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ABSTRACT

The paper presents a model comprised of variables which are hypothesized to contribute to environmental knowledge in high school students. The model assumes that environmental knowledge in high school is a function of background factors (socioeconomic status and gender) which are in place before high school and intervening factors which mediate the effects of these background factors (locus of control, highest level of science class taken, and informal science activities). The sample consists of a national probability sample made up of approximately 2,900 high school students who are participating in the Longitudinal Study of American Youth. Bivariate analysis was used to examine the relationships between environmental knowledge and independent variables. Multiple regression procedures were used to analyze direct and indirect relationships among independent and dependent variables. Socioeconomic status, being male, and internal locus of control were all positively related to environmental knowledge. As expected, the level of science and amount of informal science exposure were also positively related to environmental knowledge. Implications for environmental education and recommendations for future models and research in this area are given. (LZ)

A Model of Twelfth-Grade Environmental Knowledge

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Recent reports (Berke, 1990; Miller, 1990) indicate that American citizens are becoming more concerned with environmental issues, however; little research has been presented which investigates levels of environmental knowledge or the factors which contribute to that knowledge. The scarce research that has been reported indicates alarmingly low levels of environmental knowledge along with a small number of variables related to environmental knowledge (Arcury & Johnson, 1987; Council on Environmental Quality, 1980; Miller, 1990). The analyses which report these findings are limited in that the variables (i.e., income and gender) related to environmental knowledge were usually studied in isolation with adult samples. Currently, there is no theoretical framework which attempts to explain the collective influence of variables on the development of environmental knowledge.

One of the major obstacles to understanding the development of environmental knowledge stems from a lack of understanding of those factors which contribute to or hinder the acquisition of environmental knowledge. Comprehension of these factors will help researchers and educators interpret, predict, and modify the growth process of environmental knowledge. Such environmental knowledge is becoming more relevant in social, political, and educational circles.

The purpose of the present study is two-fold. First, the study will examine the relationships among several variables which have been found to be relevant to environmental knowledge as well as some variables not previously investigated in the context of environmental knowledge. Second, the study will utilize longitudinal data to test relations between predictor variables and their causal links to environmental knowledge using sophisticated structural equation modeling techniques. This preliminary model will serve as a foundation for fut re research which will develop and test additional models.

Importance

Understanding the development of environmental knowledge and the factors which influence that development is becoming increasingly important. High school students, the next generation of voters, will be required to make vital decisions

regarding environmental issues. The general public is already taking an active role in policy decisions in regard to environmental issues. Over the last several years a series of popular referenda on nuclear power appeared on the general election ballots of various states (Miller, 1983). If the citizenry is going to effectively confront the growing environmental problems and make informed decisions, it must be equipped with at least a fundamental knowledge of the problems that face the environment.

Environmentalists and educators are becoming more sensitive to environmental knowledge. Both seek an environmentally educated public in the hope that knowledge and understanding of environmental problems will lead to more responsible environmental behavior as well as environmental activism.

The field of environmental education is growing, and the present study will provide a conceptual framework for future investigations. This study ties together research which has been scattered and generally unrelated. Understanding factors associated with knowledge is the first step toward making the acquisition of knowledge easier and improving the knowledge base of citizens.

Selection of Relevant Variables

In recent studies, sociodemographic characteristics such as education, income, and gender have been found to be major indicators of environmental knowledge (Arcury & Johnson, 1987; Arcury, Johnson, & Scollay, 1986). While research is beginning to discover some of the sociodemographic variables related to environmental knowledge, there remains a lack of understanding concerning factors which mediate the effects of background variables on knowledge.

A potential mediating variable is locus of control. Locus of control represents the degree to which a person perceives whether or not they have the ability to bring about change through their own behavior (Hines, Hungerford, & Tomera, 1987). Individuals classified as relatively internally controlled accept personal responsibility for what happens to them and feel that their behavior is likely to have an impact. On the other hand, individuals with an external locus of control do not attempt to bring about change because they attribute change to chance or external sources (e.g. God, government, technology).

