The Notions of Science as Human Capital: An Empirical Analysis of Economic Growth and Science Curriculum

by

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I certify that I have read this dissertation and that in my opinion it meets the academic and professional standards required by Wilmington College as a dissertation for the degree of Doctor of Education in Innovation and Leadership.

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Dedication

To my mother, Joan, and wife, Karen—women of courage.

Acknowledgements

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For the long nights, family gatherings missed, and Sundays in the library, I thank Karen, my wife, whose understanding and patience sustained me throughout the entire program. I am indeed a fortunate man.

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Abstract

This study was designed to determine the strength of the relationship between a nation's human capital in the form of the "Notions of Science" (NOS) and the growth rate of gross domestic product per capita for 43 countries during the years 1988 through 1998. This relationship was studied from two perspectives: first, the study sought to determine if there was a significant relationship between a country's NOS and its growth rate in gross domestic per capita; second, the study sought to determine if the NOS had a greater relationship with the growth rate of gross domestic product per capita than a more commonly used measure of human capital, amount of schooling.

The NOS for the participating countries were proxied by the percentage of a country's science curriculum devoted to teaching the NOS. The science curricula used in this study were obtained from the International Association for the Evaluation of Educational Achievement's (IEA) *Curriculum Frameworks for Mathematics and Science*. These curricular frameworks were written as one part of the Third International Math and Science Study (TIMSS). The NOS were extracted from the science curriculum frameworks through the construction of a content-by-cognitive-behavior-grid. The categories, or codes, for the NOS used in this grid were based on the work of Clarence Irving Lewis in *Mind and the World Order*. Holding several other explanatory variables constant, the NOS percentage for each country were

regressed against each country's average growth rate of gross domestic product per capita for the period of 1988 through 1998.

The results indicate that there was not a significant relationship between human capital, as proxied by the percentage of the curriculum devoted to the notions of science, and a country's economic growth rate. Because the regression coefficient for the NOS was not statistically significant, this study was not able to determine if the NOS had a stronger relationship with growth in GDP per capita than years of schooling.

Chapter I

Introduction

Economics, Our Standard of Living, and Education

Adam Smith pointed out in *The Wealth of Nations* that the wealth, or standard of living, of any country would be determined by the acquired abilities of its citizenry—their education, experience, skills, and health (Smith, 2001). On Smith's work, Heilbroner (1992) wrote that:

> He (Adam Smith) is concerned with promoting the wealth of the entire nation. And wealth, to Adam Smith, consists of the goods that *all* the people of society consume; note *all*—this is a democratic, and hence radical, philosophy of wealth. Gone is the notion of gold, treasures, kingly hoards; gone the prerogatives of merchants or farmers or working guilds. We are in the modern world, where the flow of goods and services consumed by everyone constitutes the ultimate aim and end of economic life. (p. 53)

If one accepts Smith's notion of what constitutes the economic well-being of a nation, Americans have good reason to be concerned about our economic competitiveness and, hence, our standard of living in the new millennium. As the standard of living Americans have come to expect has declined, Judy and D'Amico (1997) foresee a bifurcated American society:

> America in the year 2020 consists of two societies: In the first, a relatively small elite of highly skilled workers (designers and manipulators of the most advanced ideas and technologies) command the highest earnings on the planet and enjoy lifestyles free of material self-denial. These workers are masters of their own destinies, remaining in demand for their flexibility and ingenuity. A second society coexists with the first. It is the world of low-income, low-skilled workers; they earn a respectable living in some locales, though their prospects for advancement are limited. Most of them are subjected to the vagaries of economic cycles and variations in wage levels on the other side of the planet. Families of these workers are often broken by lives on the economic precipice, further darkening their prospects for their children. They are America's third world. (p. 123)

A society divided into economic strata by virtue of their educational level is a concept not limited to 21st century America: Mankiw (1997) posited that because of the differences in education levels (i.e., productivity levels) of a country's workforce, we have already observed large differences in the standard of living among many countries of the world. "There is enormous variation in per capita income across economies, with the poorest countries having a per capita income that are less than five percent of the per capita incomes in the richest countries" (Jones, 1998, p. 5).

Table 1

1998 International Differences in the Standard of Living

Country	Income per Person (in U.S. dollars)
United States	$23,571
Japan	$19,840
West Germany	$19,320
Soviet Union (1989)	$10,168
Mexico	$8,213
Brazil	$5,099
Indonesia	$2,761
Bangladesh	$1,983
China	$1,961
Pakistan	$1,881
India	$1,683
Nigeria	$1,285

Table 1 indicates that in 1998 the United States enjoyed the most productive (in terms of income or gross domestic product per capita) workforce in the world. However, the growth rate in gross domestic product per capita by the United States over the past 30 years does not even rank among the top 20 countries. Even small improvements (or declines) in the trend rate of economic growth can have great effects on the quality of life (Romer, 2001). Thus, according to Denison (1985), the declining growth rate of the American economy has threatened the American standard of living and has been a cause for serious concern.

Porter (1990) noted that the standard of living experienced by any country was primarily a function of the productivity of that nation's workforce. Schultz (1981) contended that:

> Although there is a wide range of innate abilities (i.e., production capabilities) among nations, it is convenient to assume that in large populations the distribution of these innate abilities tend to be similar from one county to the next. Proceeding on this assumption, it follows that the differences in population quality between such countries are a consequence of the differences in acquired abilities. (p. 21)

Porter (1990) asserted that nations can choose to acquire higher productivity abilities if they organized their policies, laws, and institutions based on productivity: "Nations choose productivity if, for example, they upgrade the capabilities of all their citizens" (p. xii). Schultz (1981) underscored the importance of any nation investing in the skill base of its citizenry: "Increases in the acquired abilities of people throughout the world and advances in useful knowledge hold the key to future economic productivity and to its contribution to human well-being" (p. xi). Few, if any, countries have achieved a sustained period of economic development without having invested substantial amounts in their labor force, and most studies that have attempted quantitative assessments of contributions to growth have assigned an important role to investment in so-called human capital, and for this reason we have in recent years witnessed intensive growth in research on the effects of investing in human capital on economic growth (Becker, 1993).

Robitaille, Schmidt, Raizen, McKnight, Britton, and Nicol (1993) found that a nation's educational system was one of the primary ways of investing in human capital for the purpose of economic development. Becker and Baumol (1996) asserted that education is an investment in human capital that creates economic value by increasing students' skills and future earning power. "For society as a whole, schools foster the productivity improvements that drive economic growth, inform the dialogue of democracy, and reduce the gaps of understanding and income dividing the groups that make up the nation's diverse society" (Hanushek, 1994, p. xvii).

The movement to improve our schools in the United States has been motivated in large measure by economic issues. Concerns over the strength of the U.S. economy, the incomes of American citizens, and gaps between the standards of living for different racial groups are consistently grounded in questions about the quality of our schools (Hanushek & Jorgenson, 1996). "In the end it is this (our public) system of public education that lies behind this continuous improvement in standards of living and the ever rising levels of wealth we now take for granted" (Thurow, 1999, p. 131).

The concept of education as a contributor to human capital for the purpose of economic growth and hence material well-being is not new. Horace Mann, in writing his *Fifth Annual Report* in 1841 envisioned common schools as ". . . the great equalizer of human conditions, the balance wheel of the social machinery, and the creator of wealth undreamed of" (Cremin, 1957, p. 8). Poverty, according to Mann, would ". . . disappear as a broadening popular intelligence tapped new treasures of natural and material wealth" (Cremin, 1957, p. 8). Thurow (1999) shared Mann's vision of the value to society of universal education. Thurow saw universal education, much like Mann did, as a means to an end. "Continuous economic improvement was not even a concept, much less a reality, before universal education was invented in the 19th century in the United States" (Thurow, 1999, p. 131).

The Economics of Education

Clearly, then, reducing the rising economic inequality between individuals and countries requires an understanding of what sustains a growing economy (Thurow, 1999). Developmental economic analysis is concerned with identifying those factors, from a theoretical point of view, that influence economic growth (Mokyr, 1990). A sub-set of developmental economics is the economics of education, which is concerned with identifying attributes of a nation's educational system that contribute in a positive way to economic growth through increasing the human capital stock. According to Cohn and Geske (1990), the economics of education can be defined thus:

> The economics of education is concerned with what educational activities should be selected, of how men and society choose, with or without the use of money, to employ scare productive resources to produce various types of training, the development of knowledge, skill, mind, character, and so forth—especially by formal schooling—over time and to distribute them, now and in the future, among various people and groups in society. (p. 2)

Because the development of a nation's economy has been so dependent on its stock of human capital and how its educational system builds that stock, interest in the economics of education and the identification of educational factors that contribute to economic growth has increased throughout the world (Becker, 1993). Thus, one of the primary tasks in the economics of education has been to identify the specific educational factors that augment a nation's stock of human capital so that less developed economies can focus on these educational factors to accelerate their own economic growth (Chandran, 1992). From a developmental economist's perspective, the economics of education studies the entire educational process, involving all relevant inputs and outputs—as well as current and potential teaching techniques influencing inputs and outputs—that might result in the identification of techniques for improving human capital (Cohn & Geske, 1990). Developmental economists have viewed education not as an expense, but as an investment that creates economic value by increasing a nation's human capital stock for the purpose of improving living standards in a society (Becker & Baumol, 1996).

Human Capital: The Education and Technology Connection

The neoclassical economic growth model identified technological progress as the engine of sustained economic growth (Jones, 1998). Education, as it adds to a nation's capital stock, has augmented the rate of economic growth via its effect on the rate of creation, adoption, and adaptation of technological changes (Mansfield, 1982).

Rowe (1983) posited that while scientific and engineering breakthroughs occasionally raise economic productivity dramatically, long-term economic growth comes mainly from the systematic application of technology to incremental improvements in services, manufacturing, new materials development, and reduction in costs. "It is now widely accepted that modern capitalistic societies have achieved high levels of productivity because of their systematic application of scientific knowledge [new technologies] to the productive sphere" (Rosenberg, 1982, p. 41).

The systematic application of technology to the production of goods has greatly increased the value of education and technical schooling for developing a workforce that is capable of applying technology to the production process (Becker, 1993). Success in growing an economy will not be determined by the accidental possession of natural resources and cheap energy, but by the capacity to generate new knowledge and the ability of the workforce to apply that knowledge and new technologies skillfully in the production process; thus, human resources—ideas, skills, and knowledge—have replaced natural resources as a major source of increases in national wealth (Marshall & Tucker, 1992).

Technology and the Notions of Science

Human capital, in the form of new knowledge and the capacity to adopt or adapt this new knowledge to the productive process, has been identified as the basis for new wealth, and how societies become organized to generate and adopt the new knowledge is important to determine (Thurow, 1999). According to Dewey, innovation (the creation and adoption of new knowledge) has been brought about through the application of scientific inquiry or certain "habits of mind" (Dewey, 1910, p. 83). Technology, then, was essentially epistemological in nature (Mokyr, 1990). Rosenberg (2000) also saw technology as a mode of thinking: "There is widespread agreement that technological change is, at bottom, some kind of learning process, or, intellectual discipline" (Rosenberg, 2000, p. 81). Essentially, technology could be thought of as the direct application (to the production process) of scientific principles (or the notions of science) and theory (McClellan & Dorn, 1999).

The perception of technology as the application of scientific inquiry found its foremost ideologue in Francis Bacon (McClellan & Dorn, 1999). Bacon's conception of science was as an inductive process: collecting information, formulating and conducting experiments, and interpreting their results (Jacob, 1999). In contrast to the theory-dependent and more mathematical classical sciences, Baconian science was generally more qualitative in character and more experimental in approach (McClellan & Dorn, 1999). "It stands to reason then, that the greater familiarity with the scientific enterprise should help to promote the habits of mind necessary to think clearly about evidence and to steer clear of dubious beliefs. Involvement in the process and concepts of science not only teaches those habits of mind directly, it also provides experience with problems, phenomena, and strategies from which they can sometimes be intuited, or at least more deeply understood" (Gilovich, 1993, p. 189).

Building a Technology Enhanced Science Curriculum

John Dewey believed the purpose of education was to instill in students certain ways of thinking. In *How We Think*, Dewey (1910) stated the following: "The main office of education is to supply conditions that make for their (the habits of mind) cultivation. The formation of these habits is the Training of the Mind" (Dewey, p.

28). Dewey further stated that, "...The work of teaching must not only transform natural tendencies into trained habits of thought, but must also fortify the mind against irrational tendencies current in the social environment, and help displace erroneous habits already produced" (p. 26).

Rowe (1983) outlined a framework for decision makers (primarily science teachers and scientists) as they contemplate the role of science education as it relates to teaching the skills of scientific inquiry:

> To understand why science has become so important to the well-being of people and the prosperity of a nation, one has to look at its methods as well as its content. The methods create a capacity for progress by making possible a systematic increase of trustworthy knowledge—that is, knowledge that has been subject to test and verification. . . . They (science educators) want students to consider the roots of belief, to examine evidence, to construct explanatory systems of their own that were fundamentally scientific in nature. They encouraged students to seek alternative explanations and to appreciate the provisional nature of explanations. (p. 128)

The view that the goals for school science should be the inculcation of the scientific thought process has also been adopted by the National Research Council. In 1996 the NRC published the National Science Education Standards, in which they stated that one of the goals of science education should be to ". . . educate students who can use appropriate scientific processes and principles in making personal decisions and in increasing their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person" (National Science Education Standards, 1996, p. 13). In *Every Child a Scientist,* the National Research Council called for a science education that focuses on teaching key scientific concepts, asserting that students who are scientifically literate ". . . need to be able to ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others" (1998, p. 1).

