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Giftedness and Expertise

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ABSTRACT

This monograph explores the relationship between expertise and giftedness, and presents a model of intelligence as developing expertise. The argument, advancing that of Sternberg (1998), is that the traditional view of what intelligence is and of what intelligence tests measure may be incorrect. An alternative view is that of intelligence as developing expertise and intelligence tests as measuring an aspect—typically a limited aspect—of developing expertise. Developing expertise is defined here as the ongoing process of the acquisition and consolidation of a set of skills needed for a high level of mastery in one or more domains of life performance.

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EXECUTIVE SUMMARY

This monograph explores the relationship between expertise and giftedness, and presents a model of intelligence as developing expertise. Traditionally, IQ has been used as the primary measure of giftedness in children, and hence was considered an important predictor of success in adulthood. However, there is increasing recognition that giftedness is more than intellectual ability, and that intellectual ability is more than IQ. Sternberg's research on the triarchic theory in education supports a broader conceptualization of ability. Yet it is still unclear as to what distinguishes gifted from non-gifted children.

In adulthood, giftedness is often viewed in terms of expertise. We rarely use conventional intelligence tests with adults to identify which adults are "gifted." What is viewed as gifted is expertise in one's field, whatever that field may be. The expert is someone who has reached levels of performance not matched by the majority of peers.

The concept of expertise also can be applied to giftedness in childhood. Because expertise is relevant to the behaviors that are most valued by society at the particular stage in life, the gifted child can be considered an expert in school achievement and taking intelligence tests. This raises the question of how expertise is developed, be it in school or in one's field. The question of whether expertise is developed through practice or an inherent ability has implications for the identification and instruction of gifted students.

Table of Contents

Table of Contents (continued)

List of Tables

List of Figures

Giftedness and Expertise

Robert J. Sternberg
Elena L. Grigorenko
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Intervention Study I—Intelligence as Developing Expertise

Robert J. Sternberg

Introduction

The conventional view of intelligence is that it is some relatively stable attribute of individuals that develops as an interaction between heredity and environment. Factor analysis and related techniques then can be used on tests of intelligence to determine the structure of intellectual abilities, as illustrated by the massive analysis of Carroll (1993).

Sternberg's (1998a) argument is that this view of what intelligence is and of what intelligence tests measure may be incorrect. An alternative view is that of intelligence as developing expertise and intelligence tests as measuring an aspect—typically a limited aspect—of developing expertise. Developing expertise is defined here as the ongoing process of the acquisition and consolidation of a set of skills needed for a high level of mastery in one or more domains of life performance. Good performance on intelligence tests requires a certain kind of expertise, and to the extent this expertise overlaps with the expertise required by schooling or by the work place, there will be a correlation between the tests and performance in school or in the work place. But such correlations represent no intrinsic relation between intelligence and other kinds of performance, but rather overlaps in the kinds of expertise needed to perform well under different kinds of circumstances. The goal of this study is to carry the argument made by Sternberg (1998a) a step further by showing that a conjunction of research results that would seem puzzling and contradictory when taken together make sense as a whole when considered from the standpoint of ability tests as measuring developing expertise.

There is nothing privileged about intelligence tests. One could as easily use, say, academic achievement to predict intelligence-related scores. For example, it is as simple to use the SAT-II (a measure of achievement) to predict the SAT-I (a measure formerly called the Scholastic Assessment Test and the Scholastic Aptitude Test) or vice versa, and of course, the levels of prediction will be the same. Both tests measure achievement, although the kinds of achievements they measure are different.

According to this view, although ability tests may have temporal priority relative to various criteria in their administration (i.e., ability tests are administered first, and later, criterion indices of performance, such as grades or achievement test scores, are collected), they have no psychological priority. All of the various kinds of assessments are of the same kind psychologically. What distinguishes ability tests from other kinds of assessments is how the ability tests are used (usually predictively) rather than what they measure. There is no qualitative distinction among the various kinds of assessments. All tests measure various kinds of developing expertise.

Conventional tests of intelligence and related abilities measure achievement that individuals should have accomplished several years back (see also Anastasi & Urbina, 1997). Tests such as vocabulary, reading comprehension, verbal analogies, arithmetic problem solving, and the like are all, in part, tests of achievement. Even abstract-reasoning tests measure achievement in dealing with geometric symbols, skills taught in Western schools (Laboratory of Comparative Human Cognition, 1982). One might as well use academic performance to predict ability-test scores. The problem regarding the traditional model is not in its statement of a correlation between ability tests and other forms of achievement but in its proposal of a causal relation whereby the tests reflect a construct that is somehow causal of, rather than merely temporally antecedent to, later success. The developing-expertise view in no way rules out the contribution of genetic factors as a source of individual differences in who will be able to develop a given amount of expertise. Many human attributes, including intelligence, reflect the covariation and interaction of genetic and environmental factors. But the contribution of genes to an individual's intelligence cannot be directly measured or even directly estimated. Rather, what is measured is a portion of what is expressed, namely, manifestations of developing expertise, the kind of expertise that potentially leads to reflective practitioners in a variety of fields (Schon, 1983). This approach to measurement is used explicitly by Royer, Carlo, Durfresne, and Mestre (1996), who have shown that it is possible to develop measurements of reading skill reflecting varying levels of developing expertise. In such assessments, outcome measures reflect not simply quantitative assessments of skill, but qualitative differences in the types of developing expertise that have emerged (e.g., ability to understand technical text material, ability to draw inferences from this material, or ability to draw about "big ideas" in technical text).

According to this view, measures of intelligence *should* be correlated with later success, because both measures of intelligence and various measures of success require developing expertise of related types. For example, both typically require *metacomponents* of thinking: recognition of problems, definition of problems, formulation of strategies to solve problems, representation of information, allocation of resources, and monitoring and evaluation of problem solutions. These skills develop as results of gene-environment covariation and interaction. If we wish to call them *intelligence*, that is certainly fine, so long as we recognize that what we are calling intelligence is a form of developing expertise.

A major goal of work under the point of view presented here is to integrate the study of intelligence and related abilities (see reviews in Sternberg, 1990, 1994a) with the study of expertise (Chi, Glaser, & Farr, 1988; Ericsson, 1996; Ericsson & Smith, 1991;

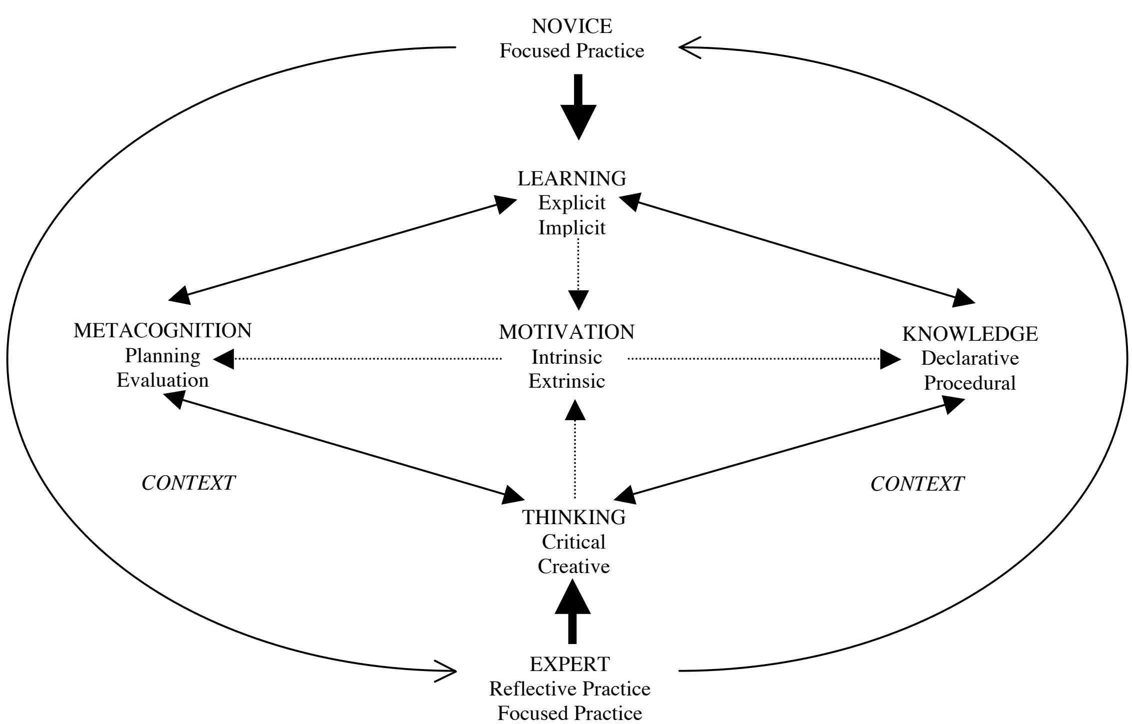
Hoffman, 1992). These literatures, typically viewed as distinct, are here viewed as ultimately involved with the same psychological mechanisms.

The Specifics of the Developing-expertise Model

The specifics of the developing-expertise model are shown in Figure 1.1. At the heart of the model is the notion of *developing expertise*—that individuals are constantly in a process of developing expertise when they work within a given domain. They may and do, of course, differ in rate and asymptote of development. The main constraint in achieving expertise is not some fixed prior level of capacity, but purposeful engagement involving direct instruction, active participation, role modeling, and reward.

Elements of the Model

The model of developing expertise has five key elements (although certainly they do not constitute an exhaustive list of elements in the development of expertise): metacognitive skills, learning skills, thinking skills, knowledge, and motivation. Although it is convenient to separate these five elements, they are fully interactive, as shown in the figure. They influence each other, both directly and indirectly. For example, learning leads to knowledge, but knowledge facilitates further learning.



<u>Figure 1.1.</u> Developing-expertise model.

These elements are, to a large extent, domain specific. The development of expertise in one area does not necessarily lead to the development of expertise in another area, although there may be some transfer, depending upon the relationship of the areas, a point that has been made with regard to intelligence by others as well (e.g., Gardner, 1983).

In the theory of successful intelligence (Sternberg, 1985, 1997a), intelligence is viewed as having three aspects: analytical, creative, and practical. Our research suggests that the development of expertise in one creative domain (Sternberg & Lubart, 1995) or in one practical domain (Sternberg, Wagner, Williams, & Horvath, 1995) shows modest correlations with the development of expertise in other such domains. Psychometric research suggests more domain generality for the analytical domain (Jensen, 1998). Moreover, people can show analytical, creative, or practical expertise in one domain without showing all three of these kinds of expertise, or even two of the three.

1. Metacognitive skills. Metacognitive skills (or metacomponents—Sternberg, 1985) refer to people's understanding and control of their own cognition. For example, such skills would encompass what an individual knows about writing papers or solving arithmetic word problems, both with regard to the steps that are involved and with regard to how these steps can be executed effectively. Seven metacognitive skills are particularly important: problem recognition, problem definition, problem representation, strategy formulation, resource allocation, monitoring of problem solving, and evaluation of problem solving (Sternberg, 1985, 1986). All of these skills are modifiable (Sternberg, 1986, 1988; Sternberg & Spear-Swerling, 1996).

2. Learning skills. Learning skills (knowledge-acquisition components) are essential to the model (Sternberg, 1985, 1986), although they are certainly not the only learning skills that individuals use. Learning skills are sometimes divided into explicit and implicit ones. Explicit learning is what occurs when we make an effort to learn; implicit learning is what occurs when we pick up information incidentally, without any systematic effort. Examples of learning skills are selective encoding, which involves distinguishing relevant from irrelevant information; selective combination, which involves putting together the relevant information; and selective comparison, which involves relating new information to information already stored in memory (Sternberg, 1985).

3. Thinking skills. There are three main kinds of thinking skills (or performance components) that individuals need to master (Sternberg, 1985, 1986, 1994b). It is important to note that these are sets of, rather than individual, thinking skills. Critical (analytical) thinking skills include analyzing, critiquing, judging, evaluating, comparing and contrasting, and assessing. Creative thinking skills include creating, discovering, inventing, imagining, supposing, and hypothesizing. Practical thinking skills include applying, using, utilizing, and practicing (Sternberg, 1997a). They are the first step in the translation of thought into real-world action.

4. Knowledge. There are two main kinds of knowledge that are relevant in academic situations. Declarative knowledge is of facts, concepts, principles, laws, and the like. It is "knowing that." Procedural knowledge is of procedures and strategies. It is "knowing how." Of particular importance is procedural tacit knowledge, which involves knowing how the system functions in which one is operating (Sternberg et al., 1995).

5. Motivation. One can distinguish among several different kinds of motivation. A first kind of motivation is achievement motivation (McClelland, 1985; McClelland, Atkinson, Clark, & Lowell, 1976). People who are high in achievement motivation seek moderate challenges and risks. They are attracted to tasks that are neither very easy nor very hard. They are strivers—constantly trying to better themselves and their accomplishments. A second kind of motivation is competence (self-efficacy) motivation, which refers to persons' beliefs in their own ability to solve the problem at hand (Bandura, 1977, 1996). Experts need to develop a sense of their own efficacy to solve difficult tasks in their domain of expertise. This kind of self-efficacy can result both from intrinsic and extrinsic rewards (Amabile, 1996; Sternberg & Lubart, 1996). Of course, other kinds of motivation are important, too. Indeed, motivation is perhaps the indispensable element needed for school success. Without it, the student never even tries to learn.

6. Context. All of the elements discussed above are characteristics of the learner. Returning to the issues raised at the beginning of this study, a problem with conventional tests is that they assume that individuals operate in a more or less decontextualized environment. A test score is interpreted largely in terms of the individual's internal attributes. But a test measures much more, and the assumption of a fixed or uniform context across test-takers is not realistic. Contextual factors that can affect test performance include native language, emphasis of test on speedy performance, importance to the test taker of success on the test, and familiarity with the kinds of material on the test.

Interactions of Elements

The novice works toward expertise through deliberate practice. But this practice requires an interaction of all five of the key elements. At the center, driving the elements, is motivation. Without it, the elements remain inert. Eventually, one reaches a kind of expertise, at which one becomes a reflective practitioner of a certain set of skills. But expertise occurs at many levels. The expert first-year graduate or law student, for example, is still a far cry from the expert professional. People thus cycle through many times, on the way to successively higher levels of expertise. They do so through the elements in the figure.

Motivation drives metacognitive skills, which in turn activate learning and thinking skills, which then provide feedback to the metacognitive skills, enabling one's level of expertise to increase (see also Sternberg, 1985). The declarative and procedural knowledge acquired through the extension of the thinking and learning skills also results in these skills being used more effectively in the future.

All of these processes are affected by, and can in turn affect, the context in which they operate. For example, if a learning experience is in English but the learner has only limited English proficiency, his or her learning will be inferior to that of someone with more advanced English-language skills. Or if material is presented orally to someone who is a better visual learner, that individual's performance will be reduced.

How does this model of developing expertise relate to the construct of intelligence?