Arbuthnot (1977) examined the relationships of personality variables in the prediction of environmental knowledge. External locus of control was a relatively good predictor of environmental knowledge ($\underline{b}$ = -.234). One of Arbuthnot's conclusions was that environmentally knowledgeable individuals perceive that their actions have potential impact. Consequently, students with a relative internal locus of control are hypothesized to be more highly motivated to seek out information concerning environmental issues and be more knowledgeable than those students with an external locus of control.

A second potential mediating variable is the type of science classes a student has taken in school. The highest level of science class (i.e., physics vs. earth science) a student has taken should influence environmental knowledge. Because scientific principles underlie environmental problems, students who have taken higher level science classes will develop a broader knowledge base when considering environmental issues and should be better prepared to answer questions dealing with those issues. Also, the level of science classes taken may reflect students' motivation or interest in learning about scientific topics.

A third potential mediating variable is informal science education. When an individual is exposed to a variety of situations which present an opportunity to learn, that individual has an advantage over those who do not have such opportunities. Because environmental issues are now becoming more popular in American culture it is not always necessary to have formal classroom instruction in order to gain an understanding of the issues. Individuals exposed to an assortment of constructive experiences outside of the classroom are likely to gain knowledge about environmental issues and reinforce concepts learned in the classroom.

Theoretical Framework

The current model views the development of environmental knowledge as a component process of overall science achievement. Recent research has revealed that achievement can be viewed as the complex result of several dynamic variables. Social-psychological variables, course selection, and exposure to learning experiences have been found to intervene between background variables

(e.g., socioeconomic status) and educational achievement. In order to better understand the various relationships among variables, this study will utilize a theoretical framework based on research used to validate more general models of educational achievement. Several researchers (Bloom, 1976; Carroll, 1963; Walberg, 1984) have developed successful models of educational achievement which view achievement as a function of background factors and various intervening variables such as school experiences and student characteristics.

The implication of this view suggests that environmental knowledge is a consequence of unalterable background factors (socioeconomic status and gender) which are mediated through intervening variables. The present study will determine the relative contribution of background factors and the intervening factors of locus of control, level of science class, and exposure to informal science activities.

The current model incorporates several aspects of an individual's environment and will provide information regarding the complex relationships among variables which contribute to the development of environmental knowledge. The model suggests that the effects of background variables can be direct or mediated by intervening variables which can promote or inhibit the development of knowledge. The mediating variables can have direct effects on environmental knowledge as well.

Insert Figure 1 about here

A Model of Environmental Knowledge

Figure 1 displays a model comprised of variables which are hypothesized to contribute to environmental knowledge in high school students. The model assumes that environmental knowledge in high school is a function of background factors (socioeconomic status and gender) which are in place before high school and intervening factors which mediate the effects of the background factors. The intervening factors included represent affective personality variables (locus of control), cognitive variables (highest level of science class taken), and

informal exposure to science opportunities (informal science activities). The arrows extending from one block to another represent effects to be examined. This model blends educational theory and research and presents a theoretical framework for understanding variables which have demonstrated significance in the contexts of environmental knowledge and general educational achievement.

Method

Design and Procedure

A longitudinal design was utilized with three waves of data making up the mediating variables and two waves making up the dependent and baseline variables. The data analyzed are from the Longitudinal Study of American Youth, a four-year panel study collecting data from students, teachers, and parents.

The data collection spanned from fall 1987 to fall 1989. Student attitude questionnaires were administered each fall and spring. The questionnaire included data on courses taken, locus of control, and out-of-school activities. Math and science tests were administered each fall; however, environmental questions only appeared on the 1987 and 1989 versions of the science test. Parent telephone interviews were conducted each spring to measure educational attainment, current occupation, and attitudes concerning a variety of topics.