The notions of science (or a scientific way of thinking) according to The American Association for the Advancement of Science, were concepts that could, and should, be learned by all students. The AAAS stated the following:

> The scientific way of thinking is neither mysterious nor elusive. Scientific thinking skills can be learned by anyone, and once acquired, they can serve a lifetime, regardless of one's occupation and personal circumstances. That is certainly true of the ability to think quantitatively, simply because so many matters in everyday life, as in science and many other fields, involve quantities and numerical relationships. (Benchmarks for Science Literacy, 1993, p. 288)

Statement of the Problem

According to Jones (1998), human capital in the form of education is an integral component of the neo-classical economic production function. Becker and Baumol (1996) posited that educational policy makers should be concerned with providing an education that augments a nation's productive capacity to the greatest degree possible through planning and efficient use of school resources. These researchers noted that

"The economic returns to education must be considered by educationalists, particularly in a world in which those who are poorly educated face handicaps affecting every element of their existence, handicaps whose immediate source is to be traced to the economic disadvantages to which inadequate education condemns them" (Becker & Baumol, 1996, p. 2).

Although the research has generally supported the notion that investment in human capital through more education, as measured by average years of schooling or enrollment rates, is associated with economic growth, the current researcher found a dearth of research regarding the strength of the association between specific curricula and economic growth. Levin (1997) stated that:

> Almost nothing is known about the relation between specific standards and economic productivity, even in a static economy with unchanging technology, markets, organization, and incentives. Needless to say, the precise prediction of specific educational standards on economic performance in a future economy is even more obscure. (p. 3)

Carnoy (1995) also noted the lack of evidence showing what kinds of education best support economic growth. He stated that "It is not clear what kinds of education are best at assisting growth" (p.192). Thus, decisions concerning the quality of education a nation provides its students are being made without specific evidence of the strength of the relationship between national (or widely-used) curricula and economic growth (Psacharopoulos, 1996).

Purpose of the Study

The purpose of this study will be to determine the strength of the relationship between a country's human capital in the form of scientific knowledge, as proxied by the notions of science (NOS) in a nation's science curriculum, and the growth rate of gross domestic product per capita. The strength of this relationship will be studied from two perspectives:

1. This study will determine if there is a significant relationship between the NOS in a nation's science curriculum and the growth rate in gross domestic product per capita.
2. This study will also determine if the relationship between a nation's NOS and its growth rate in GDP per capita is stronger than the relationship of the growth rate in GDP per capita with a more commonly used measure of human capital, years of schooling.

Need for the Study

In *The Wealth of Nations*, Adam Smith argued that the welfare of any nation depends on the abilities of its people. Despite Smith's opinion offered nearly 200 years ago, Levin (1997) found that there is still a general lack of empirical evidence linking specific types of educational human capital with economic growth. Writing for the Panel on the Economics of Educational Reform, Levin stated the following: "There is a considerable accumulation of evidence that more education is tied to higher earnings and, by implication, productivity, but precious little that links specific achievements of education to economic outcomes" (p. 5).

Other researchers have noted the need for empirical evidence establishing the strength of the relationship between specific types of human capital and economic growth:

1. Purves (1989) noted the lack of empirical evidence concerning the specificity of human capital links to economic growth. Commenting on the 1983 SCANS report "A Nation at Risk," this researcher noted that no economic data or correlations were given anywhere in this report to support the position that U.S. economic competitiveness was compromised by an under-performing educational system.
2. Benavot (1992) noted that even though there is little conclusive scientific evidence confirming its long-term economic effect, science education has become a core component of the school curriculum in most countries. He wrote that "It is accepted wisdom that national variations in the composition of the official curriculum, by their influence on student achievement levels, have important long-term effects on the quality and the productivity of the labor force and, consequently, of a nation's competitive position in the world economy. But how valid and logically consistent are such claims?" (p. 153)
3. Psacharopoulos (1996) posited that the most important policy issue and research agenda facing education is determining the benefits of education by curriculum type. Psacharopoulos stated the following: "We need more

estimates of the returns to education by curriculum type in secondary education, and especially in higher education . . . " (Psacharopoulos, 1996, p. 343).

Despite the lack of specific empirical evidence, Carnoy (1995) asserted that "It is necessary to know what benefits accrue from education in order to allocate resources not only among schools of various types and levels, but also between educational and other social programs" (p. 118). "We need to understand more clearly how curriculums vary among different countries and how these differences relate to achievement and, ultimately, to the productivity of its workforce" (Robitaille et al., 1993, p. 77).

According to Cohn and Geske (1990), the following questions need to be answered regarding a nation's educational system, its curriculum, and its relationship to economic growth:

1. How does the investment in education affect economic growth?
2. Do different types of curricula have different impacts on economic growth?
3. What is the magnitude of the effect?

Carnoy (1995) depicted the issue thus: "It is simply not clear what kinds of education are best at assisting growth" (p. 192). Educational economists have been, therefore, calling for more study to ascertain what educational variables can make a difference in a nation's economic growth rate and how we can manipulate those variables (Purves, 1989). Using a cross-national comparison of curriculum types to determine their effect on economic growth would provide a series of benchmarks which could suggest means of improving our educational systems (Purves, 1989).

Research Questions

1. Is there a significant relationship between the type of science curriculum offered by a country and its growth rate in real gross domestic product per capita?
2. Does the type of science curriculum offered by a country have a significantly greater relationship with the growth rate in real gross domestic product per capita than another measure of educational human capital, average years of schooling?

Hypotheses

Hypothesis #1

$$H_0 : \beta_n \ NOS = 0$$
$$H_a : \beta_n \ NOS \neq 0 \qquad (1)$$

The null hypothesis states that the regression coefficient for the NOS will be statistically insignificant (i.e., there is not a significant relationship between NOS and the growth rate of the gross domestic product per capita).

Hypothesis #2

$$H_0 : \beta_n \ NOS \leq \beta_n \ Education\ Quantity$$
$$H_a : \beta_n \ NOS > \beta_n \ Education\ Quantity \qquad (2)$$

The null hypothesis states that the regression coefficient for the NOS will be significantly less than or equal to the regression coefficient for another measure of educational human capital, average years of schooling.

Definition of Terms

Laspeyres index. Price index with a fixed basket of goods, otherwise called purchasing power parity.

National income. Net national product minus business taxes.

Net national product (NNP). Gross National Product minus depreciation of capital stocks.

Nominal GDP. GDP measured at current prices.

NOS (Notions of Science). The scientific thought process.

Panel data. The repeated observation of a set of fixed parameters.

Real GDP. GDP measured at constant prices (i.e., adjusted for inflation).

State variable. A variable measured at a given point in time.

Chapter II

Review of the Literature

Sources of Information and Inclusion Criteria

Information for this study came from three primary sources: journal articles, statistical databases, and textbooks. A majority of the journal articles were located either through searching electronic journal collections (e.g., Kluwer, First Search, ERIC) or reviewing the archives of organizations (e.g., National Bureau of Economic Research, National Research Council) that publish research about the economics of education. The statistical databases used in this study (e.g., Penn World Tables, TIMSS, Barro and Lee) were free of charge and readily available over the World Wide Web. Others statistical databases (e.g., The World Bank) were also available over the World Wide Web, but required a modest subscription fee.

The inclusion criteria for this literature review were that the sources must be a primary or secondary source that meet any one of the following descriptions:

1. How economic models are used in the study of economic growth and the economics of education.
2. How the notions of science (NOS) constitute a specific form of human capital.
3. What percentage of a country's science curriculum is devoted to the notions of science (NOS).

4. The results from empirical studies depicting the relationship between explanatory variables, particularly those concerned with human capital, and the rate of economic growth per capita in a cross-section of countries.

Human Capital and Economic Growth

The Importance of Economic Growth

A nation's standard of living has been, in the long term, dependent upon its ability to attain a high and rising level of productivity (Porter, 1990). For this reason, Jones (1998) posited that "The importance of economic growth is difficult to overstate" (p. XI). Yet economists have observed enormous disparity in levels and growth rates of gross domestic product per capita across economies of the world, with the poorest countries of the world having a per capita income that was less than five percent of the per capita incomes in the richest countries of the world (Jones, 1998).

A country's relative position in the world's distribution of per capita incomes is not, however, immutable: countries can move from a relatively low rate of productivity growth, with its attendant low standard of living, to a relatively high rate of productivity growth, with its attendant high standard of living (Jones, 1998).

Economic Growth Modeling

In their effort to understand variations in economic growth, economists have used models to understand how different factors contribute to economic growth (Mankiw, 1997). "In modern economics, a model is a mathematical representation of some aspect of the economy" (Jones, 1998, p. 19). Regarding the use of economic models to understand economic growth, Jones described how models are used: "The best models are often very simple but convey enormous insight into how the world works" (Jones, 1998, p. 19). However, while models provided economists with a framework for understanding the factors contributing to economic growth, there was no single correct model for describing productivity growth; Economists have noted that there were many models that described economic growth, each of which was useful for a different purpose (Mankiw, 1997).

Current economic growth theory stems from the now generally accepted production function first proposed by Robert Solow in 1956 while working at the Massachusetts Institute of Technology. According to Mankiw (1997), the basic Solow Model stated that the output of an economy depends on two main inputs, capital and labor:

$$Y = K^{\alpha} L^{1-\alpha} \tag{3}$$

where "Y" is economic output, "K" is capital, "L" is labor, and "α" is a number between zero and one designating the relative contribution of each factor. According to this model, differences in national incomes arose from differences in capital and labor. The model can be rewritten in terms of output per worker:

$$Y/L = (K^{\alpha} L^{1-\alpha})/L \tag{4}$$

$$\therefore y = k^{\alpha} \tag{5}$$

Technology and Human Capital In Economic Growth Modeling

While studying the dynamics of economic growth, a number of economists noted that a large portion of economic growth remained unexplained when the classical inputs (labor and capital) were accounted for. "One possible explanation for this residual phenomenon is that the classical inputs include only the quantity of labor, not its quality" (Cohn & Geske, 1990, p. 41).

The unaccounted for portion of growth came to be known as the Solow Residual. Jones (1998) explained how the residual could be accounted for by using a descendent of the Solow Model. According to Jones, the descendents of the Solow Model, grouped under the rubric of "neoclassical growth models," further incorporated human capital. Jones references a paper published in 1992 titled, "A Contribution to the Empirics of Economic Growth," by Gregory Mankiw, David Romer, and David Weil. This paper evaluated the implications of the Solow Model and concluded that it performed very well. However, they noted that the "fit" of the model could be improved even more by extending the model to include human capital—that is, by recognizing that labor in different economies may possess different levels of education and different skill levels. According to Jones (1998), the neoclassical model could be rewritten thus:

$$Y = K^{\alpha}(AH)^{1-\alpha} \qquad (6)$$

where "Y" still represents economic output, or gross domestic product, "A" represents the labor-augmenting index of technology, and "H" represents the skill level of the workforce. Jones then derives "H" thus:

$$H = e^{\psi\mu} L \tag{7}$$

where "e" represents exponential growth, ψ is a positive constant, μ is the fraction of time an individual spends acquiring education, and "L" represents the total amount of raw labor used in the economy. According to this function, unskilled labor acquires new skills for a time period represented by μ. Thus, by increasing μ, a unit of unskilled labor increases the effective units of skilled labor "H," thereby increasing productivity. Jones (1998), drawing on this equation, posited that countries are rich because they have (a) high investment rates in physical capital, (b) spend a large fraction of their time accumulating skills, (c) have low population growth rates, and (d) have high levels of technology.

Education as Human Capital: Its Contribution To Economic Growth

"Traditionally, economic analysis of investment and capital tended to concentrate on physical capital, namely machinery equipment, or buildings, which would generate income in the future by creating productive capacity (Carnoy, 1995, p. 24). Regarding capital investment in an economy, however, Mankiw (1997) noted that an economy will eventually reach a steady state, or a point where investment and depreciation of capital stock are equal. Because any economy must theoretically reach a steady-state, growth in GDP/capita with persistently rising living standards can only be accomplished through technological progress and/or increases in human capital (Mankiw, 1997).

The Notions of Science as Human Capital

Gagne, Briggs, and Wagner (1992) stated that to design instruction, the educator must seek and identify the specific human capabilities—human capital— that lead to the outcomes specified by an educational institution. There has been, however, no universal agreement over what form human capital, or valid knowledge, should take in order to ensure economic growth, and agreement among educators regarding valid human capital can be a difficult proposition, as noted in *Curriculum Inquiry: The Study of Curriculum Practice*:

> Agreeing on and justifying curricular decisions to guide learning and teaching is exceedingly difficult even under the best supporting circumstances. Even the most experienced, thoughtful teachers do many things because that is the way things have been done over time, not because they have thought their way through to a defensible position. (1979, p. 7)

Writing in *Curriculum Frameworks,* Robitaille et al. (1993) established a theoretical link between a nation's human capital stock in science literacy and economic development: "The interest that governments around the world have shown in what is learned in school reflects a global recognition of the belief that scientific literacy and economic productivity are inextricably linked" (p. 15). Dewey's conception of the required curriculum revolved around "the notions of science," or NOS. Dewey (1910) was more concerned with science as a set of "habits of mind." He (Dewey) saw the nature of science as a " . . . model for reflective thought. It [science] defines the subject matter of instruction as a unique mode of thinking and doing" (Dewey, 1910, p. xviii). Abd-El-Khalick and Lederman (2000) agreed with Dewey that science is a way of thinking when they stated: "The phrase 'nature of science' refers to the epistemology of science, science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge" (p. 665).