The *g*-factor and the Structure of Abilities

Some intelligence theorists point to the stability of the alleged general factor of human intelligence as evidence for the existence of some kind of stable and overriding structure of human intelligence. But the existence of a *g* factor may reflect little more than an interaction between whatever latent (and not directly measurable) abilities individuals may have and the kinds of expertise that are developed in school. With different forms of schooling, *g* could be made either stronger or weaker. In effect, Western forms and related forms of schooling may, in part, create the *g* phenomenon by providing a kind of schooling that teaches in conjunction the various kinds of skills measured by tests of intellectual abilities.

Suppose, for example, that children were selected from an early age to be schooled for a certain trade. Throughout most of human history, this is in fact the way most children were schooled. Boys, at least, were apprenticed at an early age to a master who would teach them a trade. There was no point in their learning skills that would be irrelevant to their lives.

To bring the example into the present, imagine that we decided, from an early age, that certain students would study English (or some other native language) to develop language expertise; other students would study mathematics to develop their mathematical expertise. Still other students might specialize in developing spatial expertise to be used in flying airplanes or doing shop work or whatever. Instead of specialization beginning at the university level, it would begin from the age of first schooling.

This point of view is related to, but different from, that typically associated with the theory of crystallized and fluid intelligence (Cattell, 1971; Horn, 1994). In that theory, fluid ability is viewed as an ability to acquire and reason with information, whereas crystallized ability is viewed as the information so acquired. According to this view, schooling primarily develops crystallized ability, based in part upon the fluid ability the individual brings to bear upon school-like tasks. In the theory proposed here, however, both fluid and crystallized ability are roughly equally susceptible to development through schooling or other means societies create for developing expertise. One could argue that the greater validity of the position presented here is shown by the near-ubiquitous Flynn effect (Flynn, 1987; Neisser, 1998), which documents massive gains in IQ around the world throughout most of the twentieth century. The effect must be due to environment, because large genetic changes worldwide in such a short time frame are virtually impossible. Interestingly, gains are substantially larger in fluid abilities than in crystallized abilities, suggesting that fluid abilities are likely to be as susceptible as or probably more susceptible than crystalloid abilities to environmental influences. Clearly, the notion of fluid abilities as some basic genetic potential one brings into the world, whose development is expressed in crystallized abilities, does not work.

These students then would be given an omnibus test of intelligence or any broad-ranging measure of intelligence. There would be no general factor because people schooled in one form of expertise would not have been schooled in others. One can imagine even negative correlations between subscores on the so-called intelligence test. The reason for the negative correlations would be that developing expertise in one area might preclude developing expertise in another because of the form of schooling.

Lest this tale sound far-fetched, it is a true tale of what is happening now in some places. In the United States and most of the developed world, of course, schooling takes a fairly standard course. But this standard course and the value placed upon it are not uniform across the world. And we should not fall into the ethnocentric trap of believing that the way Western schooling works is the way all schooling should work.

In a collaborative study among children near Kisumu, Kenya, conducted with Kate Nokes, Wenzel Geissler, Frederick Okatcha, Ruth Prince, Don Bundy, and Elena Grigorenko (see Sternberg & Grigorenko, 1997a), we devised a test of practical intelligence that measures informal knowledge for an important aspect of adaptation to the environment in rural Kenya, namely, knowledge of the identities and use of natural herbal medicines that could be used to combat illnesses. The children use this informal knowledge an average of once a week in treating themselves or suggesting treatments to other children, so this knowledge is a routine part of their everyday existence. By *informal knowledge*, we are referring to kinds of knowledge not taught in schools and not assessed on tests given in the schools.

The idea of our research was that children who knew what these medicines were, what they were used for, and how they should be dosed would be in a position better to adapt to their environments than would children without this informal knowledge. We do not know how many, if any, of these medicines actually work, but from the standpoint of measuring practical intelligence in a given culture, the important thing is that the people in Kenya believe that the medicines work. For that matter, the effectiveness of medicines used in the Western World is not always clear.

We found substantial individual differences in the tacit knowledge of like-aged and schooled children about these natural herbal medicines. More important, however, was the correlation between scores on this test and scores on an English-language vocabulary test (the Mill Hill), a Dholuo equivalent (Dholuo is the community and home language), and the Raven Coloured Progressive Matrices. We found significantly *negative* correlations between our test and the English-language vocabulary test. Correlations of our test with the other tests were trivial. The better children did on the test of indigenous tacit knowledge, the worse they did on the test of vocabulary used in school, and vice versa. Why might we have obtained such a finding?

Based on ethnographic observation, we believe a possible reason is that parents in the village may emphasize either a more indigenous or a more Western education. Some parents (and their children) see little value to school. They do not see how success in school connects with the future of children who will spend their whole lives in a village, where they do not believe they need the expertise the school teaches. Other parents and children seem to see Western schooling as of value in itself or potentially as a ticket out of the confines of the village. The parents thus tend to emphasize one type of education or the other for their children, with corresponding results. The kinds of developing expertise the families value differ, and so therefore do scores on the tests. From this point of view, the intercorrelational structure of tests tells us nothing intrinsic about the structure of intelligence per se, but rather, something about the way abilities as developing forms of expertise structure themselves in interaction with the demands of the environment.

Nuñes (1994) has reported related findings based on a series of studies she conducted in Brazil (see also Ceci & Roazzi, 1994). Street children's adaptive intelligence is tested to the limit by their ability to form and successfully run a street business. If they fail to run such a business successfully, they risk either starvation or death at the hands of death squads should they resort to stealing. Nuñes and her collaborators have found that the same children who are doing the mathematics needed for running a successful street business cannot well do the same types of mathematics problems presented in an abstract, paper-and-pencil format.

From a conventional-abilities standpoint, this result is puzzling. From a developing-expertise standpoint, it is not. Street children grow up in an environment that fosters the development of practical but not academic mathematical skills. We know that even conventional academic kinds of expertise often fail to show transfer (e.g., Gick & Holyoak, 1980). It is scarcely surprising, then, that there would be little transfer here. The street children have developed the kinds of practical arithmetical expertise they need for survival and even success, but they will get no credit for these skills when they take a conventional abilities test.

It also seems likely that if the scales were reversed, and privileged children who do well on conventional ability tests or in school were forced out on the street, many of them would not survive long. Indeed, in the ghettoes of urban America, many children and adults who, for one reason or another end up on the street, in fact barely survive or do not make it at all.

Jean Lave (1988) has reported similar findings with Berkeley housewives shopping in supermarkets. There just is no correlation between their ability to do the mathematics needed for comparison shopping and their scores on conventional paper-and-pencil tests of comparable mathematical skills. And Ceci and Liker (1986) found, similarly, that expert handicappers at race tracks generally had only average IQs. There was no correlation between the complexity of the mathematical model they used in handicapping and their scores on conventional tests. In each case, important kinds of developing expertise for life were not adequately reflected by the kinds of developing expertise measured by the conventional ability tests.

One could argue that these results merely reflect the fact that the problem that these studies raise is not with conventional theories of abilities, but with the tests that are loosely based on these theories: These tests do not measure street math, but more abstracted forms of mathematical thinking. But psychometric theories, deal with a similarly abstracted general factor. The abstracted tests follow largely from the abstracted theoretical constructs. In fact, our research has shown that tests of practical intelligence generally do not correlate with scores on these abstracted tests (e.g., Sternberg et al., 1995).

The problem with the conventional model of abilities does not just apply in what to us are exotic cultures or exotic occupations. In a collaborative study with Michel Ferrari, Pamela Clinkenbeard, and Elena Grigorenko (Sternberg, Ferrari, Clinkenbeard, & Grigorenko, 1996), high school students were tested for their analytical, creative, and practical abilities via multiple-choice and essay items. The multiple-choice items were divided into three content domains: verbal, quantitative, and figural pictures. Students' scores were factor analyzed and then later correlated with their performance in a college level introductory psychology course.

We found that when students were tested not only for analytical abilities, but for creative and practical abilities too (as follows from the model of successful intelligence, Sternberg, 1985, 1997b), the strong general factor that tends to result from multiple ability tests becomes much weaker. Of course, there is always some general factor when one factor analyzes but does not rotate the factor solution, but the general factor was weak, and of course disappeared with a varimax rotation. We also found that all of analytical, creative, and practical abilities predicted performance in the introductory psychology course (which itself was taught analytically, creatively, or practically, with assessments to match). Moreover, although the students who were identified as high analytical were the traditional population—primarily White, middle- to upper middle-class, and well educated, the students who were identified as high creative or high practical were much more diverse in all of these attributes. Most importantly, students whose instruction better matched their triarchic pattern of abilities outperformed those students whose instruction more poorly matched their triarchic pattern of abilities.

Thus, conventional tests may unduly favor a small segment of the population by virtue of the narrow kind of developing expertise they measure. When one measures a broader range of developing expertise, the results look quite different. Moreover, the broader range of expertise includes kinds of skills that will be important in the world of work and in the world of the family.

Analytical, creative, and practical abilities, as measured by our tests or anyone else's, are simply forms of developing expertise. All are useful in various kinds of life tasks. But conventional tests may unfairly disadvantage those students who do not do well in a fairly narrow range of kinds of expertise. By expanding the range of developing expertise we measure, we discover that many children not now identified as able have, in fact, developed important kinds of expertise. The abilities conventional tests measure are important for school and life performance, but they are not the only abilities that are important.

Teaching in a way that departs from notions of abilities based on a general factor also pays dividends. In a recent set of studies, we have shown that generally lower socioeconomic class third grade and generally middle- class eighth grade students who are taught social studies (a unit in communities) or science (a unit on psychology) for successful intelligence (analytically, creative, and practically, as well as for memory) outperform students who are taught just for analytical (critical) thinking or just for memory (Sternberg, Torff, & Grigorenko, 1998a, 1998b). The students taught "triarchically" outperform the other students not only on performance assessments that look at analytical, creative, and practical kinds of achievements, but even on tests that measure straight memory (multiple-choice tests already being used in the courses). None of this is to say that analytical abilities are not important in school and life—obviously, they are. Rather, what our data suggest is that other types of abilities—creative and practical ones—are important as well and that students need to learn how to use all three kinds of abilities together.

Thus, teaching students in a way that takes into account their more highly developed expertise and that also enables them to develop other kinds of expertise results in superior learning outcomes, regardless of how these learning outcomes are measured. The children taught in a way that enables them to use kinds of expertise other than memory actually remember better, on average, than do children taught for memory.

We have also done studies in which we have measured informal procedural knowledge in children and adults. We have done such studies with business managers, college professors, elementary school students, sales people, college students, and general populations. This important aspect of practical intelligence, in study after study, has been found to be uncorrelated with academic intelligence as measured by conventional tests, in a variety of populations, occupations, and at a variety of age levels (Sternberg et al., 1995). Moreover, the tests predict job performance as well as or better than do tests of IQ. The lack of correlation of the two kinds of ability tests suggests that the best prediction of job performance will result when both academic and practical intelligence tests are used as predictors. Most recently, we have developed a test of common sense for the work place—for example, how to handle oneself in a job interview—that predicts self-ratings of common sense but not self-ratings of various kinds of academic abilities (Sternberg & Grigorenko, 1998).

Although the kinds of informal procedural expertise we measure in these tests does not correlate with academic expertise, it does correlate across work domains. For example, we found that subscores (for managing oneself, managing others, and managing tasks) on measures of informal procedural knowledge are correlated with each other and that scores on the test for academic psychology are moderately correlated with scores on the test for business managers (Sternberg et al., 1995). So the kinds of developing expertise that matter in the world of work may show certain correlations with each other that are not shown with the kinds of developing expertise that matter in the world of the school.

It is even possible to use these kinds of tests to predict effectiveness in leadership. Studies of military leaders showed that tests of informal knowledge for military leaders predicted the effectiveness of these leaders, whereas conventional tests of intelligence did not. We also found that although the test for managers was significantly correlated with the test for military leaders, only the latter test predicted superiors' ratings of leadership effectiveness (Hedlund, Sternberg, Horvath, & Dennis, 1998).

Both conventional academic tests and our tests of practical intelligence measure forms of developing expertise that matter in school and on the job. The two kinds of tests are not qualitatively distinct. The reason the correlations are essentially null is that the kinds of developing expertise they measure are quite different. The people who are good at abstract, academic kinds of expertise are often people who have not emphasized learning practical, everyday kinds of expertise, and vice versa, as we found in our Kenya study. Indeed, children who grow up in challenging environments such as the inner city may need to develop practical over academic expertise as a matter of survival. As in Kenya, this practical expertise may better predict their survival than do academic kinds of expertise. The same applies in business, where tacit knowledge about how to perform on the job is as likely or more likely to lead to job success than is the academic expertise that in school seems so important.

The practical kinds of expertise matter in school, too. In a study at Yale University, Wendy Williams and Robert Sternberg (cited in Sternberg, Wagner, & Okagaki, 1993) found that a test of tacit knowledge for college predicted grade point average as well as did an academic ability test. But a test of tacit knowledge for college life better predicted adjustment to the college environment than did the academic test.

Taking Tests

Developing expertise applies not only to the constructs measured by conventional intelligence tests, but also to the very act of taking the tests. In a collaborative study in Bagamoyo, Tanzania, with Elena Grigorenko and Professor Akundaeli Mbise, we have been investigating dynamic tests administered to children. Although dynamic tests have been developed for a number of purposes (see Grigorenko & Sternberg, 1998), one of our particular purposes was to look at how dynamic testing affects score patterns. In particular, we developed more or less conventional measures but administered them in a dynamic format. First students took a pretest. Then they received a short period of instruction (generally no more than 10 to 15 minutes) on how to improve their performance in the expertise measured by these tests. Then the children took a posttest.

A first finding was that the correlation between pretest scores and posttest scores, although statistically significant, was weak (about .3). In other words, even a short period of instruction fairly drastically changed the rank orders of the students on the test. The critical question, of course, is not whether there is a change, but what it means. In particular, which predicts other kinds of cognitive performance better, pretest scores or learning? We found that posttest minus pretest learning scores predicted other kinds of cognitive performance about four times as well as did pretest scores. We examined the pretest data for floor effects, as the lower correlation for the pretest might have been due to such effects. There were no such effects.

We again interpret these results in terms of the model of developing expertise. The Tanzanian students had developed very little expertise in the skills required to take American-style intelligence tests. Thus even a short intervention could have a fairly substantial effect on their scores. When the students developed somewhat more of this test-taking expertise through a short intervention, their scores changed and became more reflective of their true capabilities for cognitive work.

Sometimes the expertise children learn that is relevant for in-school tests may actually hurt them on conventional ability tests. In one example, we studied the development of children's analogical reasoning in a country day school where teachers taught in English in the morning and in Hebrew in the afternoon (Sternberg & Rifkin, 1979). We found a number of second grade students who got no problems right on our test. They would have seemed, on the surface, to be rather stupid. We discovered the reason why, however. We had tested in the afternoon, and in the afternoon, the children always read in Hebrew. So they read our problems from right to left, and got them all wrong. The expertise that served them so well in their normal environment utterly failed them on the test.