The first and third year science achievement tests, developed from the 1985-1986 National Assessment of Educational Progress (NAEP), included several items pertaining to the environment. These items make up the environmental knowledge scale. The items covered environmental issues such as acid rain, the greenhouse effect, and future sources of energy.

Sample

The sample consists of a national probability sample made up of approximately 2,900 high school students who are presently participating in the Longitudinal Study of American Youth (LSAY). The LSAY is designed to map the development of the cognitive science and mathematic skills of middle and high school students and their attitudes toward science and mathematics as areas of study. The LSAY subjects were selected through the use of a stratified

probability sample design. The sample was stratified in two ways: (a) by geographic region (North, South, East, and West) and (b) by degree of urban development (Urban, Suburban, and Rural). Fifty pairs of high schools and middle schools were selected. Once the schools were selected random samples of approximately 60 students were drawn from each school.

Data Analysis

Analysis proceeded in two stages. First, bivariate analysis (polychoric correlations) was used to examine the relationships between environmental knowledge and independent variables. Joreskog and Sorbom (1989) describe the polychoric correlation as, "an estimate of the correlation between two latent variables n and e underlying x and y, where n and e are assumed to have a bivariate normal distribution" (p. 1-23). PRELIS, the LISREL preprocessing program, was used to generate a pairwise polychoric correlation matrix for the categorical, ordinal and continuous variables in the model. Secondly, structural equation modeling techniques (LISREL) were used to test a causal model of both the direct and indirect relationships among environmental knowledge and the independent variables.

Structural equation modeling is a statistical procedure which is frequently used to test causal models. This technique uses multiple regression procedures to analyze direct and indirect relationships among independent and dependent variables. Structural equation modeling also allows for the evaluation of the relative effects of each independent variable while controlling for the other factors in the causal model (Hayduk, 1987). In the present study, structural equation modeling will be used to examine the influence of variables on the growth of environmental knowledge over a two year period in high school.

Operational Definitions or Variables

Exogenous Variables

If a variable in a model always acts as a "cause" and never as an "effect", it is classified as an exogenous variable (Hayduk, 1987). Variance in the values of these variables are not to be explained within the model. In the present

model socioeconomic status and gender are exogenous variables.

Socioeconomic status is a composite measure of parental educational attainment and occupational status. Parental educational attainment was calculated by taking the highest level of education of the student's mother or father as reported by parents in a telephone interview in spring 1988 or spring 1989. If parent interview data was unavailable, the student's fall 1987 report of his or her parents education was used. The scale ranges from "less than high school diploma" to "doctorate or other professional degree". The six-point scale is listed below.

1 - Less than high school
2 - High school only
3 - Associate's degree
4 - Bachelor's degree
5 - Master's degree
6 - Doctorate or other professional degree

Parental occupational status consists of socioeconomic index scores (updated Duncan scores calculated by Stevens and Featherman, 1981) based on the parent's occupation as reported in telephone interviews in the spring of 1988 or 1989. If both mother and father occupations were available the greater was used.

Girls were coded as 1 and boys were coded as 2.

Endogenous Variables

If a variable is directly influenced by any other variable, it is classified as an endogenous variable (Hayduk, 1987). In the present study the endogenous variables include: locus of control, informal science activities, level of science class, and tenth- and twelfth-grade environmental knowledge.

Locus of control is a latent variable which consists of cumulative scales administered in the fall 1987 and fall 1988. The scales were developed from four items concerning fate control. Each item was give a value of 1 through 5 (strongly agree through strongly disagree). The responses were then added together, creating a sixteen-point scale ranging from four (external locus of control) to twenty (internal locus of control). The items are presented below.

Locus of Control Scale:

How do you feel about each of the following statements?

(1=Strongly agree 2=Agree 3=Not sure 4=Disagree 5=Strongly disagree)

1. Good luck is more important than hard work for success.
2. Every time I try to get ahead, it seems that something or somebody stops me.
3. Planning only makes a person unhappy, since plans hardly ever work out anyway.
4. People who accept their condition in life are happier than those who try to change things.