The nature of science as a collection of habits of mind was explained by Trowbridge and Bybee (1990) in the following way: "Among the methods of science common to scientists are observation, measurement, hypothesis formulation and testing, data collection, experimental investigation, prediction, and inference. Scientific knowledge enables one to make probabilistic predictions and temporary predictions " (p. 48). The process of science also often resulted in continuous modification and reconstruction of ideas rather than outright rejection of ideas (Trowbridge & Bybee, 1990). *Every Child a Scientist*, a publication of The National Research Council, defined the notions of science as the use of the inquiry teaching method. "The ability to learn how to learn through inquiry should also be a crucial component of exemplary science teaching and learning" (National Research Council, 1998).

Science Curriculum and the Notions of Science

Gagne et al. (1992) explained that defining goals for education has been a complex problem, and this was true in part because so much was expected from education: some people would prefer education to emphasize the importance of understanding the history of mankind; some would have liked it to perpetuate the present culture or current academic disciplines; some would have liked education to stress the need to help children and young adults adjust to a rapidly changing society; and others would have hoped that education could prepare students to become agents improving themselves and the society in which they live.

Educational institutions must first answer the question, What educational purpose does the institution seek to attain? (Curriculum Inquiry: The Study of Curriculum Practice, 1979). Writing in *Curriculum: An Integrative Introduction,* Sowell (2000) described five main types of curriculum an educational institution can adopt:

1. Social Relevance: societal needs (social issues) dominate both subject matter and individual needs.
2. Self-actualization: seeks to develop individuals to their fullest potential through providing personally satisfying experiences.
3. Development of Cognitive Processes: intended to sharpen students' intellectual processes and help them develop cognitive skills for studying virtually anything. Subject matter is used to develop intellectual processes that can be used in areas other than which they were learned. The focus is on the

acquisition of learning processes (e.g., inferring, speculating, deducing, analyzing).

4. Technology: Seeks to make learning systematic and efficient through the use of predefined and simplistic outcomes (i.e., programmed instruction) with the focus on the technology by which knowledge is communicated.
5. Core Knowledge: articulated by E. D. Hirsch and characterized by its specific, shared curriculum, the primary aim is consistency in instructional content.

According to Trowbridge and Bybee (1990), the curriculum prescribed the content, manipulative skills, attitudes, environment of the classroom, and the means the teacher would use to assess student progress. If an educational institution decided to include the notions of science, or NOS, as part of the development of cognitive processes of their students, the written science curriculum would be the main means whereby these purposes of education would be specified (Robitaille et al., 1993).

In the opinion of Abd-El-Khalick and Lederman (2000), the primary purpose of a science curriculum was to impart an adequate understanding of the notions of science. Indeed, when these researchers reviewed curriculum from a cross-national sample, they found that the notions of science were some of the most commonly stated objectives for science education, having been agreed upon by most scientists and science educators for the past 85 years. When the notions of science were included as curricular outcomes, "Students learn that what they are doing is similar to the way scientists develop hypotheses, test their ideas, and discover new ideas or create new products" (Every Child a Scientist, 1998, p. 11). Trowbridge and Bybee concurred with Abd-El-Khalick and Lederman regarding what a science curriculum should focus on, stating that "Science education should develop a fundamental understanding of, and ability to use, the methods of science investigation" (Trowbridge & Bybee, 1990, p. 134).

The Effect of Education on Economic Growth—Empirical Studies

The Direct Returns Approach

Cohn and Geske (1990) noted that one method for determining the effect of education on economic growth was the direct returns approach. According to these authors, the principle effect of education was measured by an increase in productivity, measured as a function of increased wages, of the recipients of the education. Given perfect labor markets, labor services would be sold at their market price and the productivity increase generated by education would then be reflected in the wage rates and the earned income of the recipients of education (Haveman & Wolfe, 1982). Becker (1993) noted the following regarding the direct returns approach:

> More highly educated and skilled persons almost always tend to earn more than others. This is true of developed countries as different as the United States and the Soviet Union, of undeveloped countries as different as India and Cuba, and of the United States one hundred years ago as well as today. (p. 12)

The direct returns approach has been further categorized according to the incidence of the benefits: private returns are those retained by the individual, while social returns are the benefits obtained by other members of society, usually through increased tax revenues (Cohn & Geske, 1990).

An international study using the direct returns approach was carried out by Psacharopoulos in 1981. In this study, depicted in Table 2, Psacharopoulos determined the private rate of return for several economically advanced countries.

Table 2

Private Return Rates To Education For Economically Advanced Countries

Country	Survey Year	Secondary Education Percent Return	Higher Education Percent Return
Australia	1969	14.0	13.9
Belgium	1960	21.2	8.7
Canada	1961	16.3	19.7
Denmark	1964		10.0
France	1970	13.8	16.7
Germany	1964		4.6
Italy	1969	17.3	18.3
Japan	1973	5.9	8.1
Netherlands	1965	8.5	10.4
New Zealand	1966	20.0	14.7
Norway	1966	7.4	7.7
Sweden	1967		10.3
United Kingdom	1972	11.7	9.6
United States	1969	18.8	15.4

The percent return numbers in Table 2 represent how much more an individual can expect to earn over a typical working life (age 22 through 65) as a percentage of forgone wages and other expenses during the time the individual attended secondary school (age 14 through 18) or participated in higher education (age 18 through 22).

Calculating the returns to education using the direct returns approach was not without its problems:

> There is no hard evidence that more schooling raises industrial worker productivity—only that higher levels of schooling are associated with higher wages. Why and how workers produce more because they acquire knowledge in schools is still subject to considerable controversy. (Carnoy, 1995, p. 2)

Carnoy (1995) also noted the possibility that higher levels of education might merely act as qualifiers for higher paying positions. Labeled by Carnoy as "credentialing," or "screening," this phenomena posited that there was no real productivity gain as a result of more education, simply higher wages.

The Growth Accounting Approach

Another method for determining the effect of education on economic growth was the growth accounting approach, which was a national income-based technique for evaluating the contribution of various factors to observed growth in national output, or gross domestic product (Haveman & Wolfe, 1982). With this methodology, factor inputs, including education as human capital, were the determinants of increases in gross domestic product per capita.

Early growth accounting studies.

Dean (1980) noted that early attempts (research conducted through the 1970s) to analyze the growth in gross domestic product per capita of the U.S. economy gave rise to a large "residual" (i.e., an increase not due to increases in labor or capital). According to Dean (1980), the residual was so large that researchers began to search for concrete ways of explaining it, and a number of researchers quickly pointed to improvements in the quality of the labor force attributable mainly to increased levels of education. "One of the first applications of human capital theory was the attempt to explain the sources of economic growth and identify the factors that constituted the 'residual' after increases in physical capital and labor had been measured" (Carnoy, 1995, p. 27).

In one of the earlier growth accounting studies, depicted in Table 3, Dean (1980) found that increased educational levels in the workforce accounted for approximately 25 % of the increase in national income during the period of 1964 through 1969. Because of the large contribution of education to economic growth, Dean (1980) suggested that new government policies designed to increase productivity should give high priority to education.

Growth accounting studies like the one exhibited in Table 3 calculated the increase in national income due to the increased number of years of schooling in the population as a whole without disaggregating by type of schooling.

Table 3

Contribution To Growth In National Income per Employed Person

	Years		
	1948-53	1953-64	1964-69
Yearly percent growth in national income per employed person	2.85	2.93	1.85
Factor Input			
Labor:	0.47	0.15	-0.18
Hours Worked	-0.08	-0.25	-0.29
Age Demographic Changes	0.09	-0.11	-0.38
Education	0.46	0.51	0.49
Capital	0.48	0.41	0.36
Land	-0.05	-0.01	-0.10
Other Productivity Improvements	1.95	2.38	1.77

Dean (1980) asserted, however, that the disaggregation of education's contribution to productivity output may have been more important for policy formulation purposes than the overall contribution when education was treated as a single variable. "The rate of return to education when broken down by curriculum type, race, sex, major, and institution setting could vary widely and have clear implications for educational policy formation" (Dean, 1980, p. 22).

Another researcher, Edward Denison (1985), also focused on measuring the sources of growth in national income. The results from his research, depicted in Table 4, showed that increases in the overall educational level of the workforce accounted for 14% of the growth in total national income in the United States between 1929 and

1982, thus verifying Dean's earlier finding for education's prominent role in economic growth.

Table 4

Percent Factor Contribution To National Income Growth, 1929 - 1982

Growth rate for whole economy	2.9
Factor:	Percent Contribution
Labor input (except education)	32.0
Education per worker	14.0
Capital	19.0
Advances in knowledge	28.0
Improved resource allocation	8.0
Economies of scale	9.0
Changes in legal environment	-1.0
Various negative determinants	-8.0

When Denison disaggregated his data (depicted in Table 5), he found that the rate of growth in national income was slowing, and he believed this was a cause for concern. Writing in *Trends in American Economic Growth, 1929-1982*, Denison (1985) noted the following:

> Growth of the United States national income fell off sharply after 1973 and even more, it appears, after 1979. This is a serious reason for concern because national income measures the output that our economy makes each year for private consumption, including education, national security, and capital stock.

Expenditures for one or more of these purposes must be curtailed when there is less output to be distributed, and in practice all are likely to be reduced. (p. 1)

Table 5

Percentage Change In Growth Rate of National Income (U. S. only)

	Years		
	1948 - 1973 to 1973 - 1982	1964 - 1973 to 1973 - 1979	1973 - 1979 to 1979 - 1982
Output change	-2.15	-1.31	-3.15

Problems with early growth accounting studies.

As early as 1982, Haveman and Wolfe wrote that the methodologies employed in growth accounting studies to determine the contribution of human capital to education were flawed. Because human capital's educational component only referred to the formal education received by members of the labor force, improvements in the quality of a year's worth of schooling or increases in a variety of educational services were not factored into the production equation. "Neither of the two standard approaches, direct returns and growth accounting, capture the full value of education's effect: they ignore non-market productivity increases, such as (a) home productivity (efficiency of raising children), (b) health of oneself and of one's children, (c) nutritional intakes, and (d) fertility and contraception" (Haveman &

Wolfe, 1982, p. 24). Mansfield (1982) further elucidated the problems with the growth accounting methodology:

> It is difficult to measure how much education a person has. Years of schooling obviously are not a satisfactory measure for many purposes; e.g., a year at one school may represent far more education than a year at another school. Also, education is far from homogenous. It is possible to spend a year at school studying Greek, physical education, or civil engineering, and it seems doubtful that each should be given the same weight in such a production function. (p. 36)

Haveman and Wolfe (1982) concluded that the provision of education was " . . . likely to have a larger impact on economic well-being than is estimated by studies based upon either the direct returns approach or growth accounting frameworks" (p. 58).

In *Making Schools Work*, Hanushek (1994) recognized that when calculating education's contribution to human capital and economic growth, education had historically been thought of simply in terms of the amount of schooling that an individual has obtained. Hanushek contended that " . . . there is growing appreciation that simply measuring the amount of schooling attained does not account for differences in schooling. Individuals with the same years of schooling can have widely differing skills and cognitive abilities" (p. 13).

Barro's cross-country regression.

Writing in *The Quarterly Journal of Economics* in May, 1991, Robert Barro published "Economic Growth in a Cross Section of Countries." Using initial school enrollment rates as a proxy for human capital, Barro found that " . . . the growth rate of real per capita GDP is positively related to initial human capital (proxied by 1960 school enrollment rates) and negatively related to the initial (1960) level of GDP per capita GDP" (p. 407). Barro explained the positive relationship between school enrollment rates and economic growth by suggesting " . . . a larger stock of human capital makes it easier for a country to absorb the new products or ideas that have been developed elsewhere" (p. 407). In 1998, Barro updated his 1991 work with *Determinants of Economic Growth: A Cross-Country Empirical Study*. In the latter study, however, Barro used the average years of school attainment for males age 25 and above as his proxy for the educational component of human capital.

In both his 1991 and 1998 studies, Barro was concerned with the incorporation of conditional convergence into his empirical framework. According to the neoclassical growth model, the economies of all countries will converge to their steady state levels. Mankiw (1997) described the steady state as the long-run equilibrium of the economy, or the point at which investment capital equals capital depreciation. Barro noted that the neoclassical growth model predicts that countries with lower initial levels of GDP per capita would grow, or converge on their individual steady states, more quickly than countries with higher initial levels of GDP per capita. However, Barro found the hypothesis that poor countries tend to grow faster than rich countries to be inconsistent with the cross-country evidence obtained from the Summers and Heston Penn World Tables 5.1 dataset compiled for 98 countries between 1965 and 1990. A regression analysis indicated that per capita productivity growth rates had a low correlation with the initial (1960) level of per capita productivity. Barro surmised that economies of the world appeared to exhibit conditional convergence; the growth rate at which countries converge to their own steady state was determined by several factors other than their initial starting level of GDP per capita. Barro's 1998 analysis identified the factors that affected a nation's economic growth rate as they converge on their steady state: (a) human capital (proxied by schooling levels), (b) health (proxied by life expectancy), (c) fertility rates, (d) government expenditures, (e) the democracy index, (f) changes in the inflation rate, (g) terms of trade, and (h) the initial level of the GDP/capita. Barro (1998) found that the growth rate of real GDP

1. Positively related to higher initial human capital levels, life expectancy, the democracy index, and favorable terms of trade.
2. Negatively related to initial levels (1960) of real GDP per capita, fertility rates, higher government expenditures, and higher changes in inflation rates.

In Barro's 1998 regression analysis, the dependent variable (the growth rate of GDP per capita) was regressed against several independent variables over three time periods: 1965-1975, 1975-1985, and 1985-1990. The results of his analysis are given in Table 6.