Our sample was of upper middle-class children who, in a year or two, would know better. But imagine what happens with other children in less supportive environments who develop kinds of expertise that may serve them well in their family or community lives or even school life, but not on the tests. They will appear to be stupid rather than lacking the kinds of expertise the tests measure.

Patricia Greenfield (1997) has done a number of studies in a variety of cultures and found that the kinds of test-taking expertise assumed to be universal in the United States and other Western countries are by no means universal. She found, for example, that children in Mayan cultures (and probably in other highly collectivist cultures as well) were puzzled when they were not allowed to collaborate with parents or others on test questions. In the United States, of course, such collaboration would be viewed as cheating. But in a collectivist culture, someone who had not developed this kind of collaborative expertise, and moreover, someone who did not use it, would be perceived as lacking important adaptive skills (see also Laboratory of Comparative Human Cognition, 1982).

Conclusion

Intelligence tests measure developing expertise. Tests can be created that favor the kinds of developing expertise formed in any kind of cultural or subcultural milieu. Those who have created conventional tests of abilities have tended to value the kinds of skills most valued by Western schools. This system of valuing is understandable, given that Binet and Simon (1905) first developed intelligence tests for the purpose of predicting school performance. Moreover, these skills are important in school and in life. But in the modern world, the conception of abilities as fixed or even as predetermined is an anachronism. Moreover, our research and that of others (reviewed more extensively in Sternberg, 1997b) shows that the set of abilities assessed by conventional tests measures only a small portion of the kinds of developing expertise relevant for life success. It is for this reason that conventional tests predict only about 10% of individual-difference variation in various measures of success in adult life (Herrnstein & Murray, 1994).

Not all cultures value equally the kinds of expertise measured by these tests. In a study comparing Latino, Asian, and Anglo subcultures in California, for example, we found that Latino parents valued social kinds of expertise as more important to intelligence than did Asian and Anglo parents, who more valued cognitive kinds of expertise (Okagaki & Sternberg, 1993). Predictably, teachers also more valued cognitive kinds of expertise, with the result that the Anglo and Asian children would be expected to do better in school, and did. Of course, cognitive expertise matters in school and in life, but so does social expertise. Both need to be taught in the school and the home to all children. This latter kind of expertise may become even more important in the work place. Until we expand our notions of abilities, and recognize that when we measure them, we are measuring developing forms of expertise, we will risk consigning many potentially excellent contributors to our society to bleak futures. We will also be potentially overvaluing students with expertise for success in a certain kind of schooling, but not necessarily with equal expertise for success later in life.

Intervention Study II—Fostering Intellectual Excellence Through Developing Expertise

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What made Dostoyevsky a world-class novelist, Einstein a world-class physicist, Disraeli a world-class diplomat, or Mozart a world-class musician? We suggest that what made such world-class leaders excellent is that they were experts in their areas of skill. To explore this possibility, we first consider alternative views of the nature of expertise and of how expertise develops. We then present a demonstration study that argues for our own preferred point of view about how developing expertise translates into excellence.

We begin by making a strong claim: A key aspect of intellectual excellence is expertise. The advantage of referring to excellence instead of merely to speaking about expertise is that expertise essentially refers to a high level of skill, whereas excellence has a broader meaning that allows one to ascribe a positive value to that expertise. In other words, while one can be an expert criminal, it is less common to refer to an excellent criminal (except in a sense one speaks of a "good" criminal).

Excellence as Expertise

Granting then that we are considering excellence to reflect socially valued expertise, an obvious question becomes: What makes someone excellent? The answer is far from straightforward. Sometimes the question of "What is excellence?" is not squarely addressed in the literature on expertise, making it hard to say whether individuals studied as experts truly are excellent, or even expert. There are several different conceptions of what would constitute an expert (Sternberg, 1994a) and which conception one adopts will determine, in large part, what one studies when one seeks to understand excellence as individual expertise.

Expertise as Knowledge

One conception of expertise is *knowledge-based*. On this view, an expert is someone who knows a lot about a given area of endeavor. Knowledge is certainly a necessary condition for expertise: No one would want to go to a doctor, lawyer, or psychotherapist who lacked knowledge of his or her field. One probably would not wish to pay a lot for a ticket to listen to musicians who knew little or nothing about their musical instruments or the music they were playing. However, while knowledge seems to be a necessary condition for expertise, it does not seem to be a sufficient condition. Memorizing vast volumes of medical or legal references would not make one an expert doctor or lawyer. Expert musicians have gone far beyond memorizing the pieces they play.

Theories focusing on the role of the knowledge base and its organization often stress the role of stored information in long-term memory as a key to understanding expertise (Ericsson & Smith, 1991a). These theories generally have their origins in the work of De Groot (1965) and of Chase and Simon (1973). Because this work often is considered the seminal work in the study of expertise, let us consider it in somewhat more detail.

De Groot (1965) asked chess players of differing levels of expertise to think aloud while they contemplated the next moves they would make from several different presented chess positions. In most cases, grand masters and chess experts below the grand master level evaluated moves similarly. Subjects at both levels of expertise considered a similar number of moves. (Both groups considered somewhat more than 30 possible moves.) But grand masters arrived at the best move earlier in their consideration of moves than did the more typical experts. De Groot concluded that the grand masters must rely on a more extensive knowledge base than the more typical chess experts; they recognized the presented position as similar or identical to one they had seen before and hence were able to zero in rapidly on the optimal move. Knowledge acquired through experience rather than any special kind of information processing seemed to be what distinguished the chess experts.

Furthermore, De Groot asked both the grand masters and the experts to recall a middle-game position shown to them for just short amounts of time. The grand masters were able to recall the positions of 63 to 94% of chess pieces, whereas the experts were able to recall with only 50 to 70% accuracy. Why the difference? De Groot again attributed it to differences in knowledge base. The grand masters were recalling a configuration they had seen before. They were able to *integrate* all of what they were seeing into a single whole. The experts, in contrast, either had not seen the position or had not seen it as often. Hence they were not able to integrate it into a single whole or as easily encode it so they could retrieve it easily.

Chase and Simon (1973) recognized a flaw in the design of De Groot's study. Perhaps the grand masters simply had better memories than did the more common experts. Perhaps the greater knowledge base of the grand masters was due to their exceptional generalized memory skills. Chase and Simon tested this hypothesis by presenting grand masters and experts with chess configurations for 5 seconds and then asking the two groups to recall them. The critical difference was that Chase and Simon included both configurations of pieces from real games and random configurations of pieces. If the grand masters simply had better memories for pieces than the experts, then their recall should have been better for all chess board configurations, regardless of whether they were real or not. The same applied for experts versus novices. The results were clear: Level of chess expertise influenced recall only of sensible (real-game) configurations of chess pieces. It had no influence on recall for random chess positions. In other words, what distinguished the experts from the novices and the grand masters from the experts was not overall superior recall abilities, but rather the extent and organization of their knowledge base.

Chase and Simon (1973) took things one step further by observing how individuals at various levels of expertise produced their recall. The investigators noted that recall did not happen in a smooth ordered progression but rather in bursts. In other words, some chess pieces would be rapidly placed on the board; then there would be a pause; then more chess pieces would be rapidly placed on the board; and so on. The sets of pieces placed in a single burst were viewed as chunks, in the sense described by Miller (1956). Miller had concluded that people were able to hold in their available short-term memory about 7 plus or minus 2 chunks of information, where chunks were groupings of information encoded by individuals trying to recall the information. A critical feature of Miller's analysis, and of Chase and Simon's as well, was that chunks could vary in size, depending on how the information was encoded. Chase and Simon found that the chunk size of more expert players was larger than the chunk size of less expert players, including novices. In other words, the more expert players were able to use their knowledge base to retrieve large amounts of information in each burst of recall of chess pieces.

Exactly how many chunks of information did people at various levels of expertise have? Simon and Gilmartin (1973) showed via computer simulation that one could reproduce the performance of chess experts with just 1,000 chunks stored in memory. But they estimated that experts had stored in memory anywhere from 10,000 to 30,000 chunks. Thus experts were drawing on huge knowledge bases unavailable to novices in doing the chess-related tasks. These knowledge bases may be organized into problem schemas, or organized bodies of knowledge on which people can draw in order to help them represent and then solve a problem.

If Chase and Simon's findings applied only to chess, they would be of only modest interest. But the same basic finding regarding the role of the knowledge base has been replicated in a number of other domains, such as the game of Go (Reitman, 1976), electronic circuit diagrams (Egan & Schwartz, 1979), and bridge (Charness, 1979; Engle & Bukstel, 1978). Thus, the importance of vast and organized knowledge base and the problem schemas that come with it seem to be fundamental to many different kinds of expertise. Such schemas and the information within them are not rapidly acquired. Simon and Chase (1973) estimated that it would take about 3,000 hours of play to become a chess expert and 30,000 hours to become a chess master.

Adaptive Expertise

Curiously, some research has shown that there are costs as well as benefits to expertise (e.g., Adelson, 1984; Frensch & Sternberg, 1989; Hecht & Proffitt, 1995; Luchins, 1942; Sternberg & Lubart, 1995). One such cost is the potential for increased rigidity: The expert can become so entrenched in a point of view or a way of doing things that it becomes hard to see things differently.

In fact, knowledge can interfere with expertise, at least the flexible kind of expertise that is needed for success in many pursuits (Adelson, 1984; Frensch & Sternberg, 1989). For example, Frensch and Sternberg (1989) compared the performance of expert and novice bridge players when playing bridge against a computer. Predictably, the experts played better than the novices when the game was played in the usual way; however, Frensch and Sternberg also modified the game in two ways. One modification (which they viewed as a surface-structural modification) varied the game only in the names of the suits. Instead of using the term clubs, diamonds, hearts, and spades, the experimenters used different names (neologisms) for the four suits. Both the experts and the novices were initially hurt in their playing but quickly recovered.

A second modification was viewed as a deep-structural modification, in which a basic rule of the game was changed. Typically, in bridge, the high player on a given round opens the next round of play. In this version of the game, however, the player putting out the low card led off. This change, because it affects the basic way the game is played, disrupts fundamental strategies experts develop. But novices are less likely to have any fundamental strategies and so are less likely to be disrupted. This result is exactly what the investigators discovered. Experts were actually disrupted more than novices in their playing, although only initially. Eventually they recovered and once again started playing better than the experts.

This result makes a potentially important point about flexible expertise. A risk of expertise is entrenchment, or a kind of comfort with old ways of doing things. A danger in acquiring expertise can be that knowledge interferes with, rather than facilitates, new ways of looking at things. Flexible experts constantly have to be on guard against letting their knowledge of a domain interfere with their work. Clearly, something more is needed to be an expert than just knowledge.

Indeed, expertise seems to require not just knowledge, but the flexible application of knowledge. Thus, the most effective experts are adaptive experts (Ferrari, 1996; Gott, Hall, Pokorny, Dibble, & Glaser, 1993). Adaptive experts: (a) use knowledge critically; (b) adapt prior knowledge to the specific case at hand; and (c) have high motivation and perceived competence. Studies of air force technicians (Gott et al.) and experts in motor skills have shown that adaptive experts tailor their knowledge based on a critical consideration of the existing circumstances. Such experts are in the best position to profit from their knowledge while adapting to the specifics of the problem at hand, leading to further development of their expertise.

Three Critical Aspects of Expert Performance

In any case, no matter what the field or endeavor or the degree of flexibility demonstrated by particular experts, analytical, creative, and practical skills all seem important to expertise (Sternberg, 1994a). Experts need to *analyze* problems that are presented to them. Thus, doctors must analyze reports of symptoms and themselves look for diagnostic signs of various illnesses. Musicians must analyze the pieces they play to meet their technical requirements. Chess players must analyze the challenges of each chess game they play. Artists must analyze the attributes of the persons, scenes, or whatever else they decide to paint or otherwise represent.

Analytical thinking is needed for expertise, but like knowledge, it too is not enough. For one thing, some people can analyze and criticize the work of others without themselves being capable of outstanding work. Furthermore, there seems to be quite a difference between criticizing ideas and coming up with one's own ideas. For example, an art critic might critique an artistic exhibition, or a music critic might critique a work of music or a concert, but these critics might not be able to—nor would they claim to be able to—produce their own expert artistic or musical work.

Coming up with one's own ideas and how to implement them requires *creative* thinking. The doctor dealing with a difficult case may soon find him or herself in uncharted waters, having to synthesize information that does not fall into any routine pattern previously encountered. Lawyers devise creative legal strategies to free their clients from legal jeopardy. Musicians not only play musical notes, but create unique interpretations of the music they play. Chess players make moves that go beyond any exact situations they have encountered before. And of course, scientists create new theories and experiments to chart the unknown.

But creative and analytcal thinking are still not enough. An expert needs to know how to get people to pay attention to and then accept his or her creative ideas. Such efforts require *practical* thinking on the part of the expert. Successful doctors needs "patient skills"—ways to reach, comfort, and reassure patients that they are getting expert care. Lawyers need to convince their clients to tell them the truth so that they can adequately represent them. Scientists need to convince a frequently skeptical public—scientific or otherwise—that their ideas reflect the scientific truth, not just some hare-brained blend of fact and fiction. Musicians and artists need to reach out to potential audiences so that they will appreciate their performances or art works.

Expertise as a Label

If performers have knowledge and the analytic, creative and practical skills needed to use that knowledge effectively, then their audiences may label them experts. Thus, in some sense, expertise is a labeling phenomenon whereby some group of people declares a person an expert. Without that declaration, the person may have difficulty in exercising his or her expertise. For example, an individual trained in medicine cannot practice without a license; an individual trained in the law cannot represent clients without having passed the bar. A scientist can do science without academic credentials, but may have difficulty obtaining an academic job or research funding without those credentials. In chess, expertise is often recognized in terms of a person's numerical rating according to a system of evaluation (discussed below) of how well the person plays chess. So labeling seems to play some role in expertise, or at least in its recognition. On this view, expertise is not just as an attribute of a person, but of the way the person is perceived by others—as an interaction between a person and a situation.

If one thing should be clear by now, it would be that there is no simple definition of excellence as expertise that will suffice. Expertise does not seem to be a "classical concept" with a clearly delineated set of defining features. Expertise is perhaps a prototypically defined construct where it is quite difficult to specify any one set of characteristics each of which is singly necessary and all of which are jointly sufficient for a person in any field to be labeled an expert. Or perhaps there are multiple exemplars that serve as bases for our recognizing expertise. But what is clear is that in studying excellence as expertise, we cannot simply take for granted that a given person or group of persons is an expert.

Theories of Expertise

Having considered definitional issues surrounding the notion of excellence as expertise, let us now consider some of the major theories that address the issue of excellence.