The level of science course variable represents the highest level of science course reported by the student in either 1987 or 1988. The five-point scale includes: no science class, low level science class, biology class, chemistry class, and physics/advanced science class.

The informal science education is a latent variable constructed from check lists of activities which the students reported participating in the fall of 1987 and 1988. The following activities made up the scale: visiting a science museum, reading a science fiction story, using computers, participating in math and science clubs, reading science magazines, and taking a summer math or science course. Students were given one point for each activity in which they reported participating. The scale ranged from 0 to 7 representing increasing informal science activity.

Tenth and twelfth-grade environmental knowledge is a student's score on a subscale of seven items. Students were given one point for each item correctly answered, creating an eight-point scale ranging from 0 to 7 representing increasing environmental knowledge. The items covered environmental issues such as acid rain, the greenhouse effect, and future sources of energy. The items measure a student's ability to recall specific facts and concepts as well as use higher-order cognitive processing. The questions included material from the more general domains of life science, earth science and chemistry. The subscale was taken from a battery of 71 multiple-choice items measuring general science achievement. The items were developed for the 1985-1986 National Assessment of Educational Progress (NAEP), and were administered to LSAY students during the fall of 1987 and 1989. The multiple-choice items included questions on the

following content:

1. Sulfur dioxide causes acid rain.
2. What is the greatest source of energy today?
3. Increasing CO2 leads to a warmer climate.
4. The best solution to acid rain is to neutralize it.
5. Sulfides of metals cause acid rain.
6. Environmentalists are concerned with burning coal because it causes air pollution.
7. The greenhouse effect may cause flooding.

Results

Table 1 presents the PRELIS polychoric correlation estimates among the predictors of environmental knowledge. The matrix reveals that socioeconomic status, locus of control, level of science class, and informal science activities are all moderately related to the dependent variable (r = .27 to .35). Being male has a weaker positive relationship to environmental knowledge with a coefficient of .16. The baseline measure, tenth-grade environmental knowledge, produced the highest correlation (r = .56). All of the coefficients are in the expected direction and are consistent with previous research.

Table 1: Correlations among Predictors of Twelfth-Grade Environmental Knowledge.

Construct	SES	Male	Env. Kno.10	Locus	Sci. Class	Infl. Sci.	Env. Kno.12
SES	1.000						
Male	0.026	1.000					
Env.Kno.10	0.268	0.161	1.000				
Locus	0.325	-0.134	0.344	1.000			
Sci. Class	0.297	-0.038	0.357	0.352	1.000		
Infl. Sci.	0.312	0.107	0.274	0.141	0.143	1.000	
Env.Kno.12	0.272	0.159	0.556	0.349	0.319	0.267	1.000

Note.Correlations are based on pairwise deletion of missing data minimum N = 1644, maximum N = 2793). (SES = socioeconomic status, male = gender (coded males=1, females =0), Env.Kno.10 = grade 10 environmental knowledge, Locus = locus of control, Sci. Class = level of science class taken, Infl. Sci. = informal science activities, Env.Kno.12 = grade 12 environmental knowledge)

The over-all goodness of fit of the initial hypothesized model indicates an acceptable fit with the data (Chi-square ratio = 3.01, Adjusted Goodness of Fit Index = .980, Root Mean Square Residual = .028). These multiple criteria suggest that the likelihood is low that the fit of the model was due to sampling

error (Carmines & McIver, 1981; Hayduk, 1987; Reynolds & Walberg, 1991). The total model accounted for approximately 37 percent of the variance in twelfth-grade environmental knowledge.

Insert Figure 2 about here

Significant (t > 1.96 or p < .05) standardized estimates of the full information maximum likelihood analysis are displayed in Figure 2. The arrows extending from one factor to another represent tested effects. The standardized beta coefficients printed on the arrows indicate the direct effect of one factor on another after controlling for all the other variables in the model.