Table 6

Barro's Regressions

Independent Variables	Average Regression Coefficients* 1965-1975, 1975-1985, 1985-1990
Log Initial Level of GDP/Capita	-0.025
Male Secondary and Higher Schooling	0.012
Log(life expectancy)	0.042
Log(fertility rate)	-0.016
Government Consumption Ratio	-0.136
Terms of Trade	0.137
Democracy Index	0.088
Inflation Rate	-0.043
R^2	0.58, 0.52, 0.42

* Rounded to three decimal places.

Barro described his independent variables as follows:

1. State variables:

    a. Initial Level of GDP: entered in logarithmic form, this variable reflects a country's endowment of physical capital, natural resources, and the unobserved level of technology. The neoclassical model predicts a negative regression coefficient (i.e., the lower the starting point of the GDP per capita, the higher the growth rate when other explanatory variables are held constant).

    b. Human Capital: this state variable was proxied in two ways:

        i. The average years of secondary and higher school attainment for males aged twenty-five and over, and

ii. The log of life expectancy at birth as an indicator of the general health of a country's population.

2. Choice Variables:

   a. Fertility rate: if the population is growing, then a greater proportion of the economy's investment is used to provide capital for new workers rather than to raise capital per worker. A higher rate of population growth has a negative effect on economic growth.

   b. Government spending: government spending (exclusive of education and defense) is used to proxy capital that can not be put towards variables that will promote growth.

   c. Terms of trade: measured as the change in the ratio of export to import amounts, this is an important influence on an economy's ability to grow, especially among developing countries.

   d. Democracy Index: the principle measure of democracy used in this study was the indicator of political rights compiled in Raymond Gastil's 1991 study, "Freedom in the World" (as cited in Barro, 1991). The Gastil concept of political rights is the right to participate meaningfully in the political process (e.g., vote and compete for public office). In this ranking, zero corresponds to the fewest political rights, and one corresponds to the most political rights.

   e. Inflation rate: measured as the change in inflation rates, businesses generally perform more poorly when inflation is unpredictable.

Barro's 1998 study showed a significantly positive effect on GDP/capita growth from the years of schooling at the secondary and higher level for males aged twenty five and over (0.0118). Therefore, the general notion of conditional convergence was strongly supported.

Chandran's cross-county regressions.

Using Barro's 1991 study as a model, Chandran's 1992 doctoral dissertation determined the effect of human capital, as proxied by school enrollment rates, on economic growth between 1975 and 1985. Barro's regression analysis included only one proxy for human capital, male secondary and higher schooling. Chandran's regression analysis, however, added other proxies for human capital. Depicted in Table 7, his regressions for school enrollment rates showed that the secondary school enrollment rate was positive and significant, while the primary school enrollment rate was negative but insignificant. Chandran posited that the skills required for increasing productivity in an industrializing economy may not have been taught at the primary level. His study also showed that the initial level of physical capital had a negative effect on growth, thus confirming the convergence hypothesis.

Table 7

Chandran's First Regression (1975 to 1985)

Number of Observations (countries)	98
Independent Variables	Regression Coefficients*
Constant	0.048
GDP per capita, 1975	-0.006**
Secondary School Enrollment Rate, 1975-1985	0.056**
Primary School Enrollment Rates, 1975-1985	-0.007
Ratio of government consumption to GDP	-0.002**
Revolutions, 1975-1985	-0.053**
Assassinations, 1975-1985	-0.008
R^2	0.420

* Rounded to three decimal places.
** Indicates significance at the 99% confidence level.

Regarding the use of school enrollment rates as a proxy for human capital, Chandran noted that two assumptions were made: (a) there was a positive relationship between the abilities needed to run an advanced economy and what is taught in schools, and (b) more time spent in schools led to higher levels of those abilities. On these assumptions, Chandran stated the following:

> When considering the effect of human capital on growth rates, what we are interested in is a measure of human capital that adequately represents the abilities and attributes that enhance an individual's productivity. School enrollment rate, which is the proxy which Barro uses for measuring human capital may not represent abilities that make for productivity in an individual. (1992, p. 39)

Chandran, therefore, used an additional measure of human capital: school achievement scores. Using science scores from The International Association for the Evaluation of Educational Achievement's Six-subject Study carried out in 1970-1971 for 16 countries, a regression analysis gave the information depicted in Table 8.

Table 8

Chandran's Second Regression (1975 to 1985)

Number of Observations (countries):	16
Independent Variable	Regression Coefficient
Constant	1.49705
GDP per capita, 1975	-0.00034**
Average Science Test Score	0.15064**
Ratio of government consumption to GDP	-0.04557
Assassinations, 1975-1985	0.09970
R^2	0.51

** Indicates significance at the 99% confidence level.

Thus, using science test scores as a proxy for human capital, Chandran showed that school achievement scores had a greater impact on economic growth than school enrollment rates.

Chandran stated that "The findings of this study may have policy implications for developing countries in their growth strategy through human capital accumulation" (1992, p. vi). He concluded that if school achievement is an important factor in determining the productivity of a country's workforce, than the LDCs (least developed countries) should be concentrating on factors that influence achievement and not just enrollment rates.

Benavot and Kamens' cross-country regression.

Benavot and Kamens' 1991 study examined the relationship between economic growth and a different proxy for educational human capital: a country's national curriculum. These authors stated that the teaching of mathematics and science in national school systems has not only become universal, but were viewed as core knowledge in the modern world, the teaching of which had become a precondition for successful industrial development. They noted that "More so than any other curricular subjects, achievements in mathematics and science are viewed as the main harbingers of economic development and national progress" (Benavot & Kamens, 1991, p. 139).

Based on a broad analysis of historical documents and official curricular documents (depicted in Table 9), Benavot and Kamens' data showed an increase in the number of countries teaching science, as well as an increase in the amount of curricular time devoted to science.

Table 9

The Emphasis on Science Education in Primary School Curricula

	Time Periods		
	1920 - 44 N = 63	1945 - 69 N = 105	1970 - 86 N = 133
Proportion of countries offering science instruction	83.0	91.0	98.0
Mean percentage of total curricular time devoted to science instruction	5.8	6.9	7.7

These authors also studied variations in emphasis given to science curriculum in certain periods by world region. Depicted in Table 10, their data showed that over time the emphasis given to science curriculum has increased for most areas of the world. They noted, however, that contrary to popular belief, there was no evidence that the Asian countries devote substantially more of their curriculum to science education.

Table 10

Primary Curriculum and Science Education by World Region

	Percentage of Curriculum Devoted To Science					
Region:	Sub-Saharan Africa	Middle East/ North Africa	Asia	Latin America	Eastern Europe	The West
Period:						
1920-44	.0	4.9	4.7	6.8	9.4	5.5
1945-69	5.2	5.7	8.9	9.2	7.8	6.3
1970-86	7.1	6.7	7.9	10.9	7.7	6.5

According to Benavot and Kamens, these data were surprising: "In the post-World War II periods, poorer, agrarian nations devote more curricular time to science subjects than do richer, industrialized nations" (Benavot & Kamens, 1991, p. 164). They concluded, therefore, that the proportion of the curriculum devoted to science, at least at the primary level, was a weak predictor of economic development. Because of this, Benavot and Kamens called for a detailed examination of the specific scientific content and principles taught in these countries and the long-term consequences—economic or otherwise—of this curricular emphasis.

Depicted in Table 11, these authors disaggregated the data by socio-economic level.

Table 11

Primary Curriculum and Science Education by Economic Status

	Percentage of Primary Curriculum Devoted to Science	
Period	More Developed Countries	Less Developed Countries
1920 - 44	6.2	5.1
1945 - 69	6.8	7.2
1970 - 86	6.9	8.2

In a follow-up study conducted by Aaron Benavot (1992), a panel design regression analysis was used to study the effect of official curricular policy declarations and economic growth. The official policy declarations were generally produced by government education offices in the form of national syllabi of subject categories to be taught in primary schools. Benavot's 1992 study yielded the results depicted in Table 12. Benavot concluded from this panel regression that the annual hours of instruction devoted to science education had strong, positive effects on economic growth, and that expansion in the enrollment rates at both the primary and secondary level had a strong and positive effect on economic growth between 1960 and 1985.

Table 12

Primary Education Curricular Content and Economic Growth

Dependent variable was the average real GDP/capita in 1960-1985

Average annual instructional time in each subject area (circa 1960)	Regression Coefficient
Mathematics	-0.00021
Sciences	0.00102
Languages	0.00015
Arts/music	0.00064
All social studies	-0.00001
Moral/religion	0.00059
Physical education	-0.00027
Prevocational education	-0.00042
Educational enrollment rates	
Primary	0.0042
Secondary	0.0035
GDP/Capita, 1960 (lagged control variable)	0.69
N=63	

Hanushek and Kim's cross-country regression.

In Hanushek and Kim's 1995 study entitled, "Schooling, Labor Force Quality, and Economic Growth," earlier efforts to proxy and measure education's impact on economic growth (e.g., years of schooling) were described as " . . . a crude measure of skill differences in the workforce and ineffective in explaining student cognitive achievement" (p. 5). Instead, Hanushek and Kim used a direct measure of school quality in their cross-country regression: cognitive skills from math and science tests. Their comparison of cognitive achievement relied on splicing together the data from a series of science and math tests conducted over the past three decades (ending in 1995), with four tests being administered by the International Association for the Evaluation of Educational Achievement (IEA) and two being administered by the International Assessment of Educational Progress (IAEP). Their cross-country regression yielded the coefficients depicted in Table 13.

Hanushek and Kim found that using math and science test scores as a measure of school quality significantly improved the predictions of growth rates, particularly at the high and low ends of the growth distribution, with school quantity, quality, and the initial level of real gross domestic product per capita explaining about 40 per cent of the variation in growth rates.

Table 13

Cross-Country Growth Model Regression

Dependent variable: Average annual growth rate of gross domestic product per capita, 1960 – 1990.

Independent Variable	Regression Coefficient
Initial income of RGDP/capita	-0.49 (-4.38)*
Average amount of schooling	0.363 (3.16)*
Composite measure of schooling quality (math and science test scores)	0.095 (4.40)*

N = 100
$R^2 = 0.365$

* T statistics.

These authors concluded that " . . . both cognitive skills as well as schooling quantity positively contribute to explaining variations in per capita growth rates" (Hanushek & Kim, 1995, p. 22).

Lee and Barro's cross-country regression.

In their 1998 paper entitled, "Schooling Quality in a Cross Section of Countries," Jong-Wha Lee and Robert Barro investigated the educational quality determinants of economic growth. Commenting on earlier cross-country regression analysis, Barro and Lee (1998) stated the following:

> One problem with these previous studies, however, is that the schooling variables, such as enrollment ratios and average years of attainment, are imperfect measures of the educational component of human capital. For example, they measure only the quantity of schooling, not the quality. (p. 1)

Similar to Chandran's 1992 doctoral dissertation, their premise was that the quality of education should be reflected in scores on internationally comparable tests of achievement in knowledge, skills, behavior, and attitudes. Using a dataset of combined science and math test scores compiled by the United States Department of Education (with the data coming from the IEA and IAEP) in 1993 as the dependent variable, they regressed a set of independent variables. Table 14 depicts their results.

Table 14

Lee and Barro Regression for Test Scores

Dependent Variable: Test Scores

Independent Variables	Regression Coefficients
Log (GDP/capita)	3.19
Primary education of adults	1.33
Pupil-teacher ratio	-0.15
Log of average teacher salary	1.62
Length of school day	0.01

The positive coefficient on the log of per capita gross domestic product (3.19, t = 3.00) confirms that school children from higher income countries tend to achieve higher test scores, when holding fixed other school resource factors that influence student achievement. Average years of schooling, entered in the form of average years of primary school attainment for adults aged 25 and above, used as a proxy for human capital in other studies, also has a strong, positive coefficient (1.33, t = 4.93), but not as strong as compared to GDP per capita. Lee and Barro disaggregated the math and science scores and regressed these two dependent variables, with the results depicted in Table 15.

Table 15

Lee and Barro Regression for Test Scores by Subject

Dependent Variable: Disaggregated Test Scores

	Regression Coefficients	
Independent variables:	Mathematics	Science
Log (GDP/capita)	1.14	2.80
Primary education of adults	2.81	1.93
Pupil-Teacher ratio	-0.31	-0.31
Log of average teacher salary	1.19	1.34
Length of school day	0.13	0.09

Lee and Barro noted the strong, positive relationship between math and science test scores and the log of GDP per capita. These authors also noted that science test scores had a stronger relationship with GDP per capita than do math test scores.

Summary

The neoclassical economic growth model, as envisioned by Jones (1998), incorporated human capital and technology as variables in the economic production function. Quantifying the contribution of human capital, as proxied by education, to economic growth has been the focus of several researchers:

1. Using the direct returns approach for several economically advanced countries, Psacharopoulos (1981) found that the private rate of return was approximately 14% for secondary education and approximately 12% for higher education.
2. Using the growth accounting approach, several researchers found that higher levels of human capital, either in the form of higher enrollment rates or higher levels of average years of schooling, were positively and significantly related to higher rates of economic growth.

Thus, the literature review done by the current researcher generally supported the role of human capital as a contributory factor in the neoclassical economic growth model. However, the relationship between specific types of education (i.e., specific types of curricula) and economic growth rates in different countries was not studied in the literature reviewed by the current researcher.

Chapter III

Methodology

Research Design

According to Wallen and Frankel (2001), research questions that determine relationships between a set of variables are important because they " . . . help us to explain the nature of the world in which we live" (p. 31). Thus, using the statistical tool known as a regression analysis to determine the relationship between a dependent variable and a group of independent variables will enable the researcher to test specific research hypotheses (Trochim, 2001). For this study, the current researcher used a regression analysis to study the relationship between the growth rate of gross domestic product per capita (the dependent variable) and several explanatory (independent) variables for a population of 43 countries. The explanatory variables were the exogenous variables identified in Barro's 1998 study with one new educational proxy for human capital.