Map Models of Expertise

One view of what constitutes excellence is a traditional view that inborn or largely innate capacities develop into expertise over time. In modern times, this point of view has taken the form of a *psychometric* or "geographic" approach to abilities (Sternberg, 1990). The geographic metaphor of expertise presupposes a theory of intelligence as a map of the mind in which individual differences in expertise can be mapped through appropriate tests of mental abilities. The psychologist studying intelligence was both an explorer and a cartographer, seeking to chart the innermost regions of the mind. According to this approach, people differ in abilities at birth, and these differences remain fairly stable throughout the course of their lives. Thus, people like Dostoyevsky, Einstein, Disraeli, and Mozart had the good fortune to be born with high levels of these abilities and this is why they later became excellent in their areas of expertise.

This view may have originated with Plato, but in modern psychology, it extends back at least to Gall, perhaps the most famous of phrenologists (see Boring, 1950). Gall implemented the metaphor of a map in a literal way: He investigated the topography of the head, looking (and feeling) for the hills and valleys in each specific region of the head that would tell him a person's pattern of abilities. The measure of intelligence, according to Gall, resides in a person's pattern of cranial bumps.

During the first half of the twentieth century, the metaphor of intelligence as something to be mapped dominated theory and research. However, the metaphor of the map became more abstract, and less literal, than it had been for Gall. Visual inspection and touching just would not do; instead, the indispensable map-making tool appeared to be the statistical method of factor analysis.

Factor analysis was invented by Charles Spearman, and so to understand its origins we need have some understanding of Spearman's work. Spearman was nothing if not contentious. He criticized Wundt and other experimental psychologists of the late nineteenth century on two grounds. Spearman (1923) argued that the methods of early experimental psychology were insignificant and trivial; in words that might still apply to some contemporary researchers in basic information processing, he "regarded as an infatuation to pass life in measuring the exact average time required to press a button or in ascertaining the precise distance apart where two simultaneous pin pricks cannot anymore be distinguished from one another" (p. 203). Furthermore, Spearman believed that there had come to be a "yawning gulf" between science and reality and that this gulf was the result of experimental psychology's use of trivial methods to solve trivial problems.

Spearman dismissed the work of Galton and his disciples, then in a decline (the approach of Binet had not yet gained momentum). He criticized much of the experimental work thereby paved the work for his own correlational psychology, the fullest expression of which was in his 1927 book, *The Abilities of Man*, which presents the major statement of his "two-factor" theory of intelligence. Note that the name of the theory is something of a misnomer. Spearman did not claim that there are two factors of intelligence, but rather two kinds of factors: general and specific. The general factor is indeed a single one, but there are as many different specific factors as there are tests to measure mental abilities, and each specific factor is uncorrelated with every other.

Spearman got the idea that a general factor underlies all tests of human intelligence by noticing what is sometimes called the "positive manifold," or *g*, namely, the tendency for different tests of intellectual abilities to correlate positively with each other. What is *g*, the general factor? Spearman considered a number of alternative explanations, such as attention, will, plasticity of the nervous system, and the state of the blood, but his preferred explanation was that of "mental energy." Spearman's theory thus remains one of the most durable in all of psychology. While his specific interpretation of *g* as a general factor is not undisputed, the notion of *g* is still popular today; in fact, the *g* Factor is the title of two recent volumes (Brand, 1996; Jensen, 1998).

In contrast to Spearman, Louis Thurstone proposed a theory of primary mental abilities that remains popular today. In general, Thurstone believed that Spearman's general factor was obtained only because Spearman failed to rotate his factorial axes upon obtaining an initial solution. Thurstone was a major contributor to the literature of factor analysis and proposed a form of rotation—simple structure—that is still widely used today. Because Thurstone believed that simple-structure rotation is in some sense psychologically natural, he believed his theory to be more valid than Spearman's.

However, the argument between Spearman and Thurstone was not soluble in the terms in which these scientists presented it. Mathematically, either rotation is correct, and it is of course arguable which is psychologically more valid. There exist today mathematical algorithms for rotations that approximate simple structure and that yield orthogonal factorial axes. However, factor scores on primary mental abilities are almost invariably intercorrelated (and not simply due to error of estimation of the factor scores). The result, of course, is that if one factor analyzes the factor scores, one can end up with a general second-order factor. Thus *g* reappears in another form.

The fact that *g* reappears when the factors are themselves analyzed led to the formation by some theorists of *hierarchical theories*. A number of hierarchical theories of intelligence have been proposed, but perhaps the most sophisticated hierarchical model is three-tiered model proposed by John Carroll (1993). The first tier includes minor group factors, the second tier, major group factors, and the third tier, general ability. This theory is unique in that it is based on a reanalysis of hundreds of data sets taken from previous psychometric work. A similar model has been proposed by Horn (1994), which builds upon the earlier model of Cattell (1971).

However, despite the widespread notion of individual excellence as reflecting a mental map, and the factor-analytic methods used to create the maps became increasingly unpopular in the second half of the twentieth century, for three main reasons.

First, the mental maps have little, if anything, to say about mental processes. Yet two individuals could receive the same score on the mental ability test through very different processes, and indeed, by getting completely different items correct (Horn & Knapp, 1973; Sternberg, 1977).

Second, it proved to be extremely difficult to test factor-analytic models against each other, or even to falsify them at all (Sternberg, 1977), a difficulty that stems largely from the problem of deciding how best to rotate factorial axes. The fit of different mathematical models to the data does not change as a function of orientation of axes, and each orientation is equally acceptable mathematically. But different factorial theories proved to differ as much in terms of the orientations of factorial axes for a given solution as in terms of anything else, so that model fitting did not prove to be useful in distinguishing among theories (Sternberg, 1977). Thus, psychometricians resorted to arguing about the psychological plausibility of the various rotations; but such arguments were inconclusive since theorists in each camp thought their rotations to be the most psychologically plausible. Modern, confirmatory methods of factor analysis yield solutions with non arbitrary axes (Joreskog & Sorbom, 1978), and such methods are now gaining widespread use among those wedded to a psychometric approach to intelligence and other psychological constructs (Whitely,1980).

Third, the whole notion of trying to understand intelligence primarily on the basis of individual differences data came under attack. McNemar (1964) asked whether two identical twins, stranded on a desert island and growing up together, would ever generate the notion of intelligence if they never encountered individual differences in their mental abilities. Psychologists were coming to answer "yes" and to believe that they should not depend upon substantial individual differences in isolating abilities. Since factor analysis, as it was typically used, critically depended upon such differences, psychologists either had to find a new model, a new method, or both. Most psychologists opted for both, and in recent years, most research on intellectual excellence has not followed the map model nor used the factor analytic method.

Theories Focusing on Mental Processing

Some early theories of intellectual excellence emphasized the role of planning, problem solving, and reasoning processes (Ericsson & Smith, 1991a). Adriaan De Groot (1965), mentioned earlier as a pioneer in the study of expertise in chess, found no reliable differences in the depth to which experts versus novices planned in advance. However, Neil Charness (1981; see also Charness, 1991; Charness, Krampe, & Mayr, 1996), found that chess players at higher levels of skill tended to plan possible move sequences to greater depths. That is, more skilled players planned further in advance than did less skilled players.

One possible reconciliation of these conflicting findings might be that Charness detected differences that De Groot, with weaker methods, was unable to detect. Or it may be that the differences are so small that they are detectable but of no practical importance. Charness (1989) suggested, however, that the difference are real, but nonlinear. In other words, perhaps depth of search may increase up to a certain level of expertise, after which it stops increasing and other factors become more important in distinguishing who will or will not succeed in games of chess.

But whatever the depth to which expert chess players *plan* in advance, it is clear that they and other experts need to engage in highly sophisticated *information processing*. For example, they need to be able to engage, not only in the cognitive processing that underlies successful performance, but in what Sternberg (1985) calls metacomponential processing. Metacomponential processing involves planning, monitoring, and evaluating one's problem solving and decision making. Thus, experts need to be able to define problems and redefine them as further information arrives. Medical doctors, for instance, need to revise the way they view information as further information is presented (Lesgold et al., 1985; Patel & Groen, 1991).

Experts also set up strategies and monitor their performance in sophisticated ways. For example, several teams of investigators have studied expert versus novice physicists as they solve problems or sort them into categories (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Larkin, McDermott, Simon, & Simon, 1980). They found that experts and novices represented information quite differently. Novices tend to represent problems in terms of them (e.g., seeing a problem as being about pulleys or inclined planes) whereas experts tend to represent problems in terms of underlying physical principles (e.g., seeing a problem as being one of Newton's first law).

Consider how experts versus novices might go about solving a physics problem or other problem in their domain of expertise. The expert and the novice both will first read the problem but the expert is likely to spend more time reading the statement of the problem than is the novice, or at least more time relative to the total amounts of time each will spend in problem solving (Larkin et al., 1980; Sternberg, 1981). The expert thus spends relatively more time than does the novice in global planning, or strategic planning for solving the problem as a whole. This up-front planning time will save the expert time later on, because the expert will be less likely than the novice to misrepresent the problem and thus pursue blind alleys that later will require starting over.

The novice, in contrast, is more likely to begin problem solution relatively quickly, but with the result that later on during problem solving he or she is more likely to have to restart his or her work. The dividends of more time spent in global planning are later paid in less time that needs to be devoted to local planning, or planning that is done along the way in problem solving. Local planning is the tactical planning that needs to be done as one proceeds through the steps of problem solving. In the long run, it is likely to drain more time from the problem solving process when global planning was incomplete or inadequate. Experts, therefore, better balance strategic and tactical thinking than do novices.

Because experts can recognize the deep structure of the problem, they are able to solve problems working forward, whereas novices are much more likely to solve problems working backward. In other words, experts look at the terms of the problem and then proceed forward from the problem statement to a conclusion. Novices are more likely to start with the known or intended solution and then to work backward to try to figure out how they could get to the terms of the problem, given where they are trying to go.

Thus, the expert is more likely than the novice to initially draw some kind of schematic representation of the problem, such as a simple diagram outlining the elements of the problem and their interrelations (Larkin & Simon, 1987). In the verbal domain, such as in writing an essay, the expert may use some kind of outline or map of how the essay will be constructed rather than a graphical figure. The expert may also write down formulas for quantitative types of problems but only the formulas that actually are needed; the novice, in contrast, may write down or at least consider the use of a wide range of formulas, trying to figure out which one is appropriate. In other kinds of problem solving as well, experts are likely to zero in quickly on relevant information through selective encoding and selective comparison, while novices seem to muddle through.

The persistent difference in representation of problems (Chi et al., 1989) is crucial for understanding an important aspect of the difference between experts and novices. Although the apparent problem being solved by the expert and the novice is the same, the psychological problem being solved, or at least the representation of it, is different. The problem that the expert physicist sees as being about a principle of physics the novice physicist might see as being about a mechanical device. The problem the layperson might see as being about a person's mood swings a psychiatrist might see as being about a manic-depressive personality. The differences in representations show how difficult it is to separate knowledge from information processing: The representations experts construct typically would not be possible without very extensive and well-organized knowledge bases.

Experts also need to use sophisticated processes of insightful thinking (Sternberg & Davidson, 1995). They need to be able to engage in *selective encoding*, distinguishing what information is relevant for their purposes. For example, a radiologist needs to know what to look for in an X-ray. A scientist needs to know what to look for in the massive computer outputs that often result from complex data analyses. A lawyer needs to know which facts are relevant to his or her case and which facts, although they might be interesting, are not legally relevant. They also need to be able to integrate large amounts of information in order to make skilled judgments. This is the process Sternberg (1985) has called *selective combination*. For example, a doctor needs to figure out how to put together the different clues presented by an array of symptoms in order to reach a diagnosis. A detective needs to put together clues to decide who committed a crime. Finally, they need to be able to do sophisticated *selective comparison*, figuring out what information they already possess is relevant for the solution of the problems presented to them.

Doctors, lawyers, scientists, chess players—all, as we shall see—draw on very large-scale knowledge bases to solve problems. Thus, we see again the necessity of knowledge for the work of any expert.

The sophisticated use of these processes typically develops over long periods of time. But individuals can be taught to use these processes to good effect. For example, Davidson and Sternberg (1984) gave fourth grade students (roughly 9 years old) verbal and mathematical insight problems to solve, both initially as a pretest and later as a posttest. An example of such a problem might be "Suppose you have black socks and blue socks placed in a dark room and mixed in a drawer in a ratio of 4 to 5. At most how many socks do you need to withdraw from the drawer to be sure that you have two socks of the same color?" In this problem, the ratio information is irrelevant and even misleading. Regardless of the ratio, you need to withdraw three socks, because if the first two socks are not of the same color, the third one has to be of the same color (black or blue) as one of the socks previously withdrawn. Some children were taught for 5 weeks how to use the processes of selective encoding, selective combination, and selective comparison to increase the children's expertise in the solution of insight problems. Other children did not receive such instruction. The instructed children gained more from pretest to posttest than did the uninstructed children. In a similar study using only verbal problems, where adults had to learn to use these three processes to figure out meanings of words presented in contexts, individuals instructed in how to use these processes increased more from a pretest to a posttest than did individuals not so instructed (Sternberg, 1987). In effect, instruction can help speed up processes normally acquired during the development of various kinds of expertise.

The Acquisition of Expertise

Expertise takes a long time to acquire. Simon and Chase (1973) proposed that it typically takes a minimum of 10 years to acquire, and the "10-year rule" has become almost a dictum in the study of expertise. It seems to apply across a number of domains

(Charness et al., 1996; Ericsson, 1996a; Ericsson, Krampe, & Tesch-Romer, 1993; Simonton, 1996). What happens over those 10 years? How is expertise acquired? Again, several theories have been proposed of how people may become experts in the acquisition of skills, whether in music, athletics, art, or whatever (Anderson, 1987, 1993; Newell, 1990).

The development of expertise in many domains seems to go through several stages (Bloom, 1985). Interviews with exceptional performers in many domains as well as the parents and teachers of these elite performers suggest that these experts pass through a number of stages.

In Stage I, the elite performers were initially exposed as children to the domain in which they later became experts under fairly relaxed and playful conditions. At this point, the domain is engaged for pleasure. The future expert musician might be involved in piano playing or the artist in painting. Or the future ice skater may skate just for fun. Sooner or later, the parents or teacher recognize that the child shows promise. This recognition may lead to Stage II, in which parents help the child establish a regular practice schedule and arrange for a teacher or coach to work on a fairly intensive basis with the child. The child typically starts practicing daily and the amount of practice increases over time. Further signs of promise may lead to Stage III, in which a major commitment is made. A nationally or even internationally recognized teacher is sought out and the initial teacher abandoned. The parents may move to have access to this acclaimed teacher or may make arrangements so that the child otherwise can have access. This stage represents a major commitment of time and resources to the development of expertise in the child and is, in a sense, the point at which there is no easy turning back: A decision to develop an expert has been made. The investment on the part of the parents can be extremely substantial. They must invest money in the cost of lessons and possibly equipment or other material resources, time in driving their child to lessons or practice, and usually must give up some of their own personal activities in favor of the development of expertise in their child. Because of the investment required of them, typically no more than one child in the family will receive the kinds of efforts required to develop high levels of expertise. Finally, in Stage IV, the now expert performer has learned most of what even the internationally acclaimed teacher has to teach him or her. The individual, now often an adolescent or adult, moves well beyond being merely a student and him or herself creatively defines the kind of expertise that he or she will offer to the world. The individual develops a kind of "signature" that represents his or her particular way of expressing expertise.

