the particular teacher involved rather than the instructional methods and emphasis on reasoning, since I was the only teacher assigned to the experimental classes. However, prior to my adoption of the new methods and materials, my students displayed no such reasoning improvements. Moreover, such methods have been applied in a wide variety of science classes in which the instructor variable was controlled and have shown comparable reasoning gains. (See Lawson 1995.)

Anecdotal evidence also shows that students in the experimental group benefited from the emphasis on hypothetical-deductive reasoning and the inclusion of several science activities in the class. Their position papers revealed much use of: testing of hypotheses; application of more advanced forms of argument, such as argument by example (probability) and correlation; and far more adeptness in critical analysis of assertions by authors, the instructor, and other students. Student behavior in small group activities revealed, after the initial learning cycles, that they not only enjoyed the shift to active learning but realized more quickly than traditional students that they, not authority figures in their lives, were ultimately responsible for their education.

The experimental classroom looked less orderly than those involving traditional methods, but the course was structured and student-centered. Teaching style was modified to involve less lecturing but continued intervention with questions, suggestions, and directions during both small group and large group discussions. Demands that students care about improving their editing skills for use during the latter stages of their writing projects remained.

Conclusion

This lengthy experimental research in English shows that the hypothetical-deductive reasoning pattern via the Piagetian-based instructional theory designed by Lawson can be embedded into and successfully transferred across various curricula with a measurable improvement both in reasoning and subject-matter achievement. The research also defines critical thinking with more clarity and preciseness, and shows us how it can be encouraged in actual practice. The above findings are timely, for as the Rockefeller Foundation urged in its 1980 study *The Humanities in American Life*, critical thinking should be viewed as a basic skill on all educational levels.

Note

1. The ACT is offered nationally in June, October, December, February, and April. In this study, "pretest" refers to the ACT offered in June, prior to the school year. "Post-test" refers to either the ACT offered in October or the one offered in December, whichever a particular student opted to take. Minimum score is 1; maximum is 36.

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