The Neoclassical Growth Model and Variable Identification

Economists who wish to understand how different factors, including human capital as proxied by education, contribute to economic growth have used models to conceptualize the relative contribution of each factor (Mankiw, 1997). The basis for understanding human capital's contribution to economic growth in this study was the neoclassical growth model:

$$Y = K^{\alpha}(AH)^{1-\alpha} \tag{8}$$

The most common statistical technique used to determine the effect size of an exogenous variable on a dependent variable is a cross-country regression (Becker & Baumol, 1996). The framework for the cross-country growth regression was prototyped by Roger Kormendi and Phillip Meguiree in 1985 with their study *Macroeconomic Determinants of Growth: Cross-country Evidence,* and was later popularized by Barro in his 1991 study, "Economic Growth in a Cross-section of Countries" (Hanushek & Kim, 1995). A regression analysis approach isolates the effect of the independent variable that changes during periods of repeated observation (Becker & Baumol, 1996). Kuroda (1996) described the cross-national study, or cross-sectional study, as a method that uses multiple regressions to examine the effect of an independent variable (i.e., human capital in the form of education) on a dependent variable (i.e., economic growth rate). Kuroda explained that there are two possible regression models used to identify the contribution of education to economic growth:

1. Panel design: In this model, a time gap is entered between the dependant variable and the independent variables, so that:

   $$Y_t = b0 + b1*Y_{t-1} + b2*X_{t-1} + e \tag{9}$$

   Where Yt is the gross domestic product per capita at the end of the time period, Yt-1 is the gross domestic product per capita at the beginning of the time period, and Xt-1 is the human capital or educational component at (or near) the beginning of the time period.

2. Growth rate: In this model, the growth rate of the GDP per capita is regressed against the independent variables, so that:

$$Y_{(t-1,\,t)} = b0 + b1{*}X_{t-1} + e \quad (10)$$

Where Y(t-1,1) is the growth rate in gross domestic product per capita over the period of the study and Xt-1 is the educational human capital component at the beginning of the time period. Both methods have been used in cross-country studies, but more have used the growth rate approach (Kuroda, 1996). Regarding the comparison of these two methods, Kuroda noted the following:

> Although the first approach provides the regression coefficient for Yt-1, which is certainly the merit of this method, there are two main problems. First because the dependent variable and one of the independent variables are time lagged, the correlations of those variables are generally very high and the R square is also very high. Therefore, if the first model is used, the analysis of the R square is meaningless. Second, when the first method is used to examine the impact on economic growth and the dependent variable is national income, the normality of the dependent variable is unlikely to be obtained. On the other hand, the growth rate of national income is likely to be normally distributed. (p. 59)

Based on the limitations of the panel design method expounded by Kuroda, this study used the growth rate approach. While recognizing Kuroda's reservation about the R square value, the initial level of GDP/capita was entered into the regression as a controlling variable.

Participants

The educational human capital proxy used in this study, the percent of a nation's science curriculum devoted to the notions of science (NOS), was collected from the 45 countries that participated in The Third International Mathematics and Science Study (TIMSS). Sponsored by the International Association for the Evaluation of Educational Achievement (IEA) and the governments of the participating countries, TIMSS was a comparative study of math and science education in 45 countries. The participating countries are listed as Appendix 1. Bianchi, Houang, Babcock and Schmidt (1998) noted the following concerning TIMSS:

> The study was intended to provide educators and policy makers with an unparalleled and multidimensional perspective on mathematics and science curricula, their implementation, the nature of student performance in mathematics and science, and the social, economic, and educational context in which these occur. (p. 1-1)

TIMSS focused on studying the mathematics and science curricula for three different populations from each of the 45 participating countries:

1. Population one: all students enrolled in the two adjacent grades that contain the largest proportion of 9-year-old students.

2. Population two: all students enrolled in the two adjacent grades that contain the largest proportion of 13-year-old students.
3. Population three: all students enrolled in their final year of secondary education, including students in vocational education programs.

Instrumentation

Third International Math and Science Study (TIMSS) Data

Schmidt, Raizen, Britton, Bianchi, and Wolfe (1997) wrote that one of the goals of TIMSS was to assess the intended science curriculum, thereby providing educators and policy makers with an exhaustive and multidimensional perspective on science curricula in different countries. These authors ask, Why study science curriculum? Their answer to this question was as follows:

> Each day in classrooms around the world, children and their teachers engage in some aspect of learning science. These educational experiences, which seem so very ordinary, are actually guiding and shaping children's lives. *The cumulative effect of the experiences pupils share helps mold them and helps determine the course and quality of their lives...curriculum is the most fundamental structure for these experiences.* " (Schmidt et al., 1997, p. 4)

The specification of curricular goals at the national or regional level, which the IEA has termed "the intended curriculum," defined what students were expected to learn (Schmidt et al., 1997, p. x). "The curriculum differences (among countries) reflect important cultural differences as to how scientific thinking develops in a particular culture and how scientific knowledge is constructed and reconstructed socially" (Schmidt et al., 1997, p. 63). Robitaille et al. (1993) further noted that "One of the hallmarks of the IEA study is the recognition given to the importance of curriculum as a variable in explaining differences among national school systems in accounting for differences among student outcomes" (p. 11).

Document sampling.

The TIMSS science curriculum data, collected under the auspices of the IEA in 1990 and 1991, were managed and analyzed by the U. S. National Research Center at Michigan State University. According to Bianchi et al. (1998), each national document sample was composed from one or more of the following sources:

1. The official national science curriculum guide for each population.
2. The official national science textbooks for each population.
3. Regional, provincial, state, or cantonal science curriculum guides for each population.
4. The most widely used commercial textbooks if officially provided books were not used.

Document samples for all three populations in all 43 countries were representative of at least half of the students for each country.

The curriculum analysis resulted in the formation of so-called, "curriculum frameworks," which were detailed in *Curriculum Frameworks for Mathematics and*

Science (Robitaille et al., 1993). The curriculum analysis used two types of documents:

1. Curriculum guides: Virtually all educational systems use some form of curriculum guide to structure science education, and they represent the official documents that most clearly reflect the intensions, visions, and aims of a country's curriculum writers (Schmidt et al., 1997).
2. Textbooks: textbooks provide a detailed map of scientific disciplines, topics, and performances to be mastered in pursuing national goals (Bianchi, et al, 1998, p. 2-3). Difference in pedagogical strategies and approaches can be discerned from textbook data, thereby capturing important insights about science intensions and aims (Schmidt et al., 1997).

Curriculum frameworks and science aspects.

The TIMSS curriculum frameworks for science were comprised of three aspects:

1. Content: The content aspect of the curriculum framework represents the topics to be covered in the curriculum.
2. Performance Expectations: The performance expectation of the curriculum framework represents the behaviors that the curriculum might expect to be elicited from a student.
3. Perspectives: The perspectives aspect of the curriculum framework represents the perspective or view of science the curriculum might expect to be elicited from the student.

Each framework was organized hierarchically using subcategories of increasing specificity. According to Bianchi et al. (1998), these frameworks provided " . . . a set of conventions that serve as a common language system." What type of science topic was included under each of the three aspects is described in Appendix 2. The curriculum documents, having been divided into elements called "blocks," were systematically analyzed for content, performance expectation, and perspective. Any document block might contain anywhere from zero to several of the categories from the frameworks. This coding of the curricula frameworks lead to the formulation of a statistical abstract for the science curriculum for the 45 countries.

Research Data

Data collection: The NOS human capital education variable.

In Barro's 1998 study, educational attainment in the form of years of schooling was identified as an exogenous variable suitable as a proxy for educational human capital accumulation within a population. But as Chandran (1992) noted, one of the tasks in the economics of education is to identify the specific educational factors that augment a nation's stock of human capital. Chandran stated that:

> What determines the usefulness of school learning is what students imbibe from the school system and not the number of years of schooling. This argument has relevance because future productivity of individuals depends upon the way they can make use of the faculty of critical thinking and problem solving

> skills which they acquired through their schooling. Thus the *content* [italics added] of schooling, rather than the number of years spent in schooling matters greater in the future productivity of individuals. (Chandran, 1992, p. 49)

Other cross-national regressions used science or math test scores as proxies for human capital. Using this variable, however, may not have captured the level of science literacy, or the notions of science, within a population. While referring to the Third International Math and Science Scores (TIMSS), Rotberg noted that "Test score rankings provide little information about educational quality because countries differ substantially in such factors as student selectivity, curriculum emphasis, and the proportion of low-income students in the test-taking population" (1998, p. 1030). Angelo Collins, who led the development of the National Science Education Standards, also had doubts about whether international test scores (such as TIMSS) were an adequate measure of science literacy: "I am not convinced that a high score on TIMSS [science test] is equivalent to being scientifically literate. These tests don't get at long-term problem-solving skills and concepts about the nature of science" (Gibbs & Fox, 1999, p. 87).

According to Robitaille et al. (1993), the intended science curriculum of a nation represented the best measure of a nation's scientific knowledge. "The intended curriculum is the best measure because it represents the goals and purposes of an educational system, i.e., what is valued by an educational system" (Robitaille et al., 1993, p. 15). Thus, the intended curricula of the 45 TIMSS countries, as represented by their curriculum guides and text books, provided the information for the aforementioned curricular frameworks. The notions of science, culled from the statistical abstracts of the curricular frameworks, were coded and used to determine the percent of the notions of science in a country's science curriculum. This NOS percentage then served as a unique proxy for human capital provided by the educational system of each participating country.

The content-by-cognitive-behavior-grid.

Using earlier IEA studies as a model, the TIMSS curricular frameworks were coded for the NOS percentage using a "content-by-cognitive-behavior grid." The use of such a grid has relied on the work of Bloom, Hastings, and Madaus as described in *The Handbook on Formative and Summative Evaluation of Student Learning* (Robitaille et al., 1993). The vertical axis of the grid contained the curriculum frameworks, and the horizontal axis contained the criteria for scientific thought, or the notions of science (NOS), as developed by Clarence Irving Lewis in his book *Mind and the World Order*. According to C. I. Lewis (1929), the notions of science include:

1. Dialectical and Reflective Thought: using Socratic dialogue for clear understanding of ideas.
2. Inductive and Deductive Reasoning: for analytical and inferential thinking.
3. Evidence: objectively collecting and organizing data.
4. Information Organization: use of statistical methods for data analysis.
5. Scientific Method: hypothesis formation and verification of interpretation and repeatability.

6. Systems Thinking: determining the relationships of the individual parts.
7. Action: predicated upon deductive and inferential reasoning.
8. Experiential Learning: learning by doing; employing empirical methods.
9. Promote Common Understanding of Concepts: how ideas are interrelated.
10. A Priori Principles: information derived by reasoning from self-evident propositions.

The curriculum frameworks blocks that met the notions of science as described by C. I. Lewis were taken as a percentage of the total curriculum framework blocks available in each country's curriculum guides and text books. The resulting NOS percentage then comprised the unique educational human capital variable used in the regression analysis.

<u>Data collection: The variables.</u>

The data for the exogenous variables (other than the unique NOS variable) used in this cross-country regression analysis were for the years 1988 through 1998, and were collected from the following sources:

1. Dependent variable:
    a. Growth in gross domestic product per capita: The Penn World Tables
2. Independent variables:
    a. Initial level of GDP/C: The Penn World Tables
    b. Years of schooling: The Barro and Lee Dataset
    c. Life expectancy at birth: The World Bank

d. Fertility rate: The World bank

e. Government consumption of gross domestic product: The Penn World Tables

f. Terms of trade: The Penn World Tables

g. Democracy index: The Gastil Index

h. Inflation rate: The World Bank

The Dependent Variable

The dependent variable in this study was the growth in a nation's gross domestic product per capita, which is often considered the best measure of how well a nation's economy is performing (Mankiw, 1997). According to Jones (1998), per capita income is a good summary statistic for indicating the level of economic development and is highly correlated with other measures of the quality of life (Jones, 1998).

The Independent Variables

The independent (explanatory) variables identified in the 1998 Barro study were:

1. Years of Schooling (human capital): Average years of male schooling attainment, (secondary and higher education), 25 years and older at the start of the decade.
2. Life expectancy at birth: Average value of the five year period prior to start of the decade.
3. Fertility rate: Log of average births per woman over the decade.

4. Government Consumption of GDP: Average ratio of government consumption as a percent of GDP over the decade.
5. Terms of Trade: Average level of the ratio of export to import dollar amounts over the decade.
6. Democracy Index: Gastil Index—one observation for each country (1994)
7. Inflation Rate: Change in inflation/deflation rate over the decade.

Data Analysis Tools

The statistical abstracts of the curricular frameworks were readily available from the United States National Research Center for the Third International Mathematics and Science Study at Michigan State University. Compressed text files for each TIMSS country were obtained over the World Wide Web and incorporated into a Microsoft Access Database, which ultimately contained approximately 425,000 records. Queries were subsequently written to extract those records for each country that met the aforementioned NOS criteria. The final NOS percentage calculation was the number of records that met the criteria as a percentage of all the available records for each of 43 TIMSS countries.

The final regression analysis was performed in SPSS, version 8.0, which was used primarily because of its general acceptance in the social sciences and availability among academic institutions.

Validity and Reliability

The validity and reliability of a study's measurement instruments influence the extent to which something can be learned about the phenomenon you are studying (Leedy & Ormrod, 2001). Miles and Huberman (1994) noted, however, that even with the overarching importance of these two constructs, issues of validity and reliability are resolved largely through the skills of the researcher.