Granting that these stages exist, an obvious question is: What happens to individual skills as expertise progresses?

According to John Anderson's theory, which is embedded within his *ACT theory of cognition,* skill acquisition proceeds through three main stages that represent successive levels in the development of expertise.

In the *first* stage, the kind of situation that evokes the skill and the method for solving problems in that situation are encoded as declarative knowledge. Usually, this declarative knowledge derives from explicit instruction, which may include both an abstract presentation of the type of problem situation and how to solve it as well as examples of problem solving in action. In this stage of development, individuals are able to solve problems. But problem solving is relatively slow and deliberate. The more a given problem departs from the exact way in which its solution was taught, the harder the problem is, to the point that even minor levels of transfer may fail to occur.

In the *second* stage knowledge comes to be represented procedurally. Knowledge is represented in the form of productions, or condition-action statements that can be used in the performance of a task. For example, one such production might be that of "If you see a dot over a note, play that note in staccato (short and punctuated) fashion."

In the *third* stage the productions are combined into successively more elaborated production systems, or sequences of condition-action statements that can be used to execute a complex series of task requirements. Now performance of the task becomes more highly automatized and requires less conscious effort on the part of the individual doing the task.

Anderson's model is similar to three-stage model proposed earlier by Paul Fitts and Michael Posner (1967). In their model, the first stage (the cognitive stage) involves declarative encoding of information. The second stage (the associative stage) involves the formation of connections among various elements of the skill. The third stage (the autonomous stage) involves relatively rapid and automatic execution of the skill.

These characterizations of the development of skill apply to many tasks but they do so in a rather decontextualized way. Some investigators have been interested in proposing models of acquisition that deal with the question of how expertise develops in the course of a person's daily life. Not everyone progresses with equal efficacy through the stages described by Anderson. What distinguishes those who achieve the highest levels of individual excellence from those who become routine experts, or remain amateurs all their lives?

A very persuasive suggestion, made by Anders Ericcson, is that deliberate practice is crucial to how individuals develop their exceptional abilities. Deliberate practice is not just any sort of practice, but rather practice in which the task (a) is at an appropriate level of difficulty for the individual, (b) provides informative feedback to the individual, (c) provides for opportunities for repetition, and (d) allows correction of errors (Ericsson, 1996a).

Ericsson and his associates (Ericsson & Charness, 1994; Ericsson & Hastie, 1994) distinguish deliberate practice from both work and play. In work, individuals generate products and services that are rewarded socially or monetarily. As with performance- or ego-oriented instruction (Biggs, 1985; Nicholls, 1990), individuals at work seek to prove their competence to others, not necessarily to deepen their understanding of the task.

Play is ambiguous; on the one hand, some enjoyment seems necessary if one is going to invest thousands of hours of one's life learning some domain—as suggested by the study of flow (Csikszentmihalyi, 1990) and of intrinsic, mastery, or task-oriented motivation (Nicholls, 1990). On the other hand, if one is simply playing with no aim to improve and no focus to one's activity, then improvement will be slow or nonexistent (Ericsson et al., 1993).

Ericsson (1996a) seems to argue that deliberate practice is not just a necessary condition for the development of expertise, but a sufficient condition as well. In other words, engaging in sufficient deliberate practice will, under normal conditions, produce an expert. This is a strong claim but there is some evidence to back it up. For example, Ericsson et al. (1993) have reported that a study of violinists from a music academy in Germany revealed that the primary difference between students at different levels of expertise was the amount of deliberate practice in which they had engaged. The top violinists averaged almost 7,500 hours of deliberate practice by the age of 18, whereas good violinists had averaged only about 5,300. John Sloboda (1991, 1996) also has argued that deliberate practice is sufficient for the development of musical expertise.

The claim of those who believe in the sufficiency of deliberate practice is not limited to music, but rather is assumed to apply in all domains, including those that require creativity. In one study, Chase and Ericsson (1982) trained a college student, SF, who started with a fairly ordinary digit-span memory to have an exceptional memory, for digits. By the end of an extensive period of training—about 200 hours—SF was able to recall as many as 81 digits at the rate of 1 per second. A typical college student might remember 7 plus or minus 2 digits. How did SF become so adept in memorizing digits? As it turned out, he was a runner and so he used his information about races to facilitate his digit-span memory. He converted sets of digits into race times, thereby increasing the size of his chunks. As one might predict, strings of digits that did not translate into sensible race times gave him more trouble. And when asked to memorize letters, his span of recall for letters was no better than that of the average college student. In other words, he did not show transfer of the skill to another related domain.

The deliberate-practice view is becoming increasingly popular (Ericsson, 1996b, this volume; Ericsson & Charness, 1994; Ericsson & Smith, 1991a; Ericsson et al., 1993; Howe, Davidson, & Sloboda, 1998) and has an important implication that is accepted by almost all psychologists studying expertise, regardless of whether they hold to this particular view or not. This implication is related to inventor Thomas Edison's comment that creative success is 99% perspiration and only 1% inspiration. It is unlikely that one actually could assign percentages to becoming excellent, but developing expertise has always had its basis in substantial amounts of focused hard work, or what Ericsson calls deliberate practice. Many people give up because they are unwilling to engage in these high levels of deliberate practice. Others hope that they will become experts on the basis of sheer unfocused talent. Neither those who quit nor those who hope for an easy road to expertise are likely ever to become experts in their fields.

The Deliberate Practice Plus Talent View

Many theorists believe that abilities or talents play an important role in the development of expertise, not just deliberate practice (Bloom, 1985; Shiffrin, 1996; Simonton, 1996; Sternberg, 1996a; Winner, 1996a, 1996b). They argue that although deliberate practice is likely to be a necessary condition for the development of expertise, it is not likely to be a sufficient one. Scholars supporting this mixture model believe that deliberate practice is necessary but not sufficient for the development of expertise. What are some of their main arguments against the sufficiency of deliberate practice?

First, they argue that behavior-genetic studies show a role for genetic factors in interaction with environmental ones in the development of various kinds of expertise (Plomin & McClearn, 1993). Many different types of abilities seem to have at least some heritable component as a source of individual differences and the kinds of expertise studied by psychologists seem to be no exception. The counter argument proposed by Ericsson (1996b) and his colleagues is that these studies do not apply at the extremely high levels of deliberate practice that they have studied. Nevertheless, there is no reason to believe that performances at high levels of practice somehow would obey different rules.

Second, advocates of the combined talent/practice position argue that the deliberate-practice view is just not plausible. Is one to believe that anyone could become a Mozart if only they put in the time? Or that anyone could reach the level of skill shown by Michael Jordan in the field of basketball if only they worked hard enough at it, and practiced in the right way? Or, for that matter, that becoming an Einstein is just a matter of deliberate practice? Although this argument is one of plausibility rather than data, on its face it is not a simple matter to refute. Many people have tried to reach the exceptional levels of accomplishment shown by the top people in a given field and most have given up disappointed.

Third, the advocates of the mixed position argue that the demonstrations of deliberate practice lack adequate control groups or contain inadequate controls. They speculate that other people who do not become experts or even become known may put in the same hours of deliberate practice as the experts. But, because these nonexperts disappear from view, they may never make it into studies of expertise.

Fourth, the advocates of the mixed position argue that deliberate practice is itself a confounded measure, representing talent as well as practice. How could deliberate practice be a function of talent? The idea is that only those with high levels of talent continue to put in the deliberate practice it takes to reach high levels of expertise (Sternberg, 1996a; Winner, 1996b). Their talent motivates them to try harder and thus rack up more hours of deliberate practice. Consider music lessons, for example. Many millions of children over the years have music lessons but many of those quit. Why? Perhaps because they discover that they lack the talent to become professional musicians or even skilled musicians. So they never put in many hours of practice over the course of their lifetime. The result is that correlations between deliberate practice and expertise, in part, may be affected by levels of talent.

At this point psychologists have insufficient evidence to make a definitive decision about whether deliberate practice is sufficient or merely necessary for developing expertise. But whatever its role, the findings on deliberate practice should give hope to many individuals who might despair of ever becoming experts. The data suggest that deliberate practice can help a great deal in the development of expertise, and may even practically guarantee it, if it is done with sufficient devotion.

If one accepts the point of view of abilities as developing expertise, one designs studies to show the joint effects of abilities and deliberate practice. Rather than looking at the effect of the one or the other, one looks at both kinds of effects simultaneously. We designed a small-scale study as a demonstration of the kind of study we believe better addresses how both abilities and deliberate practice matter to developing expertise. The study is small, but we hope it paves the way for a new type of design that is inclusive of both abilities and deliberate practice rather than focusing on the one or the other.

A Demonstration Study Jointly Assessing Ability and Deliberate Practice

Our study involves the computer game SimCity 2000, a computer simulation game developed by MAXIS that requires subjects to (a) design and then govern cities of their own creation and (b) repair specific problems occurring in existing cities created by experts and provided with the program.

Twenty-one participants (16 males and 5 females) learned to play a computer-simulation game, SimCity 2000. Participants ranged in age from 18 to 33 years of age (mean 22.8, standard deviation 3.4). All were undergraduate and graduate students at Yale University and were paid $50 to work on designing simulated cities in six 2-hour sessions. In addition, as an incentive for the participants to stay with the rather long-term (12-hour study), participants were told that two names would be selected for two additional $100 prizes from all participants who completed the study. One prize was to be given to the individual who created the most successful SimCity simulation and the second prize would be given to an individual chosen at random from all of the participants.

Psychometric test materials included tests of reasoning ability, spatial ability, visual memory ability, mathematical ability, and verbal ability from the *French Kit of Reference Tests for Cognitive Factors*. The level of ability was specified as the first principal component (unrotated solution) of the French Kit.

The manipulated independent variable was time given for deliberate practice per session (30 versus 60 minutes). Abilities and age served as covariates in the data analysis. Participants were assigned to the two practice groups at random.

Over a series of six sessions, participants completed eight psychometric tests to assess their levels of basic cognitive abilities. In addition, participants performed the SimCity 2000 task. In Session 1, participants completed two tutorials that introduced all of the basic tools, charts, and graphs needed to build a new SimCity and to evaluate its prosperity and its simulated quality of life. In Sessions 2-5, participants first were given the opportunity to spend either 60 minutes or 30 minutes deliberately practicing the design and governance of one or more simulated cities. During the third through the fifth practice sessions, participants were allowed to continue their work from the previous session's practice simulations, if they so wished. They were allowed to use various kinds of expert advice that the program provides and that appears on the screen. The four kinds of advice were from citizens of the city, compliance with zoning ordinances, advisors to the mayor, and newspapers.

In learning about the task, participants were told that their cities would be evaluated in terms of a number of different criteria. These criteria included (a) economic viability (current funds, cash flow, land value, gross national product, city size, and employment), and (b) quality of life for the simulated inhabitants (pollution, crime, health, and education). Thus, the best city would be one that was as economically viable as possible at the same time that it would maintain the maximum possible quality of life.

Following the deliberate-practice time, participants were given 20 minutes to design a new city. They were not allowed to use the expert advice feature of the SimCity 2000 program. Instead, participants were told to use their own judgment based on their experience with the task.

In Session 6, participants were told that three cities were in serious trouble and needed help. The participants were then allowed to manipulate conditions in the cities so as to improve their economic indicators and quality of life. Thus, qualities of new cities from sessions 2-5 and of rescued cities from session 6 (altogether, seven summary indicators of cities' qualities) were treated as independent measures.

So what results did we find? To investigate the relative roles of abilities and deliberate practice on performance in the SimCity task, we carried out a set of repeated-measures analyses of variance. The dependent variable was the first principal component of seven measures of city quality (health, average education, pollution, crime, land value, city size, and total value of goods and services of SimCity residents measured on seven different occasions. The manipulated independent variable was amount of deliberate practice (30 minutes or 60 minutes). Ability level and age of participants were treated as continuous covariates.

Means and standard deviations for the various measures are shown in Table 2.1. The patterns of means show that individuals with higher levels of deliberate practice seem to outperform individuals with lower levels of deliberate practice.

Table 2.1

Descriptive Statistics

Variables	Low Practice Group (*N*=11) Mean (*SD*)		High Practice Group (*N*=10) Mean (*SD*)		*T*-value (*p*)	
Dependent Measures						
New City 1 (Session 2)	0.27	(.53)	-.029	(1.38)	.12	(.93)
New City 2 (Session 3)	-.304	(.69)	.334	(1.21)	-1.51	(.15)
New City 3 (Session 4)	-.12	(1.10)	.13	(.913)	-.55	(.59)
New City 4 (Session 5)	-.43	(.88)	.47	(.94)	-2.27	(.04)
Rescued City 1 (Session 6)	.071	(.75)	-.080	(1.26)	.34	(.15)
Rescued City 2 (Session 6)	-.133	(1.10)	.146	(.91)	-.63	(.54)
Rescued City 3 (Session 6)	-.51	(.68)	.56	(1.02)	-2.86	(.01)
Covariates						
Ability Level	-.425	(2.29)	.468	(2.54)	-.85	(.54)
Age	21.10	(1.92)	22.50	(4.60)	-.93	(.36)

The effect of group (level of practice) was significant, $F(1,17)=7.73$, $p<.01$. The effect of ability level was also significant, $F(1,17)=6.44$, $p<.05$. The effect of age was further significant, $F(1,17)=13.83$, $p<.01$. To test the significance of the interactions, four separate models retaining all the main effects and one interaction at a time were fitted. This procedure was used because of the low power obtainable through our small sample. None of the interactions were significant.

The estimated marginal means for level of practice for the seven constructed cities are shown in Figure 2.1. These statistics show comparative performances for each of the cities.

The results of the repeated measures analysis of variance demonstrated the importance of ability ($F(1,17)=6.44$). To explore this effect we investigated the distribution of the level of ability in the total sample and recoded it so that those individuals who scored below 2 *SD* of the total sample mean were categorized as lower-ability participants (*N*=6), and those individuals who scored above 2 *SD* of the total sample mean were categorized as higher-ability participants (*N*=5).