Construct validity and the coding process.

Trochim (2001) stated that for there to be construct validity, the researcher must be able to conclude that they did a credible job of "... operationalizing your [the researcher's] constructs" (p. 22). Trochim stated that this type of validity assesses the degree to which the researcher has accurately translated, through the use of a measurement tool, their constructs [ideas] into something real and concrete. To establish this type of validity, Trochim stated that the researcher must have a good, detailed description of the content domain, with inclusion criteria that are clearly spelled out.

The current researcher ensured construct validity through the use of thick, rich descriptions of the criteria used to categorize the TIMSS curriculum frameworks. These descriptions were used in the construction of the content-by-cognitive-behavior grid, thereby assuring a valid translation of the researcher's constructs.

The IEA ensured construct validity of their data coding process for the construction of the science curriculum statistical abstracts by using curriculum frameworks that were flexible and robust. Robitaille et al. (1993) stated that "The frameworks had to allow for a given assessment item or proposed instructional activity to be categorized in its full complexity and not reduced to fit a simplistic classification scheme that distorted and impoverished the student experience embedded in the material classified" (p. 42). Central to ensuring a valid translation of the IEA coding scheme was standardization of all coding and reporting procedures: Native language speakers from each country who were responsible for the data collection and coding attended regional training on the collection and coding procedures where they receive three days of training and over 400 pages of training materials. An initial quality insurance phase was used to verify the adequacy of procedure use immediately following training; those responsible for each country's curriculum data were asked to submit data samples collected by each coder to the international center where they were independently evaluated. Only when a country's coders had demonstrated criterion concordance were they instructed to proceed with the data collection and coding.

Reliability and the coding process.

Reliability is the consistency with which a measuring instrument yields a certain result when the entity being measured hasn't changed (Leedy & Ormrod, 2001). More generally, reliability is the repeatability of your measures (Trochim, 2001).

The current researcher assured reliability in five ways:

1. Detailed descriptions of the TIMSS science curriculum frameworks were available from the text *Curriculum Frameworks for Mathematics and Science*, thus providing an audit trail (Robitaille et al., 1993).
2. For the categorization of TIMSS frameworks, the aforementioned content-by-cognitive-behavior grid contained criteria, methods, and procedures that were fully described, thereby assuring consistency in the coding process.
3. The notions of science (NOS) coding criteria used in the content-by-cognitive-behavior grid were well-linked to other literature-supported notions of science.
4. Several coding checks were made, thereby assuring consistency in the coding process.
5. Data from the categorization and regression analysis were retained and made available for reanalysis in the appendices.

Reliability of the TIMSS data collection and coding process were ensured by the IEA. When completed coding data arrived at the TIMSS International Curriculum Analysis Center at Michigan State University, each curriculum sample was identified, archived, and subjected to a reliability analysis. The reliability analysis consisted of selecting a random sample of blocks from the database, a recoding by referees, and a comparison to the actual country codings. These comparisons showed concordance indices of over 80 percent in virtually all cases and often 90 per cent or more.

Internal validity.

Wallen and Frankel (2001) contend that "Many times an intended hypothesis does not really get tested because other factors account for the results the researcher obtains. In the language of research, these alternatives are threats to the internal validity of the study" (p. 154). These authors described three threats to internal validity that are pertinent to this study:

1. Data collector characteristics: The characteristics of the data gatherers can affect results. Age, language patterns, and education levels are examples of characteristics that might affect how the data are collected and coded.
2. Data collector bias: There is the possibility that data collectors or coders may unconsciously misinterpret or distort the data in such a way to make certain outcomes more likely.
3. Intervening variable(s): A variable other than the one being studied may be responsible for observed differences in the subject population.

During the coding of the Curriculum Frameworks, the IEA ensured that data collector characteristics and bias were controlled for through the use of thick, rich coding descriptions and employing a workforce that was adequately trained in the application of theses descriptions.

To eliminate the possibility that other intervening variables were responsible for the observed effect on the growth rate of gross domestic product per capita, the current researcher entered eight other exogenous variables, including another human capital variable, into the regression analysis, thereby controlling for their effect.

Ethical Issues

The original TIMSS curricular frameworks data were collected and coded under the auspices of the International Association for Evaluation of Educational Achievement (IEA). Therefore, the current researcher faced no substantive ethical issues regarding the treatment of research participants.

Chapter IV

Results and Discussion

This chapter presents the results and discussions for this research study which consisted of two parts. Part one determined the percentage of the science curriculum devoted to the notions of science (NOS) for 43 countries that participated in the Third International Math and Science Study. The notions of science were those identified by C. I. Lewis in *Mind and the World Order.* The NOS data were extracted from the science curriculum frameworks collected by the IEA for TIMSS in 1990 and 1991. Part two of this research study consisted of a regression analysis which answered two research questions:

1. Is there a significant relationship between the type of science curriculum offered by a country and its growth rate in real gross domestic product per capita?
2. Does the type of science curriculum offered by a country have a significantly greater relationship with growth rate in real gross domestic product per capita than another measure of human capital, average years of schooling.

To answer these two research questions, the growth rate in gross domestic product per capita was regressed against the explanatory variables identified by Barro in his 1998 study, *Determinants of Economic Growth*. The NOS percentage derived from the TIMSS data acted as a unique proxy for educational human capital.

Empirical Results: Science Curricula and The Notions of Science

Following the lead of Bloom, Hastings, and Madaus in their book *Handbook on Formative and Summative Evaluation of Student Learning* (1971), a content-by-cognitive-behavior grid, or an item specification table, was constructed. Consisting of a two dimensional matrix, the horizontal dimension represented the 10 notions of science (NOS), and the vertical dimension represented the categories of science curriculum identified by the IEA. A facsimile of the matrix is included as Appendix B, and Table 16 presents the results of this coding analysis.

Table 16

Notions of Science Percent for TIMSS Countries

TIMSS Country	Curriculum NOS Percent	TIMSS Country	Curriculum NOS Percent
Argentina	1.534	Japan	3.092
Australia	2.894	Korea	3.474
Austria	2.128	Latvia	2.294
Belgium—Flemish	4.071	Lithuania	2.350
Belgium—French	1.671	Mexico	3.242
Bulgaria	1.842	Netherlands	2.190
Canada	2.871	New Zealand	4.760
China	3.047	Norway	1.720
Columbia	1.996	Philippines	3.088
Cyprus	2.445	Portugal	2.455
Czech Rep.	3.054	Romania	1.310
Denmark	2.362	Russian Fed.	2.254
Dominican	0.640	Scotland	2.574
France	2.700	Singapore	5.338
Germany	1.057	Slovak Rep.	3.369
Greece	0.907	Slovenia	3.975
Hong Kong	1.157	South Africa	4.752
Hungary	1.847	Spain	1.457
Iceland	3.238	Sweden	1.809
Iran	1.619	Switzerland	1.868
Ireland	1.211	Tunisia	0.284
Israel	2.405	United States	2.405
Italy	1.017		

An average value for the NOS was used for Flemish and French speaking Belgium, which was then regressed against the GDP/capita for Belgium. Scotland was not used in the final regression analysis. Therefore, a total of 43 TIMSS countries were used in the final regression.

Empirical Results: The Regression Analysis

The dependent and independent variables used in this regression analysis, along with the years for which the data were collected, are described in Table 17.

Table 17

Regression Variable Designation

Dependent Variable	Variable Name
Log of average growth in GDP/capita, 1988 - 1998	LRGDPPC
Independent Variables	
Log of the initial level of GDP/capita	LIGDPPC
Average years of schooling, 25 years and older, 1990	YEARSSCH
Percentage of science curriculum devoted to NOS, 1991	NOS
Log of life expectancy at birth, average 1985 and 1987	LLEAB
Log of fertility rate, average 1988 - 1998	LFERT
Government consumption of GDP, average 1988 – 1998	GCPGDP
Average level in openness (terms of trade), 1988 - 1998	GROPEN
Democracy index, one value, 1994	DEMOCIND
Change in inflation rate, 1988 - 1998	INFLRFAC

Table 18 depicts the descriptive statistics for the regression variables for the 43

TIMSS countries used in this regression analysis.

Table 18

Descriptive Statistics for Variables

Variable	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Dependent Variable					
LRGDPPC	-0.174	0.285	0.070	0.014	0.093
Independent Variables					
NOS (unique variable)	0.284	5.338	2.380	0.167	1.094
YEARSSCH	3.020	12.000	7.974	0.336	2.205
LLEAB	1.775	1.890	1.858	0.004	0.028
LFRT	0.000	0.602	0.268	0.024	0.157
GCPGDP	5.670	69.950	26.736	2.746	18.215
GROPEN	0.898	1.374	1.028	0.011	0.071
DEMOCIND	0.000	1.000	0.815	0.049	0.292
INFLRFAC	0.456	3.435	1.073	0.069	0.455
LIGDPPC	3.254	4.486	4.074	0.041	0.269

These data show that there is a wide range in the dependent variable, from a low of -0.714 (Bulgaria) to a high of 0.285 (Ireland). A negative coefficient for the dependent variable, indicating an economy that contracted between 1988 and 1998, was experienced by six TIMSS countries: Bulgaria, Latvia, Romania, the Slovak Republic, South Africa, and Switzerland. Of these six countries, only Switzerland was not experiencing profound social and political changes during the 1990s. That the other five showed negative growth from 1989 to 1998 is not unexpected, given their social and political environment during this same time period.

There was also a wide range in the unique human capital variable (percent of the curriculum devoted to the notions of science, or NOS) used in this study, ranging from a low of 0.284% (Tunisia) to a high of 5.338% (Singapore). The current researcher was not surprised by the figures from these two countries, given the expected strong association between economic development level and science curriculum. That the NOS score for the United States fell within one standard deviation of the mean was also expected, given the lack of a national or regional curriculum planning agency.

However, other results were unexpected by this researcher: several countries with economies that are generally considered to be well-developed and highly competitive show low percentages of NOS in their science curriculum, while some other countries with economies that are generally considered to be less well-developed and less competitive show high percentages of NOS in their science curriculum. With the country's economic competitiveness rank according to the International Institute for Management Development given in parentheses, countries with unexpectedly low percentages of NOS are:

1. Germany: 1.057% (8)
2. Norway: 1.725% (16)
3. Sweden: 1.809% (9)

Countries with unexpectedly high percentages of NOS are:

1. Slovenia: 3.975% (35)
2. Philippines: 3.088% (39)
3. Czech Republic: 3.054% (37)

The results of the linear regressions are depicted in Table 19 (an alpha level of .05 was used for all statistical tests).

Table 19

Backward Regression Coefficients (N = 43)

Model	Variable	Standard Error	Std. Coefficients Beta	t-statistic	Significance
1	(Constant)	1.241		-2.811	0.009*
	NOS	0.010	0.096	0.551	0.587
	LLEAB	0.661	0.951	3.155	0.004*
	LFERT	0.091	0.129	0.574	0.571
	GCPGDP	0.001	-0.067	-0.393	0.698
	GROPEN	0.297	0.190	1.052	0.303
	DEMOCIND	0.048	-0.416	-1.968	0.060
	INFLRFAC	0.042	-0.027	-0.162	0.873
	LIGDPPC	0.056	-0.490	-2.040	0.052
	YEARSSCH	0.007	-0.344	-1.402	0.173
2	(Constant)	1.211		-2.864	0.008*
	NOS	0.010	0.094	0.552	0.586
	LLEAB	0.646	0.947	3.213	0.003*
	LFERT	0.089	0.125	0.573	0.572
	GCPGDP	0.001	-0.072	-0.441	0.663
	GROPEN	0.285	0.184	1.060	0.299
	DEMOCIND	0.047	-0.414	-1.999	0.056
	LIGDPPC	0.055	-0.491	-2.086	0.047*
	YEARSSCH	0.007	-0.349	-1.457	0.157
3	(Constant)	1.156		-2.886	0.008*
	NOS	0.010	0.085	0.510	0.614
	LLEAB	0.617	0.915	3.251	0.003*
	LFERT	0.087	0.109	0.511	0.614
	GROPEN	0.271	0.163	0.993	0.330
	DEMOCIND	0.045	-0.434	-2.182	0.038*
	LIGDPPC	0.052	-0.459	-2.080	0.047*
	YEARSSCH	0.007	-0.339	-1.444	0.160
4	(Constant)	1.101		-2.890	0.007*
	LLEAB	0.598	0.888	3.255	0.003*
	LFERT	0.084	0.129	0.627	0.536
	GROPEN	0.246	0.130	0.874	0.390
	DEMOCIND	0.045	-0.443	-2.268	0.031*
	LIGDPPC	0.051	-0.444	-2.058	0.049*
	YEARSSCH	0.007	-0.307	-1.375	0.180
5	(Constant)	0.910		-3.080	0.005*
	LLEAB	0.500	0.797	3.492	0.002*
	GROPEN	0.241	0.142	0.972	0.339
	DEMOCIND	0.044	-0.457	-2.376	0.024*
	LIGDPPC	0.049	-0.467	-2.216	0.035*
	YEARSSCH	0.006	-0.251	-1.240	0.225
6	(Constant)	0.803		-2.974	0.006*
	LLEAB	0.489	0.750	3.365	0.002*
	DEMOCIND	0.044	-0.476	-2.493	0.018*
	LIGDPPC	0.049	-0.455	-2.166	0.038*
	YEARSSCH	0.006	-0.222	-1.109	0.276
7	(Constant)	0.766		-2.757	0.010*
	LLEAB	0.473	0.684	3.173	0.003*
	DEMOCIND	0.041	-0.550	-3.058	0.005*
	LIGDPPC	0.049	-0.498	-2.401	0.023*

*$p < .05$.

Model one of this regression indicates that only LLEAB has the expected sign and is statistically significant. However, after eliminating the variable INFLRFAC in model two, LIGDPPC also has the expected sign and is statistically significant. After eliminating all variables that are not statistically significant, model seven indicates that only LLEAB and LIGDPPC have the expected sign and are statistically significant.

Table 20 presents the summary statistics for the regression analysis.

Table 20

Regression Model Summary Statistics (N = 43)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.667	0.445	0.245	0.058
2	0.666	0.444	0.273	0.056
3	0.663	0.440	0.295	0.056
4	0.659	0.434	0.313	0.056
5	0.653	0.427	0.328	0.055
6	0.639	0.408	0.329	0.055
7	0.619	0.384	0.324	0.055

Note. Model 1 predictors: (Constant), YEARSSCH, GCPGDP, NOS, INFLRFAC, LFERT, GROPEN, DEMOCIND, LIGDPPC, LLEAB

Model 2 predictors: (Constant), YEARSSCH, GCPGDP, NOS, LFERT, GROPEN, DEMOCIND, LIGDPPC, LLEAB

Model 3 predictors: (Constant), YEARSSCH, NOS, LFERT, GROPEN, DEMOCIND, LIGDPPC, LLEAB

Model 4 predictors: (Constant), YEARSSCH, LFERT, GROPEN, DEMOCIND, LIGDPPC, LLEAB

Model 5 predictors: (Constant), YEARSSCH, GROPEN, DEMOCIND, LIGDPPC, LLEAB

Model 6 predictors: (Constant), YEARSSCH, DEMOCIND, LIGDPPC, LLEAB

Model 7 predictors: (Constant), DEMOCIND, LIGDPPC, LLEAB

The R squared values shown in model 7 of Table 20 indicate that approximately one third of the variation in the dependent variable can be explained by the independent variables LLEAB. DEMOCIND, or LIGDPPC.

Table 21 presents the results of the zero-order correlations between the explanatory variables. The resulting correlation matrix allows us to estimate the relationship between all possible pairs of variables. The unique human capital variable used in this study, the notions of science (NOS), has a relatively high correlation coefficient (.412) with only one other independent variable, GROPEN; however, the current researcher is not aware of any theoretical construct that might account for this.

Table 21

Correlation Coefficients

Model	Variable	YEARSSCH	GCPGDP	NOS	INFLRFAC	LFERT	GROPEN	DEMOCIND	LIGDPPC	LLEAB
1	YEARSSCH	1.000	0.114	-0.263	-0.114	-0.327	-0.168	-0.392	-0.135	-0.459
	GCPGDP	0.114	1.000	-0.106	-0.196	-0.152	-0.219	-0.230	0.305	-0.224
	NOS	-0.263	-0.106	1.000	-0.066	-0.157	0.412	0.110	-0.160	0.212
	INFLRFAC	-0.114	-0.196	-0.066	1.000	-0.091	-0.197	0.069	-0.032	-0.077
	LFERT	-0.327	-0.152	-0.157	-0.091	1.000	-0.112	0.117	0.125	0.505
	GROPEN	-0.168	-0.219	0.412	-0.197	-0.112	1.000	0.152	-0.183	0.236
	DEMOCIND	-0.392	-0.230	0.110	0.069	0.117	0.152	1.000	-0.194	-0.029
	LIGDPPC	-0.135	0.305	-0.160	-0.032	0.125	-0.183	-0.194	1.000	-0.389
	LLEAB	-0.459	-0.224	0.212	-0.077	0.505	0.236	-0.029	-0.389	1.000

Discussion of Results: Explanatory Variables That Cause An Economy To Grow

Barro's 1998 study identified and described the variables that positively or negatively affected the rate of growth in gross domestic product per capita for 98 countries. According to Barro, the variables that positively affect the rate of growth are (a) DEMOCIND, (b) YEARSSCH, (c) GROPEN, and (d) LLEAB. The variables that negatively affect the rate of growth are (a) LIGDPPC, (b) GCPGDP, (c) INFLRFAC, and (d) LFERT.

Table 22 depicts the results from model 1 of the current researcher's regression analysis for variables identified by Barro as having a positive relationship with the growth rate in gross domestic product per capita.

Table 22

Explanatory Variables That Cause Economic Growth (Model 1)

Variable	Standard Error	Standardized Coefficients	t statistic	Significance
DEMOCIND	0.048	-0.416	-1.968	0.060
YEARSSCH	0.007	-0.344	-1.402	0.173
NOS	0.010	0.096	0.551	0.587
GROPEN	0.297	0.190	1.052	0.303
LLEAB	0.661	0.951	3.155	0.004

The variable DEMOCIND does not have the expected sign and is not statistically significant. GROPEN has the expected sign but is also not statistically significant. Only LLEAB has the expected sign and is statistically significant throughout all models, indicating that it had the strongest relationship with the growth rate of gross domestic product per capita for the 43 TIMMS countries. In Barro's 1998 study, the independent variable LLEAB was also identified as having a stronger relationship with economic growth than his human capital proxy, average years of schooling.

Human Capital Proxies

A review of previous studies on the effect of human capital on the growth rate of gross domestic product per capita is depicted in Table 23. All reviewed studies indicated a positive contribution by human capital, as proxied by an educational variable, to the growth rate in gross domestic product per capita. Yet in the current researcher's study, the human capital proxy YEARSSCH does not have the expected sign and is statistically insignificant, an unexpected finding given the results of previous researchers.

The unique proxy for human capital used in this study, NOS, has the expected sign but is statistically insignificant. Again, this result was unexpected because of the generally accepted paradigm that a scientifically literate workforce is required for strong economic growth. However, that the coefficient for the notions of science (NOS) was both positive and larger than the coefficient for the average years of schooling (YEARSSCH) was enlightening, their lack of significance not withstanding.

Table 23

Overview of Growth Accounting Regression Analyses for Education

Study	Year	Human Capital Variable	Regression Coefficient
Chandran	1992	Secondary school enrollment rates	0.056
Chandran	1992	Average science test scores	0.151
Benavot	1992	Average annual instructional time in science	0.001
Hanushek, Kim	1995	Average years of schooling	0.363
Barro	1998	Average years of schooling (males only)	0.012

Discussion of Results: Explanatory Variables That Cause An Economy To Contract

Table 24 presents the findings from the current researcher's study for those variables Barro identified as having a negative relationship with the growth rate of gross domestic product per capita.

Table 24

Variables That Mitigate Economic Growth

Variable	Standard Error	Standardized Coefficients	t statistic	Significance
LIGDPPC	0.056	-0.49	-2.04	0.052
GCPGDP	0.001	-0.067	-0.393	0.698
INFLRFAC	0.042	-0.027	-0.162	0.873
LFERT	0.091	0.129	0.574	0.571

LIGDPPC has the expected sign but was not statistically significant (0.052) in the first regression model. However, in regression models two through eight, LIGDPPC is statistically significant, and so the general notion of convergence theory is supported by these models. GCPGDP and INFLRFAC have the expected sign but are not statistically significant. LFERT does not have the expected sign and is not statistically significant.

Chapter V

Conclusions and Recommendations

The Relationship Between the NOS and Economic Growth

Summary of Findings: Research Question Number One

Research question number one seeks to determine if there is a significant relationship between a country's science curriculum and the growth rate of gross domestic product per capita. The linear regression for NOS yielded a beta coefficient of 0.096, indicating a positive contribution for this human capital variable. Using an alpha level of .05, the effect of NOS on GDP/capita for the 43 participating TIMSS countries was not statistically significant: $t = .551$ and $p > .05$. Based on these data, the null hypothesis for research question number one is not rejected.

Summary of Findings: Research Question Number Two

Research question number two seeks to determine if the type of science curriculum offered by a country has a significantly greater effect on the growth rate in real gross domestic product per capita than another measure of human capital, years of schooling. The beta coefficient for NOS (.096) was greater than the beta coefficient for YEARSSCH (-.344). Using an alpha level of .05, the effect of the YEARSSCH on GDP/capita for the 43 participating TIMSS countries was not statistically significant: $t = -1.402$ and $p > .05$. Based on these data, the null hypothesis for research question number two is also not rejected.

Investing In Productive Capacity: Science Education

Writing in *Human Capital*, Gary Becker, a 1992 Nobel Laureate in Economics, contends that "The most valuable of all capital is that invested in human beings" (1993, p. 27). Previous studies generally support the idea that human capital, as proxied by various measures of educational attainment, contribute to a country's economic growth rate. While most learned individuals would not dispute Becker's assertion, policy makers are left to speculate on the *best, most cost-effective* methods of investing in human beings: should a country promote policies that encourage more of its citizenry to continue with their formal education? Or should a country instead concentrate on the quality of its education as opposed to quantity? Or perhaps policy makers should de-emphasize the idea of investing in human capital through formal education and instead concentrate their capital resources on investing in other forms of human capital (e.g., health care) or physical infrastructure (e.g., roads or mass transportation).

The generally accepted notion that human capital in the form of a scientifically literate workforce is required for sustained economic growth is exemplified in a letter dated November 17, 1944, from then President Roosevelt requesting a report from Vannevar Bush, the Director of the Office of Scientific Research and Development. In this letter, Roosevelt inquires about how the federal government might promote scientific progress in the postwar era. In his report, "Science—The Endless Frontier," Bush proclaimed scientific progress to be " . . . one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress" (p. 2). Even today, it would seem that society's expectations of what science can do for us have not diminished. Yet this study failed to detect a statistically significant relationship between what many educational pundits seem to know: that science education is a prerequisite for economic growth. Therefore, the relationship between science education and economic growth will remain amorphous and largely theoretical, demonstrable only through economic models. Even if one accepts science education as a technological exogenous factor, the *specific types* of science education that contribute to a nation's technological capacity, and hence its economic growth, remain unaccounted for.

Investing In Productive Capacity: Other Forms of Human Capital

A review of the regression analyses by Barro (1998) and the current researcher, depicted in Table 25, indicates that investing in the health of the population , as proxied by the life expectance at birth (LLEAB), and terms of trade (GROPEN) both have a stronger relationship with the growth rate of gross domestic product per capita than any educational proxy for investment in human capital. This would suggest that if a policy maker was primarily concerned with economic growth, resources might better be directed towards improving health care in a population and maintaining an open trading policy with other countries.

Both of these factors (LLEAB and GROPEN), however, can be conceived of as contributors to the human capital stock of a country. A healthy population lives longer and so has more productive years to add to the human capital stock of a country. A healthy workforce is also more productive due to, for example, fewer lost working days . Barro (1998) states that favorable terms of trade cause the GDP per capita to rise because it stimulates a positive change in domestic employment and output per capita. Fewer trade barriers also results in increased market competition forcing a country's workforce to continually upgrade its skills. Thus, government policies promoting a healthy workforce and reduced trade barriers may cause an economy to grow faster than investing in an educational form of human capital.

Table 25

Regression Analyses Variable Comparison

Variable	Barro's Study Rank	Current Researcher's Study Rank	Average Rank
LLEAB	2	1	1
GROPEN	1	2	1
NOS		3	3
YEARSSCH	4	4	4
DEMOCIND	3	5	4

It stands to reason, however, that the positive effects of a healthy workforce and liberal trade policies cannot be realized without an educated workforce. But here again, we are left with the question of what forms of education would best augment, or work synergistically with, the positive effects of a healthy population and open trade policies.

Limitations of the Study

Data Analysis

The non-rejection of the null hypotheses in the current study depended upon the results obtained from a regression analysis. When using this statistical tool, one must keep in mind the requirement that all independent (explanatory) factors be held constant; in practice, however, this is difficult to achieve (Becker & Baumol, 1996). In the current researcher's study, there were nine independent variables regressed against the dependent variable. Of the nine independent variables, five (YEARSSCH, NOS, LLEAB, GROPEN, and DEMOCIND) are represented by proxies, or indirect measures, for factors identified as affecting economic growth of a nation. When proxies are used instead of some direct measure, error will enter into the regression. In the current researcher's review of the literature, no one claimed to completely understand what makes an economy grow; it is, therefore, likely that some factors that affect economic growth were not included as independent variables. "Failure to include all relevant factors in the model could bias the estimated coefficients to such an extent that they may be totally meaningless" (Becker & Baumol, 1996, p. 224). Thus, the evidence arrived at using cross-country regression analyses " . . . leaves open the possibility that unmeasured attributes cause both the variation in educational achievement across individuals and the variation in productivity" (Romer, 2001, p. 32).

The unique measure of educational human capital used by the current researcher, the notions of science included in a country's science curriculum, may be problematic. The methodology used to determine the NOS percentage for each participating TIMSS country, the content-by-cognitive-behavior grid, may have serious limitations: according to Robitaille et al. (1993), "They [content-by-cognitive grids] fail to take into account the interconnectedness of contents or behaviors, and this forces the information into unrealistically isolated segments" (p. 42). The content-by-cognitive-behavior grid created by the current researcher also represents a coding of information that had already been coded by the original TIMSS researchers. Thus, even with validity and reliability enforced to the extent possible, a certain margin of error will undoubtedly enter into this double coding process.

Inferring Cause and Effect

This study was intended to be a relational study; as such, the current researcher did not intend to imply a causal role for any independent variable. But while the intent was not causal, educational pundits may use such data to infer a causal relationship between how science is taught and the growth rate of a country's economy. But it has already been noted that the relationship between human capital in any form and the growth of a nation's economy, although studied by many researchers, is difficult to discern. Romer (2001) notes, "Because economics is not an experimental science, it is not easy to draw firm conclusions about the causal role of increase in education on earnings at the individual level or about output at the aggregate level" (p. 31). Therefore, the precise role of science education in a nation's economic development remains elusive.