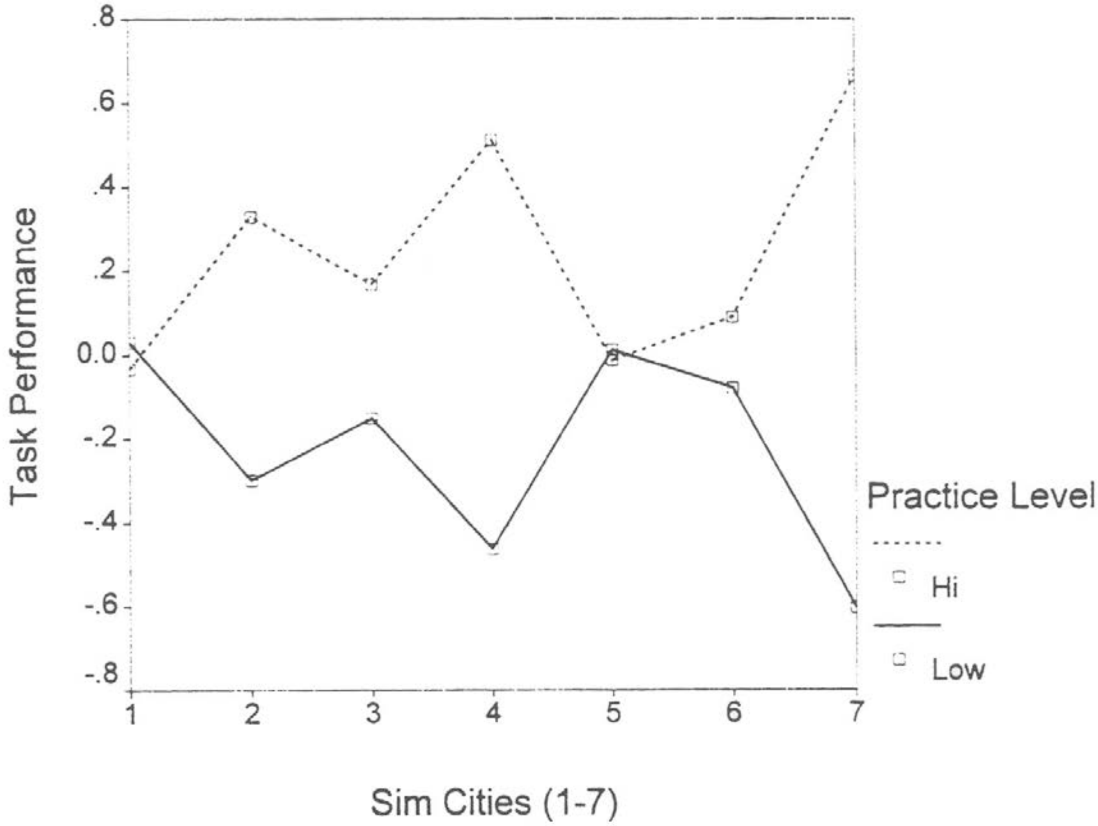

Figure 2.1. Effect of practice level on SimCity™ performance.

Then we, once again, carried out a repeated measure analysis of variance using the indicators of quality of 7 cities as dependent variables. Due to the low power of the sample, these results should be interpreted with caution. In this analysis, the independent variable was level of ability, and level of practice and age were specified as covariates. The effect of ability level was borderline-significant ($F(1,7)=3.72$ ($p<.10$)), the level of practice was significant ($F(1,7)=5.66$ ($p<.05$)), and the effect of age was significant ($F(1,7)=6.66$ ($p<.05$)). The estimated marginal means for level of ability are shown in Figure 2.2.

Taken as a whole, the results of our demonstration study suggest that expertise is not a function exclusively either of abilities or of deliberate practice. It is a function of both simultaneously.

What we mean to suggest with this synthetic point of view is that there is no qualitative distinction between abilities and deliberate practice. Higher levels of abilities arise from deliberate practice, but equally, deliberate practice, or at least the desire for it, arises from abilities. On this point of view, abilities are a form of developing expertise that are acquired by deliberate practice. People are born with innate differences, but how these differences manifest themselves depends upon deliberate practice and other environmental variables (Sternberg, 1998b). The environmental variables may end up being more important in who becomes an expert than are the innate factors. Thus, deliberate practice is a key to the development of expertise, but it builds on a genetic basis for individual differences.

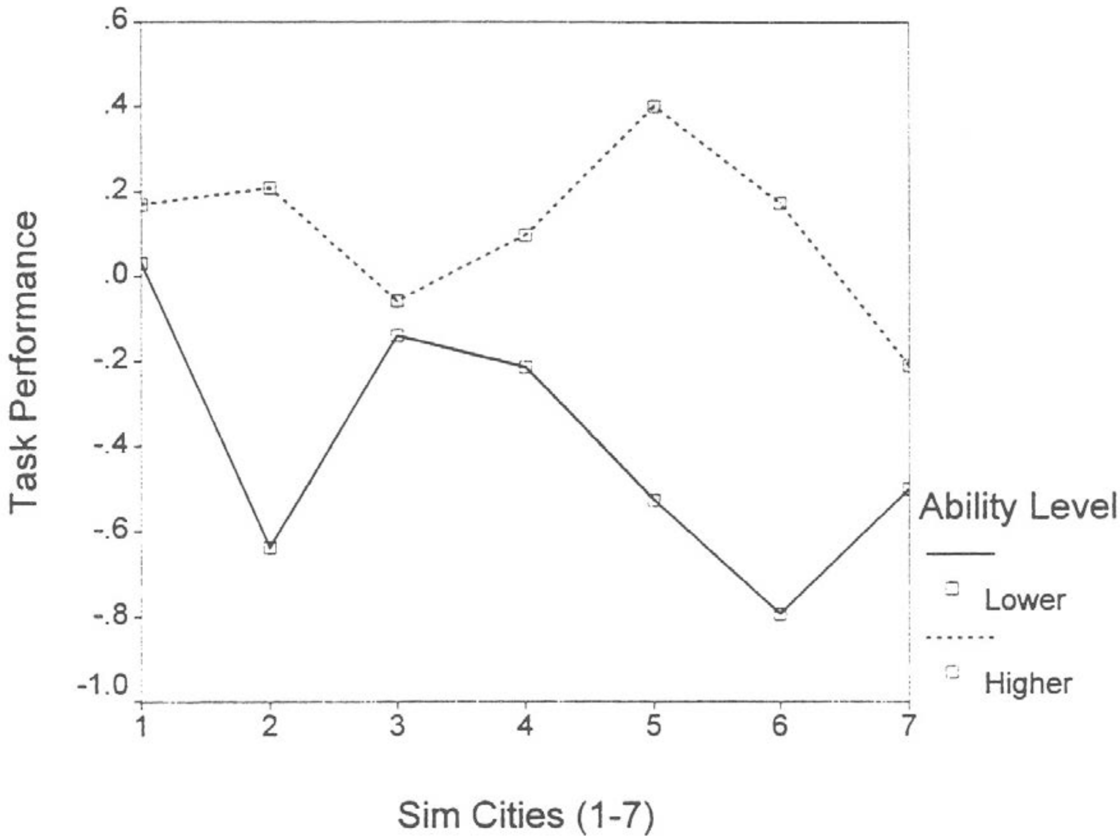

Figure 2.2. Effect of ability level on SimCity™ performace.

Although we certainly do not believe that the study we have presented here is definitive, it at least uses a design that allows one to simultaneously and systematically examine effects of abilities and deliberate practice on developing expertise. The data suggest that both matter (see also Simonton, 1998). We have no doubt that those favoring more extreme positions will rightfully point out limitations of our demonstration study. The study uses only a small number of participants on a single task at fairly low levels of deliberate practice relative to what would be seen, say, in an expert musician or chess player. We agree with these points: our study is certainly not definitive. But we would urge those taking extreme positions to design studies that allow one simultaneously to examine effects of both abilities and deliberate practice. The designs that have been used to date to examine this question look at the effects of the one or the other, and not surprisingly, the studies of each side support the positions of the respective sides. We believe this support to be at least partly spurious because the studies typically have not been designed in ways that could examine the effects of both abilities and deliberate practice simultaneously.

Conclusion

We have considered how excellence is intimately related to expertise and especially the development of expertise. We have focused particularly on the contrast between views that emphasize static mental abilities and cognitive views that emphasize deliberate practice. Traditional views that emphasize inherent abilities or more contemporary views that emphasize deliberate practice—each to the exclusion of the other—may be over-simplifications with regard to excellence as expertise. The common sense view that both abilities and deliberate practice matter is also the psychologically most viable.

We do not even see the abilities and deliberate-practice positions as mutually exclusive of each other. When abilities are viewed as forms of developing expertise, there no longer is a clear distinction between abilities and deliberate practice. Deliberate practice helps people develop their abilities, and people with higher levels of abilities are more likely to be motivated to engage in deliberate practice. This phenomenon is easy enough to experience in almost any domain. Initially engaging in the domain may be painful and frustrating. Once one reaches a certain level of expertise, however, engagement may become enjoyable and fulfilling. One may become more motivated to develop one's abilities and simultaneously one's expertise.

If there is a lesson to be learned here, it is one that the history of psychology has taught many times. There is little value in false dichotomies. Psychologists will better understand phenomena when they have embraced the dialectical synthetic relation between what often seem to be opposing points of view but what really are points of view that can and should be viewed as compatible (Sternberg, 1999).

Intervention Study III—Abilities Are Forms of Developing Expertise

Robert J. Sternberg

Billy has an IQ of 121 on a standardized individual intelligence test; Jimmy has an IQ of 94 on the same test. What do each of these scores, and the difference between them, mean? The best available answer to this question is quite different from the one that is conventionally offered—that the scores and the difference between them reflect not some largely inborn, relatively fixed "ability" construct, but rather a construct of developing expertise. Expertise that all these assessments measure are "developing" rather than "developed" because expertise is typically not at an endstate, but in a process of continual development.

In a sense, the point of view articulated in this study represents no major departure from some modern points of view regarding abilities. Abilities are broadly conceived, and are seen as important to various kinds of success. They are seen as modifiable in some degree, and as capable of being flexibly implemented, at the same time that they are viewed as having interactive genetic and environmental components. What is perhaps new here is the attempt to integrate two literatures—the literature on abilities with that on expertise, and to argue that the two literatures may be talking, at some level, about the same thing, rather than distinct or even, as some believe, constructs in opposition (see Ericsson, 1996b).

The Relation of Abilities to Expertise

Traditionally, abilities are typically seen either as (a) precursors to expertise (see essays in Chi, Glaser, & Farr, 1988) or (b) as opposed to expertise (Fiedler & Link, 1994) as causes of behavior. Sometimes, abilities are held up (c) as causes of developing expertise in contrast to deliberate practice (see also Ericsson, Krampe, & Tesch-Romer, 1993, who argue for the importance of the latter as opposed to the former). Abilities are a form of developing expertise. An important educational implication of this view is that abilities, like expertise, can be taught.

When we test for abilities, we are as much testing a form of expertise as we are when we test for accomplishments of various kinds, whether academic achievement, skill in playing chess, skill in solving physics problems, or whatever. What differs is the kind of expertise we measure, and more importantly, our conceptualization of what we measure. The difference in conceptualization comes about in part because we happen to view one kind of accomplishment (ability-test scores) as predicting another kind of accomplishment (achievement test scores, grades in school, or other indices of accomplishment). But according to the present view, this conceptualization is one of practical convenience, not of psychological reality. Thus, for example, solving problems on a verbal analogies test or a test of mathematical problem solving requires expertise, just as does any other kind of problem solving, and indeed, the components of information processing on many of these kinds of tasks are highly overlapping (Sternberg, 1983, 1985; Sternberg & Gardner, 1983).

According to this view, although ability tests may have temporal priority relative to various criteria in their administration (i.e., ability tests are administered first, and later, criterion indices of performance, such as grades or achievement test scores, are collected), they have no psychological priority. All of the various kinds of assessments are of the same kind psychologically. What distinguishes ability tests from the other kinds of assessments is how the ability tests are used (usually, predicatively), rather than what they measure. There is no qualitative distinction among the various kinds of assessments.

For example, verbal analogies tests and mathematical problem-solving tests could be, and often are, used as predictors; but they could as well be predicted by other kinds of measures, such as school performance or other measures of achievement. Indeed, the murkiness of the distinction between abilities and achievement is shown by the fact that some of the types of items that appear as ability-test items (e.g., vocabulary) on one measure appear as achievement test items on another measure. For example, the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983) labels as measuring achievement, verbal items that the Stanford-Binet Intelligence Scale (Thorndike, Hagen, & Sattler, 1986) labels as measuring abilities.

Although individual and group tests of intelligence are administered differently, they measure roughly the same skills and have underlying them the same theories of intelligence (Daniel, 1997; Gustafsson & Undheim, 1996; Sternberg, 1990). Thus, in this discussion, individual and group tests are considered jointly.

The literatures on abilities and expertise have grown up largely separately. Why? There are several reasons. First, ability testing was originally done by Binet and his colleagues (Binet & Simon, 1916) on children, whereas early studies of expertise were done on adults (De Groot, 1965). Second, Binet's work originally focused on exceptionally low levels of performance, whereas De Groot and other expertise researchers typically have focused on exceptionally high levels of performance. Third, the assessments Binet and other ability testers devised were viewed primarily as predictors (aptitudes), whereas the measures devised by De Groot and others were criterion measures of performance (achievement). Fourth, Binet focused on the world of school, De Groot and other expertise researchers on the world of work. Later work by Wechsler (1958) involved testing of adults, but on tasks almost identical to those that Wechsler used for children, which in turn are very similar to those found on the Stanford-Binet for children. Fifth, ability testing grew out of a tradition emphasizing individual differences—differential psychology—whereas expertise research grew out of a tradition—that of cognitive psychology—emphasizing commonalties across individuals, with differences of interest at the level of groups. Sixth, differential researchers quickly turned toward correlational methods, whereas expertise researchers turned toward mean differences and analysis-of-variance methodology. Seventh, abilities came to be viewed (although not by everyone) as largely innate and fixed, whereas expertise has typically been viewed as acquired and modifiable. These differences are of historical interest, but not of psychological or educational importance.

Models of Individuals' Abilities and Achievements

Alternative Models of Abilities

Before arguing for the developing-expertise point of view, it would be useful to review the more conventional point of view. The traditional model of fixed individual differences holds that, as a result of genetic endowment interacting with the environment, people come at an early age to have a relatively fixed potential for achievement. They fulfill this potential in greater or lesser degree. Those who do not fulfill it are labeled "underachievers," and those who achieve more than might have been expected may come to be labeled "overachievers." Ironically, in the case of the latter, ability-test scores are viewed as a better indicator of what people can do (or should do!) than is what they actually do. A test of verbal analogies, on this view, might actually tell us more about a person's verbal abilities than the person's actual understanding of the reading he or she does in everyday life; or a test of mathematical problem-solving skills might be viewed as more informative than the person's actual mathematical problem solving in everyday life. In fact, though, the two kinds of mathematical skills are often not even very highly correlated (Ceci & Roazzi, 1994; Lave, 1988). Indeed, we now know that there are many different kinds of mathematical thinking skills, both academic and everyday (Sternberg & Ben-Zeev, 1996).

The traditional model has led many people (e.g., Herrnstein & Murray, 1994) to observe that the more intelligent do better in school, and eventually enter the educational routes that lead them to managerial, professional, or other kinds of training that in turn lead to financial and other forms of success. The less intelligent do worse in school, and may drop out of school or else retain credentials reflecting perseverance as much as ability. Eventually, they enter the labor market to fill the jobs that the more intelligent people don't want to do. Let's look in greater detail at the traditional model, and then consider an alternative.

A wide variety of theories of abilities have been proposed to account for individual differences in observed levels of achievement. It is impossible to review them all here, although more or less complete reviews can be found elsewhere (Brody, 1992; Gardner, 1983; Gardner, Kornhaber, & Wake, 1996; Perkins, 1995; Sternberg, 1982, 1990, 1994a). The main difference among the alternative theories is in the proposed nature and structure of abilities.

Sternberg (1990) has suggested that a series of alternative metaphors underlies these theories. For example, a geographic metaphor of intelligence as a map of the mind underlies psychometric theories, whereas a metaphor of intelligence as a computational device underlies information-processing theories. By far the most widely accepted metaphor among psychologists, at least in the United States, has been the geographic, or psychometric metaphor of intelligence as a map of the mind. In Europe, the epistemological metaphor of Piaget (1972) has probably gained greater acceptance.

A well-accepted contemporary psychometric theory views intelligence as hierarchical. According to this view, intelligence comprises a general, overarching ability as well as successive levels of more and more specific abilities (e.g., Carroll, 1993; Cattell, 1971; Gustafsson, 1988; Vernon, 1971). Some prefer other contemporary psychometric theories, such as ones based on Luria (1966, 1980), and implemented in tests by Kaufman and Kaufman (1983) and Naglieri and Das (1997) (see also Das, Naglieri, & Kirby, 1994). Gustafsson and Undheim (1996), also hierarchical theorists, suggest in addition to general intelligence, crystallized ability, broad visualization, broad speediness, and broad fluency.

The model of abilities driving the present work is the triarchic theory of human abilities (Sternberg, 1985, 1988, 1996b). According to this theory, abilities take the form of various information processes operating upon mental representations at varying levels of experience to adapt to, shape, and select environments (see Sternberg, 1985, for more details). It is important to note, however, that one could accept the model of abilities as forms of developing expertise, in general, without accepting the triarchic theory, in particular. Where does the developing-expertise model lead us, both in terms of educational opportunities and in terms of societal outcomes?

One place it leads is to a view of abilities as flexible rather than fixed. There is now substantial evidence that abilities are modifiable, at least in some degree (see Feuerstein, 1980; Herrnstein, Nickerson, deSanchez, & Swets, 1986; Nickerson, 1986; Nickerson, Perkins, & Smith, 1985; Perkins, 1995; Perkins & Grotzer, 1997; Ramey, 1994; Sternberg, 1988, 1994a, 1996b; Sternberg & Spear-Swerling, 1996). If they are, then we should probably hesitate to assign any individual to a fixed group, whether it be a "cognitive elite" or any other. The best evidence, of course, is in favor of both genetic and environmental origins of intelligence, interacting in ways that are not, as yet, fully known (see Sternberg & Grigorenko, 1997b).

The Developing-Expertise Model of Abilities

There are views of abilities and their implications that diverge substantially from fixed-abilities views such as those advocated and reviewed by Herrnstein and Murray (1994). For example, Snow (1979, 1980, 1998; Snow & Lohman, 1984) has presented a much more flexible view of human abilities, according to which abilities are not limited to the cognitive domain, and also overlap with aptitudes and achievements. (Ceci 1996; Ceci, Nightingale, & Baker, 1992; Ceci & Roazzi, 1994) has proposed a bioecological model of abilities that shares some features with the view presented here, particularly with regard to the relevance of domains. Perkins (1995) and Renzulli (1986) have also proposed compatible views. The model presented here perhaps extends some of these views in its emphasis on abilities as representing developing forms of expertise.

Abilities as Developing Expertise

This alternative model sees scores on ability tests as measuring a form of developing expertise, much as would be represented by chess performance (Chase & Simon, 1973), physics performance (Chi, Glaser, & Rees, 1982; Larkin, McDermott, Simon, & Simon, 1980), radiology performance (Lesgold, 1984), teaching performance (Livingston & Borko, 1990; Sabers, Cushing, & Berliner, 1991; Shulman, 1987; Sternberg & Horvath, 1995), or any of a number of other kinds of expertise (Bereiter & Scardamalia, 1993). One comes to be an expert in the skills needed for success on ability tests in much the same ways one becomes an expert in doing anything else—through a combination of genetic endowment and experience.

Expertise involves the acquisition, storage, and utilization of at least two kinds of knowledge: explicit knowledge of a domain and implicit or tacit knowledge of a field (see Sternberg, Wagner, Williams, & Horvath, 1995), where *domain* refers to a knowledge base and *field* to the social organization of that knowledge base (Csikszentmihalyi, 1988, 1996). Explicit knowledge is the kind most frequently studied in the literature on expertise (see Chi et al., 1988; Ericsson & Smith, 1991b). It is knowledge of the facts, formulas, principles, and major ideas of a domain of inquiry. Implicit or tacit knowledge of a field is the knowledge one needs to know to attain success in a field that usually is not talked about or even put into verbal form. For example, in psychology, Freud's theory of depression would constitute explicit knowledge, whereas how to get a grant would constitute informal or tacit knowledge.

When abilities are measured, both explicit and implicit elements are involved. A verbal analogies test, for example, measures explicit knowledge of vocabulary and reasoning with this knowledge, but the test also measures implicit knowledge of how to take a test. For example, one has to work within certain time constraints, choose the best of what often are all imprecise options, and so on. The connection between explicit and implicit knowledge can be fluid, as shown by the fact that courses sometimes are constructed to make implicit knowledge, explicit (see e.g., The Practical Intelligence for School Program of Williams et al., 1996).

Characteristics of Expertise

The characteristics of experts as reflected in performance on ability tests are similar to the characteristics of experts of any kind (see Chi et al., 1988; Sternberg, 1996c). Expertise is a prototypically rather than classically defined concept (Sternberg, 1994c). Operationally, *expertise* in a given domain is a prototype of people: (a) having large, rich schemas (organized networks of concepts) containing a great deal of declarative knowledge about a given domain, in the present case, the domains sampled by ability tests; (b) having well-organized, highly interconnected (mutually accessible) units of knowledge about test content stored in schemas; (c) spending proportionately more time determining how to represent test problems than they do in search for and in executing a problem strategy (Larkin et al., 1980); (d) developing sophisticated representations of test problems, based on structural similarities among problems; (e) working forward from given information to implement strategies for finding unknowns in the test problems; (f) generally choosing a strategy based on elaborate schemas for problem strategies; (g) having schemas containing a great deal of procedural knowledge about problem strategies relevant in the test-taking domain; (h) having automatized many sequences of steps within problem strategies; (i) showing highly efficient problem solving; when time constraints are imposed, they solve problems more quickly than do novices; (j) accurately predicting the difficulty of solving particular test problems; (k) carefully monitoring their own problem-solving strategies and processes; and (l) showing high accuracy in reaching appropriate solutions to test problems.

Ability tests, achievement tests, school grades, and measures of job performance all reflect overlapping kinds of expertise in these kinds of skills. To do well in school or on the job requires a kind of expertise; but to do well on a test also requires a kind of expertise. Of course, part of this expertise is the kind of test-wiseness that has been studied by Millman, Bishop, and Ebel (1965) and others (see Bond & Harman, 1994); but there is much more to test-taking expertise than test-wiseness.

Return, for a moment, to Billy and Jimmy. Billy and Jimmy test differently on an IQ test. This difference in test scores may reflect a number of factors: differential test wiseness, differential test anxiety, differential enculturation into a culture that values IQ tests, differential mood and alertness on the day of testing, differential readiness to take the test, and most importantly, differential developing expertise in the skills that the test measures.

People who are more expert in taking IQ-related tests have a set of skills that is valuable not only in taking these tests, but in other aspects of Western life as well. Taking a test, say, of verbal or figural analogies, or of mathematical problem solving, typically requires skills such as (a) puzzling out what someone else (here, a test constructor) wants, (b) command of English vocabulary, (c) reading comprehension, (d) allocation of limited time, (e) sustained concentration, (f) abstract reasoning, (g) quick thinking, (h) symbol manipulation, and (i) suppression of anxiety and other emotions that can interfere with test performance, among other things. These skills are also part of what is required for successful performance in school and in many kinds of job performance. Thus, an expert test-taker is likely also to have skills that will be involved in other kinds of expertise as well, such as expertise in getting high grades in school.

It is not correct to argue that the tests measure little or nothing of interest. Moreover, the tests do not all measure exactly the same constructs, although they measure related constructs. For example, the Stanford-Binet Intelligence Scale (fourth edition) (Thorndike et al., 1986) provides a composite score plus four subscores: Verbal Reasoning, Abstract/Visual Reasoning, Short-term Memory, and Quantitative Reasoning. The Wechsler scales, such as the Wechsler Intelligence Scale for Children—Third Edition (Wechsler, 1991), yield a composite score plus verbal and performance scores. The Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983), based on Luria's (1966) theory, yields a composite score plus successive and simultaneous processing as well as a separate achievement score. The Cognitive Assessment System

(Naglieri and Das, 1997) yields composite as well as successive and simultaneous processing scores, and also scores for planning and attentional processes. Clearly, these tests tap a range of cognitive abilities.

At the same time, there are many important kinds of expertise that the tests do not measure (Das et al., 1994; Gardner, 1983; Sternberg, 1985), for example, what Gardner (1983, 1993) would call musical, bodily-kinesthetic, interpersonal, and intrapersonal intelligences, and creative and practical intelligence (Sternberg, 1985, 1988, 1996b).

To the extent that the expertise required for one kind of performance overlaps with the expertise required for another kind of performance, there will be a correlation between performances. The construct measured by the ability tests is not a "cause" of school or job expertise; it is itself an expertise that overlaps with school or job expertise. On the overlapping-expertise view, the traditional notion of test scores as somehow causal is based upon a confounding of correlation with causation. Differences in test scores, academic performance, and job performance are all effects—of differential levels of expertise.

Acquisition of Expertise

The literature on the acquisition of expertise, in general, is reviewed in Ericsson (1996b). Individuals gain the expertise to do well on ability tests in much the same way they gain any other kind of expertise—through the interaction of whatever genetic dispositions they bring to bear with experience via the environment. Tests measure *developing* expertise because the experiential processes are ongoing. In particular, individuals (a) receive direct instruction in how to solve test-like problems, usually through schooling; (b) engage in actual solving of such problems, usually in academic contexts; (c) engage in role modeling (watching others, such as teachers or other students, solve test-like problems), (d) think about such problems, sometimes mentally simulating what they might do when confronting such problems; and (e) receive rewards for successful solution of such problems, thereby reinforcing such behavior.

Individual Differences in Expertise

None of these arguments should be taken to imply that individual differences in underlying capacities do not exist. The problem, as recognized by Vygotsky (1978), as well as many others, is that we do not know how directly to measure these capacities. Measures of the zone of proximal development (e.g., Brown & Ferrara, 1985; Brown & French, 1979; Feuerstein, 1979) seem to assess something other than conventional psychometric *g*, but it has yet to be shown that what it is they do measure is the difference between developing ability and latent capacity.

Individual differences in developing expertise result in much the same way they result in most kinds of learning—from (a) rate of learning (which can be caused by amount of direct instruction received, amount of problem solving done, amount of time and effort spent in thinking about problems, and so on), and from (b) asymptote of learning (which can be caused by differences in numbers of schemas, organization of schemas, efficiency in using schemas, and so on) (see Atkinson, Bower, & Crothers, 1965). For example, children can learn how to solve the various kinds of mathematical problems found in tests of mathematical abilities, whether through regular schooling, a special course, or through assimilation of everyday experience. When they learn, they will learn at different rates, and reach different asymptotes. Ultimately, such differences will represent a distinct genetic-environmental interaction for each individual. Sometimes, instruction will raise mean scores but leave the existence of, or even patterns of, individual differences intact (see Sternberg, 1985).

There is no evidence that individual differences can be wiped out by the kind of "deliberate practice" studied by Ericsson and his colleagues (e.g., Ericsson & Charness, 1994; Ericsson et al., 1993; Ericsson & Smith, 1991b). Ericsson's work shows a correlation between deliberate practice and expertise; it does not show a causal relation, any more than the traditional work on abilities shows causal relations between measured abilities and expertise. A correlational demonstration is an important one; it is not the same as a causal one.

The fact that experts have tended to show more deliberate practice than novices may itself reflect an ability difference (Sternberg, 1996a). Meeting with success, those with more ability may practice more; meeting with lesser success, those with lesser ability may give up. Or both deliberate practice and ability may themselves be reflective of some other factor, such as parental encouragement, which could lead both to the nurturing of an ability and to deliberate practice. Indeed, deliberate practice and expertise may interact bidirectionally, so that deliberate practice leads to expertise, and the satisfaction brought by expertise leads to more deliberate practice. The point is that a variety of mechanisms might underlie a correlational relationship. It seems unquestionable that deliberate practice plays a role in the development of expertise. But it also seems extremely likely that its role is as a necessary rather than sufficient condition.

Deliberate practice may play a somewhat lesser role in creative performance than in other kinds of performance (Sternberg, 1996a). We might argue over whether someone who practices memorization techniques can become a mnemonist. Probably, the individual can become a mnemonist at least within certain content domains (Ericsson, Chase, & Faloon, 1980). Ericsson and his colleagues, for example, were able to work with a college student so that he attained truly impressive expertise in memorizing strings of digits, but his memorization of strings of letters was ordinary. The reason was that he could use the mnemonic of running times to memorize digits but not letters. Even such limited practice effects do not seem to apply quite so well in other domains. It seems less plausible that someone who practices composing will become a Mozart. Of course, one could always conveniently maintain that we have not proven that someone could not become a Mozart with sufficient deliberate practice. Null hypotheses do not lend themselves to proof. But in the real world, with many millions having practiced music very hard, the evidence to date appears discouraging.

Other factors seem far more important in the development of creative expertise, in whatever field. These factors include pursuing paths of inquiry that others ignore or dread, taking intellectual risks, persevering in the face of obstacles, and so on (Sternberg & Lubart, 1995, 1996).

Relations Among Various Kinds of Expertise

Although all of the various assessments considered here overlap, the overlap is far from complete. Indeed, a major problem with both ability tests and school achievement tests is that the kinds of skills measured depart in many respects from the skills that are needed for job success (see, e.g., Sternberg, Ferrari, Clinkenbeard, & Grigorenko, 1996; Sternberg et al., 1995). An individual can be extremely competent in test and school performance, but flag on the job because of the differences in the kinds of expertise required. For example, success in memorizing a textbook may lead to a top grade in a psychology or education course, but may not predict particularly well whether someone will be an expert researcher or an expert teacher. The creative and practical skills needed for these kinds of job success may be only minimally or not at all tapped in the ability testing and school assessment situations. Thus, it is not particularly surprising that although test scores and school grades correlate with job performance, the correlations are far from perfect.