Perspectives On The Purpose of Education

Writing in *The Disciplined Mind,* Howard Gardner says that "Decisions about education are, in the final analysis, decisions about goals and values" (1999, p. 61). Gagne et al. (1992) states that "Instruction should always be designed to meet accepted educational goals. When goals are matched with societal needs, the ideal condition exists for the planning of education" (p. 50). This study, however, has assumed that the primary purpose of education is to add to a country's human capital stock for the purpose of augmenting economic growth. But is this the primary purpose of education for the 43 TIMSS countries studied? This is unknown and may be unknowable. There are, after all, other reasons for educating a citizenry—maintaining a democracy or theocracy are but two examples of alternative primary purposes of education. Because the use of technologic devices embody a country's norms, students in the participating TIMSS countries may be employing the notions of science to realize goals other than economic development (Feenberg, 1999). What goes into a curriculum, then, can be a source of contention when policy makers are not in agreement regarding its primary purpose. Regarding the purpose of education, Kliebard notes the following: "In the context of status politics, then, the curriculum in any time and place becomes the site of a battleground where the fight is over whose values and beliefs will achieve the legitimation and the respect that acceptance into the national discord provides" (1995, p. 250).

Gross Domestic Product as a Measure of a Nation's Wealth

The current researcher agrees with Landau and Rosenberg when they state: "In our culture (American), economic growth is a prerequisite for a more equitable society" (1986, p. 15). But when measuring economic growth of a country in the form of gross domestic product per capita, we are simply measuring an increase in total wealth; we are not measuring economic distribution, which can be interpreted as a better measure of economic equality (Kuroda, 1996). If one accepts the premise that incorporating the NOS into the science curriculum for the purpose of developing an economy will create and distribute wealth equitably, than gross domestic product per capita is an imperfect measure. Instead of GDP/capita, perhaps future studies could use as a measure of wealth the percent of the population above the poverty level, or the percent of the population that is considered to be middle class.

Technology as an Endogenous Growth Factor

According to neo-classical growth theory, economic growth takes place as a result of exogenous technological change, which then augments the productive capacity embodied in the human capital of a population. In this sense, the NOS are exogenous factors which, although difficult to measure with any degree of certainty, can be measured with a theoretically supported proxy. However, recent theories view technology as an endogenous outcome of the education and economic forces at work within an economic system. The shift of emphasis in the literature from technology as an exogenous factor to accumulation of human factors as a key source of technological growth and development is " . . . one of the important themes of the new economic development literature" (Chandran, 1992, p. 109). If one accepts the notions that technology drives economic growth and technology is endogenous, than the unique proxy used for educational human capital in this study, NOS, can only be thought of as a variable that augments the technological capacity of a society, but is not a direct measure of technology itself. Thus, educators are left to wonder how, or even if, technology can be infused into a nation's educational system.

Homogeneity of the Intended Science Curriculum

Trowbridge and Bybee (1990) asked a teacher at Fall River High School (Fall River, MA, United States), what is was like teaching science. The teacher's answer provides an insight into what it's like teaching science in the United States:

> The district has developed a science curriculum packed with articulated objectives and brimming with specified content; and yet there remain differences in content, method, and sense of purpose from one grade level to the next, among schools, among departments within schools, even from one teacher to the next. (p. 12)

Collecting and coding curricular documents that are representative of what is actually taught to a population can be problematic. Although the IEA used data collection techniques that attempted to ensure that representative curricula were obtained, one can only imagine how hard it would be to procure samples of representative curricula in countries that have either regional or local control of curricula and textbook selection. Schmidt et al. (1997) depicted different types of educational systems from the TIMSS study:

1. National: represented by a single system, or several systems closely aligned with a central system.
2. Regional or provincial: represented by regional systems.
3. Local: represented by many local systems.

Table 26 depicts a sample of TIMSS countries and their locus of control.

Table 26

Institutional Control of Curriculum and Textbooks

Country	Locus of Control	Country	Locus of Control
Austria	National	Norway	National
Columbia	National	Portugal	National
Cyprus	National	Romania	National
Denmark	National	Russian Fed.	National
France	National	Singapore	National
Greece	National	Slovenia	National
Hong Kong	National	Spain	National
Hungary	National	Sweden	National
Ireland	National	Australia	Regional
Israel	National	Belgium (Fl)	Regional
Japan	National	Belgium (Fr)	Regional
Korea	National	Canada	Regional
Netherlands	National	Germany	Regional
New Zealand	National	Switzerland	Regional

Thus, one can expect variation in curricular frameworks within countries with either regional or local curricular control. The veracity of the content-by-cognitive-behavior grids rests on the science curriculum sample being generally representative of the population from which it was taken, a proposition that can only be assumed in those countries without nationally sanctioned science curricula.

The content-by-cognitive-behavior grid was constructed using the intended curricula, and in the TIMSS countries surveyed about 75% of teachers indicated that they were somewhat or very familiar with the intended national or regional science curriculum standards. Thus, a majority of the teachers seem to at least be aware of these curricula. However, we have no data indicating with what degree of fidelity the teachers actually taught the intended curriculum. One can safely assume that when a standardized test of the intended curriculum is not employed, the adherence to the intended curriculum diminishes. "The question of the documents' actual practical influence remains an empirical question" (Robitaille et al., 1993, p. 73).

Recommendations for Future Study

Educational Research and Scientific Experimentation

Our standard of living is dependent upon a workforce that continuously becomes more productive, and according to the neoclassical economic growth model, human capital, as proxied by education, plays a significant role. But how the educational explanatory variables used in the production function affect gross domestic capita per capita is still open to speculation, and more relational studies are unlikely to help policy makes decide how to improve education. Deciding how all the production function variables interact and what proxies should be used to measure them remains largely theoretical. Theory, according to Solow (1956) " . . . depends on assumptions which are not quite true" (p. 65). Therefore, only controlled experimentation offers the possibility of discerning what educational human capital factors are worth pursuing. In *American Schools: The 100 Billion Dollar Challenge*, Allen and Cosby call for the development of new curricula that are rigorously tested for as long as it takes to get evidence that will enable educationalists to make informed decisions. "Constant curriculum development, testing and revision should become a natural part of education practice" (Allen & Cosby, 2000, p. 38). Unfortunately, educational decisions seem to be rarely based upon scientific studies. Psacharopoulos pessimistically observes, "In the field of education, perhaps more than in any other sector of the economy, politics are substituted for analysis" (1996, p. 343).

Science Education and the Cultural Milieu

The intent of this research study was to determine if there was a significant relationship between an alternative form of educational human capital (the percent of the science curriculum devoted to the notions of science, or NOS) and the growth rate of gross domestic product per capita in 43 countries. The premises on which the hypotheses were formulated are that technology is the cornerstone for economic growth, and that technology is essentially epistemological in nature. Can the notions of science be the epistemological component of education that we should be focusing on if a strong economy is our goal? Because the regression analysis coefficient for the NOS was statistically insignificant, this question will remain, at least for the moment, unanswered. However, even if one accepts the premise that technology is essentially epistemological in nature, perhaps the idea that the technological literacy level of a country can be proxied by the percent of NOS in science curriculum is naïve. Feenberg (1999) posits that "Technological development is a social process and can only be understood as such" (p. 80). Could it be that the development, adoption, adaptation, and subsequent diffusion of technology is so much a part of a nation's value system and cultural norms that trying to augment the technological literacy of a nation through its science curriculum is an attempt to reduce a complex issue into fatuous constructs we can easily understand? In such a context, changing the science curriculum as a pretext for augmenting economic growth may simply be another example of how we expect our schools to solve all our social or economic problems. How science is taught in a nation's schools and how it impacts a nation's economy should be evaluated as it relates to local cultural norms, a process that, perhaps, may not be inductively studied. "Scientific disciplines must be studied not in terms of their relation to a universal value such as truth, but under the local horizon of the social practices, artifacts, and power relations with which they are associated" (Feenberg, 1999, p. 110).

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Appendix A

TIMSS Participating Countries

1. Argentina
2. Australia
3. Austria
4. Belgium (Flemish-speaking)*
5. Belgium (French-speaking)*
6. Bulgaria
7. Canada
8. China
9. Columbia
10. Cyprus
11. Czech Republic
12. Denmark
13. Dominican Republic
14. France
15. Germany
16. Greece
17. Hong Kong
18. Hungary
19. Iceland
20. Iran
21. Ireland
22. Israel
23. Italy
24. Japan
25. Korea
26. Latvia
27. Lithuania
28. Mexico
29. Netherlands
30. New Zealand
31. Norway
32. Philippines
33. Portugal
34. Romania
35. Russian Federation
36. Scotland**
37. Singapore
38. Slovak Republic
39. Slovenia
40. South Africa
41. Spain
42. Sweden
43. Switzerland
44. Thailand***
45. Tunisia
46. United States of America

* Average used for Belgium
** Not used—GDP/capita not available
*** Science records not available

Appendix B

Third International Math and Science Study (TIMSS) Science Curriculum Frameworks with Notions of Science Reference

1. Subject Matter Content—The content of school science:
    - 1.1. Earth Sciences:
        - 1.1.1. Earth Features
        - 1.1.2. Earth Processes
        - 1.1.3. Earth in the Universe
    - 1.2. Life Sciences:
        - 1.2.1. Diversity and Structure
        - 1.2.2. Life Processes and Systems
        - 1.2.3. Life Spirals
        - 1.2.4. Interaction of Living Things
        - 1.2.5. Human Biology and Health
    - 1.3. Physical Sciences:
        - 1.3.1. Matter
        - 1.3.2. Structure of Matter
        - 1.3.3. Energy and Physical Processes
        - 1.3.4. Physical Transformations
        - 1.3.5. Chemical Transformations
        - 1.3.6. Forces of Motion
    - 1.4. Science, Technology, & Mathematics:
        - 1.4.1. Nature or Conceptions of Technology (NOS criteria: 3, 5, 7)
        - 1.4.2. Interactions of Science, Math & Technology (NOS criteria: 3, 4, 5, 7)
        - 1.4.3. Interactions of Science, Technology & Society
    - 1.5. History of Science and Technology
    - 1.6. Environmental and Resource Issues:
        - 1.6.1. Pollution
        - 1.6.2. Conservation of Land, Water and Sea Resources
        - 1.6.3. Conservation of Material and Energy Resources
        - 1.6.4. World Population
        - 1.6.5. Food Production and Storage
        - 1.6.6. Effect of Natural Disasters
    - 1.7. Nature of Science:
        - 1.7.1. Nature of Scientific Knowledge (NOS criteria: 3, 4, 5, 8)
        - 1.7.2. The Scientific Enterprise (NOS criteria: 4, 6, 9)
    - 1.8. Science and other Disciplines:
        - 1.8.1. Science and Mathematics

- 1.8.2. Science and Other Disciplines (e.g., language arts) (NOS criteria: 6)

2. Performance Expectation—What students were expected to do with the content:
   - 2.1. Understanding:
     - 2.1.1. Simple Information
     - 2.1.2. Complex Information (NOS criteria: 3, 6)
     - 2.1.3. Thematic Information (NOS criteria: 2, 6)
   - 2.2. Theorizing, Analyzing and Solving Problems:
     - 2.2.1. Abstracting and Deducting Scientific Principles(NOS criteria: 2)
     - 2.2.2. Applying Scientific Principles to Solve Quantitative Problems
     - 2.2.3. Applying Scientific Principles to Develop Explanations (NOS criteria: 7)
     - 2.2.4. Constructing, Interpreting and Applying Models(NOS criteria: 6)
     - 2.2.5. Making Decisions (NOS criteria: 1, 7)
   - 2.3. Using Tools, Routine Procedures, and Science Processes
     - 2.3.1. Using Apparatus, Equipment, and Computers
     - 2.3.2. Conducting Routine Experimental Operations
     - 2.3.3. Gathering Data (NOS criteria: 3)
     - 2.3.4. Organizing and Representing Data (NOS criteria: 3)
     - 2.3.5. Interpreting Data (NOS criteria: 2, 3, 4, 6)
   - 2.4. Investigating the Natural World:
     - 2.4.1. Identifying Questions to Investigate (NOS criteria: 1)
     - 2.4.2. Designing Investigations (NOS criteria: 5)
     - 2.4.3. Conducting Investigations (NOS criteria: 3, 4, 8)
     - 2.4.4. Interpreting Investigational Data (NOS criteria: 3, 4, 5)
     - 2.4.5. Formulating Conclusions from Investigational Data (NOS criteria: 2, 3, 5)
   - 2.5. Communicating:
     - 2.5.1. Assessing and Processing Information (NOS criteria: 9, 10)
     - 2.5.2. Sharing Information (NOS criteria: 9, 10)
3. Perspective—Overarching orientation to the subject matter:
   - 3.1. Attitudes Towards Science, Mathematics, and Technology
     - 3.1.1. Positive Attitudes Towards Science, Mathematics, and Science
     - 3.1.2. Skeptical Attitudes Towards use of Science and Technology
   - 3.2. Careers in Science, mathematics and Technology:
     - 3.2.1. Promoting Careers in Science, Mathematics and Technology
     - 3.2.2. Promoting Importance of Science, Mathematics, and Technology in non-technical Careers (NOS criteria: 6)
   - 3.3. Participation in Science and Mathematics by Underrepresented Groups
   - 3.4. Science, Mathematics, and Technology to Increase Interest
   - 3.5. Safety in Science Performance
   - 3.6. Scientific Habits of Mind. (NOS criteria: 1, 2, 3, 4, 5, 6)