There are various measures that correlate with IQ that do not appear to be measures of achievement. But they are measures of forms of developing expertise. For example, the inspection-time task used by Nettelbeck (1987; Nettelbeck & Lally, 1976) to measure intelligence or the choice reaction-time task of Jensen (1982) both correlate with psychometric *g*. However, performances on both tasks reflect a form of developing expertise, in one case, of perceptual discriminations, in the other case, of quick responses to flashing lights or other stimuli. Of course, individuals may differ in the slopes and asymptotes of their acquisition functions.

The argument here is that ability tests are typically temporally prior in their administration to the administration of measurements of various kinds of achievements, but that what they measure is not psychologically prior. The so-called achievement tests might just as well be used to predict scores on ability tests, and sometimes are, as when school officials attempt to guess college admissions test scores on the basis of school achievement. In viewing the tests of abilities as psychologically prior, we are confounding our own typical temporal ordering of measurement with some kind of psychological ordering. But in fact, our temporal ordering implies no psychological ordering at all. The relabeling of the SAT as the Scholastic Assessment Test, rather than Scholastic Aptitude Test, reflects the recognition that what was called an aptitude test measures more than just "aptitude." Nevertheless, the SAT is still widely used as an ability test, and the SAT-II, which more directly measures subject-matter knowledge, as a set of achievement tests.

An examination of the content of tests of intelligence and related abilities reveals that IQ-like tests measure achievement that individuals should have accomplished several years back. Tests such as vocabulary, reading comprehension, verbal analogies, arithmetic problem solving, and the like are all, in part, tests of achievement. Even abstract-reasoning tests measure achievement in dealing with geometric symbols, skills taught in Western schools (Laboratory of Comparative Human Cognition, 1982). One might as well use academic performance to predict ability-test scores. The problem with regard to the traditional model is not in its statement of a correlation between ability tests and other forms of achievement, but in its proposal of a causal relation whereby the tests reflect a construct that is somehow causal of, rather than merely temporally antecedent to, later success.

Even psychobiological measures (see, e.g., Vernon, 1990) are in no sense "pure" ability measures, because we know that just as biological processes affect cognitive processes, so do cognitive processes affect biological ones. Learning, for example, leads to synaptic growth (Kandel, 1991; Thompson, 1985). Thus, biological changes may themselves reflect, in part, developing expertise.

In sum, if we viewed tested abilities as forms of what is represented by the term *developing expertise*, then there is no argument with the use of the term *abilities*. The problem is that this term is usually used in another way—to express a construct that is psychologically prior to other forms of expertise. Such abilities may well exist, but we can assess them only through tests that measure developing forms of expertise expressed in a cultural context.

Contrast With Other Views

The developing-expertise model is quite different from the traditional, fixed-abilities model. The developing-expertise model sees the growing problems in our society as deriving, in part, from the very model upon which Herrnstein and Murray (1994) base their arguments—the traditional model of relatively fixed individual differences in abilities (see Sternberg, 1995, 1996d, 1996e, for more details). In other words, the traditional model may be a cause of rather than a potential answer to educational problems, in particular, and societal problems, in general. The traditional model is part of the problem, not a basis for a solution.

Although the developing-expertise model differs from the conventional psychometric one, the new model is not an expression of the argument that conventional ability tests—because they are multiple-choice pencil-and-paper tests, measure little or nothing of much interest (e.g., Gardner, 1983). This armchair argument can be made only by ignoring thousands of criterion validity studies (see, e.g., Dawis, 1994; Gottfredson, 1986; Hunt, 1995; Hunter, 1986; Sternberg, 1982, 1994a, Wigdor & Garner, 1982). One can argue with the use of intelligence tests on many strong grounds; the existence of some level of predictive validity is probably not one of them. These tests usually measure a part of what is needed for various kinds of success, but, of course, only a part. Indeed, the developing-expertise model is consistent with theories such as those of Ceci (1996) and Gardner (1983), which take a flexible, multi-faceted view of abilities—conventional or otherwise—as fashioned by the interaction of genetic predispositions with cultural and other experiences.

At the same time, the developing-expertise model differs from these prior theories in one crucial regard. All of these theories view abilities as prior to expertise—as predicting expertise in a variety of domains. The developing-expertise model, in contrast, views abilities as developing forms of expertise themselves.

The argument here is also not akin to the one that the use of intelligence tests represents a history of racist and perhaps even conspiratorial psychologists seeking to benefit certain groups (usually White Americans) and suppress others (e.g., immigrants and people of color) (Gould, 1981). In fact, by contemporary standards, there probably have been any number of racist uses of the tests, and from time to time, there may even have been conspiracies. But psychologists (or other professionals) of the past cannot sensibly be judged according to present standards. Doctors who used leeches to cure their patients' ills would not look so competent according to today's medical practice, but they did what they believed was right at the time. Whether they were competent depends upon which standards—historical or contemporary—are being used in making a judgment.

In sum, the present argument differs from the conventional one is in rejecting the psychological priority of abilities. Even those who believe that abilities are developing may view them as somehow prior to achievement; on the present view, both abilities and achievement are forms of developing expertise. Neither is psychologically prior, although one or the other may be temporally prior in a protocol of assessment.

The Specifics of the Developing-expertise Model

The specifics of the developing-expertise model are shown in Figure 3.1. At the heart of the model is the notion of *developing expertise*—that individuals are constantly in a process of developing expertise when they work within a given domain. They may and do, of course, differ in rate and asymptote of development. The main constraint in achieving expertise is not some fixed prior level of capacity, but purposeful engagement involving direct instruction, active participation, role modeling, and reward.

Elements of the Model

The model of developing expertise has five key elements (although certainly they do not constitute an exhaustive list of elements in the development of expertise): metacognitive skills, learning skills, thinking skills, knowledge, and motivation. Although it is convenient to separate these five elements, they are fully interactive, as shown in the figure. They influence each other, both directly and indirectly. For example, learning leads to knowledge, but knowledge facilitates further learning.

1. Metacognitive skills. Metacognitive skills (or metacomponents—Sternberg, 1985) refer to people's understanding and control of their own cognition. For example, such skills would encompass what an individual knows about writing papers or solving arithmetic word problems, both with regard to the steps that are involved and with regard to how these steps can be executed effectively. Seven metacognitive skills are particularly important: problem recognition, problem definition, problem representation, strategy formulation, resource allocation, monitoring of problem solving, and evaluation of problem solving (Sternberg, 1985, 1986). All of these skills are modifiable (Sternberg, 1986, 1988; Sternberg & Spear-Swerling, 1996).

2. Learning skills. Learning skills (knowledge-acquisition components) are essential to the model (Sternberg, 1985, 1986), although they are certainly not the only learning skills that individuals use. Learning skills are sometimes divided into explicit and implicit ones. Explicit learning is what occurs when we make an effort to learn; implicit learning is what occurs when we pick up information incidentally, without any systematic effort. Examples of learning skills are selective encoding, which involves distinguishing relevant from irrelevant information; selective combination, which involves putting together the relevant information; and selective comparison, which involves relating new information to information already stored in memory (Sternberg, 1985).

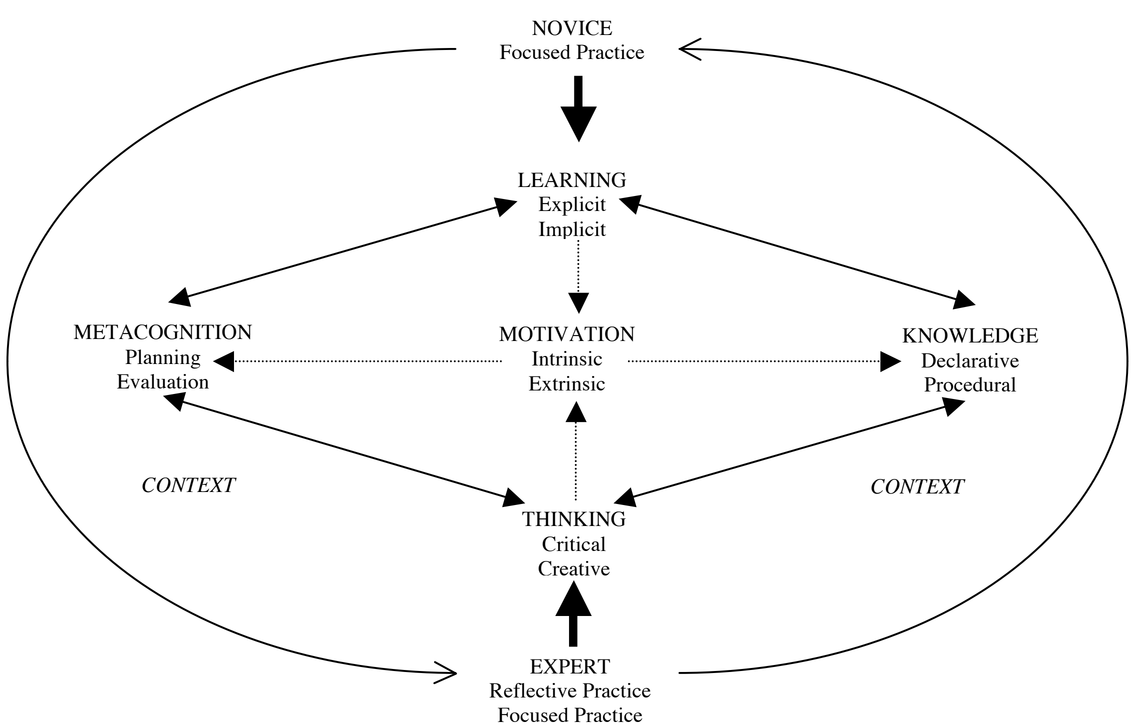

Figure 3.1. Developing-expertise model.

3. Thinking skills. There are three main kinds of thinking skills (or performance components) that individuals need to master (Sternberg, 1985, 1986, 1994c). It is important to note that these are sets of, rather than individual, thinking skills. Critical (analytical) thinking skills include analyzing, critiquing, judging, evaluating, comparing and contrasting, and assessing. Creative thinking skills include creating, discovering, inventing, imagining, supposing, and hypothesizing. Practical thinking skills include applying, using, utilizing, and practicing (Sternberg, 1997a). They are the first step in the translation of thought into real-world action.

4. Knowledge. There are two main kinds of knowledge that are relevant in academic situations. Declarative knowledge is of facts, concepts, principles, laws, and the like. It is "knowing that." Procedural knowledge is of procedures and strategies. It is "knowing how." Of particular importance is procedural tacit knowledge, which involves knowing how the system functions in which one is operating (Sternberg et al., 1995).

5. Motivation. One can distinguish among several different kinds of motivation. A first kind of motivation is achievement motivation (McClelland, 1985; McClelland, Atkinson, Clark, & Lowell, 1976). People who are high in achievement motivation seek moderate challenges and risks. They are attracted to tasks that are neither very easy nor very hard. They are strivers—constantly trying to better themselves and their accomplishments. A second kind of motivation is competence (self-efficacy) motivation, which refers to persons' beliefs in their own ability to solve the problem at hand (Bandura, 1977, 1996). Experts need to develop a sense of their own efficacy to solve difficult tasks in their domain of expertise. This kind of self-efficacy can result both from intrinsic and extrinsic rewards (Amabile, 1996; Sternberg & Lubart, 1996). Of course, other kinds of motivation are important, too. Indeed, motivation is perhaps the indispensable element needed for school success. Without it, the student never even tries to learn.

6. Context. All of the elements discussed above are characteristics of the learner. Returning to the issues raised at the beginning of this document, a problem with conventional tests is that they assume that individuals operate in a more or less decontextualized environment. A test score is interpreted largely in terms of the individual's internal attributes. But a test measures much more, and the assumption of a fixed or uniform context across test-takers is not realistic. Contextual factors that can affect test performance include native language, emphasis of test on speedy performance, importance to the test taker of success on the test, and familiarity with the kinds of material on the test.

Interactions of Elements

The novice works toward expertise through deliberate practice. But this practice requires an interaction of all five of the key elements. At the center, driving the elements, is motivation. Without it, the elements remain inert. Eventually, one reaches a kind of expertise, at which one becomes a reflective practitioner of a certain set of skills. But expertise occurs at many levels. The expert first-year graduate or law student, for example, is still a far cry from the expert professional. People thus cycle through many times, on the way to successively higher levels of expertise. They do so through the elements in the figure.

Motivation drives metacognitive skills, which in turn activate learning and thinking skills, which then provide feedback to the metacognitive skills, enabling one's level of expertise to increase (see also Sternberg, 1985). The declarative and procedural knowledge acquired through the extension of the thinking and learning skills also results in these skills being used more effectively in the future.

All of these processes are affected by, and can in turn affect, the context in which they operate. For example, if a learning experience is in English but the learner has only limited English proficiency, his or her learning will be inferior to that of someone with more advanced English-language skills. Or if material is presented orally to someone who is a better visual learner, that individual's performance will be reduced.

Implications for Education and Classroom Practice

The model of abilities as a form of developing expertise has a number of immediate implications for education, in general, and classroom practice, in particular.

First, teachers and all who use ability and achievement tests should stop viewing them as measuring two distinct constructs. Rather, there is no clear differentiation between the two constructs.

Second, tests of any kind tell us achieved levels of developing expertise. No test—of abilities or anything else—can specify the asymptote a student can achieve.

Third, different kinds of assessments—multiple-choice, short answer, performance-based, portfolio—complement each other in assessing multiple aspects of developing expertise. There is no one "right" kind of assessment.

Fourth, instruction should be geared not just toward imparting a knowledge base, but toward developing reflective analytical, creative, and practical thinking with a knowledge base. Students learn better when they think to learn, even when their learning is assessed with straightforward multiple-choice memory assessments (Sternberg, Torff, & Grigorenko, 1998a). They also learn better when teaching takes into account their diverse styles of learning and thinking, the same diverse styles shown by experts (Sternberg, 1997c).

Finally, some theories of cognitive development (e.g., Piaget, 1972) view such development in a relatively abstract way that then needs to be translated into educational practice. The translation is often less than clear. The theory of abilities as developing expertise has an advantage in its direct application to classroom strategies and goals. The overarching goal is to develop expertise and expert learning in every subject-matter area.

Conclusion

The model proposed in this document is one of abilities as forms of developing expertise. Individuals are viewed as novices capable of becoming experts in a variety of domains. A model of fixed individual differences, which essentially consigns some students to fixed levels of instruction based on supposedly largely fixed abilities, can be an obstacle to the acquisition of expertise. The key to developing expertise is purposeful and meaningful engagement in a set of tasks relevant to the development of expertise, something of which any individual is capable in some degree. For various reasons (including, perhaps, genetic as well as environmentally based differences), not all individuals will equally engage or engage equally effectively, and hence, individuals will not necessarily all reach the same ultimate level of expertise. But they should all be given the opportunity to reach new levels of competence well beyond what they, and in some cases, others may have thought were possible for them. The fact that Billy and Jimmy have different IQs tells us something about differences in what they now do. It does not tell us anything fixed about what ultimately they will be able to do.

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