Direct Effects on Twelfth-Grade Environmental Knowledge

A direct effect is an unmediated relation between two variables. As shown in Figure 2, six of seven of the predictor variables had significant (t > 1.96 or p < .05) direct effects on twelfth-grade environmental knowledge. Socioeconomic status (SES) did not have a significant direct effect on twelfth-grade environmental knowledge. Consequently, the SES path to twelfth-grade environmental knowledge was dropped from the model.

Tenth-grade environmental knowledge had the strongest direct effect (b = .61). The positive path coefficient (b = .07) between gender and twelfth-grade environmental knowledge indicates that holding constant the other variables in the model, boys are likely to have more environmental knowledge in twelfth-grade than girls.

The mediating variables (locus of control, level of science class, and informal science education) all had significant direct effects. The best predictor of a relative increase in environmental knowledge is locus of control (b = .16) suggesting that controlling for the other variables in the model, students with a relative internal locus of control will gain more environmental knowledge than those students with an external locus of control.

Students' enrollment in more advanced science classes is another important factor in the development of environmental knowledge. This suggests that when

all other variables are held constant, students who take more advanced science courses gain more environmental knowledge than students who take less advanced science courses.

The direct effect of informal science exposure had the same magnitude as the direct effect of science class level (b = .09). This indicates that students who participate in more informal science activities gain more environmental knowledge than those students who participate less in informal science activities.

Indirect Effects on Twelfth-Grade Environmental Knowledge

An indirect effect is a relation between two variables that is mediated by one or more variables. Table 2 summarizes direct, indirect, and the total effects. Socioeconomic status has the largest indirect effect on twelfth-grade environmental knowledge (b = .27). SES effect is mediated through tenth-grade environmental knowledge, locus of control, level of science class, and informal science education. This result indicates that SES directly influences previous environmental knowledge, and the mediating variables, but indirectly influences twelfth-grade environmental knowledge.

Table 2: Estimates of the Direct, Indirect, and Total Effects of Predictor Factors on 12th-grade Environmental Knowledge.

	Direct	Indirect	Total
Socioeconomic Status.....	.00	.27	.27
Gender.....	.08	.07	.15
Tenth-Grade Environmental Knowledge....	.61	.09	.70
Locus of Control.....	.16	.00	.16
Level of Science Class.....	.09	.00	.09
Informal Science Exposure.....	.09	.00	.09

Discussion

This study began with a dual purpose. The first purpose was to examine the relationships among several variables which have been found to be relevant to environmental knowledge as well as some variables not previously investigated in the context of environmental knowledge. The second purpose was to utilize longitudinal data to test relations between predictor variables and their causal links to environmental knowledge using structural equation modeling techniques.

The bivariate analyses revealed several interesting relationships which are consistent with previous research involving environmental knowledge. Socioeconomic status, being male, and internal locus of control were all positively related to environmental knowledge. As expected, the level of science class and amount of informal science exposure were also positively related to environmental knowledge. Together these variables represent a student's social background, internal psychological processes, school course enrollment, and out-of-school experiences. These findings reveal a variety of diverse variables which are influential in the development of environmental knowledge. In order to examine these variables in the developmental process we shall discuss the findings of the structural model.

On a general level, this model demonstrates that environmental knowledge is the complex result of several diverse variables. Several different aspects of a student's world combine to influence the development of knowledge. Social background, school factors, exposure to informal science opportunities, and internal processes all significantly contribute to the development of environmental knowledge. This analysis also suggests that models of general scholastic achievement can provide an adequate theoretical framework from which to view the development of environmental knowledge.

The model indicates a number of factors that are important to the development of environmental knowledge. Aside from the baseline measure, tenth-grade environmental knowledge, internal locus of control had the strongest direct influence on twelfth-grade environmental knowledge. This suggests that individuals who accept personal responsibility for what happens to them and

believe that their behavior is likely to have an impact seem to be motivated to develop more environmental knowledge than those students with an external locus of control.

The positive influence of science course enrollment is not surprising since environmental problems are based on scientific principles. Students who took more advanced science classes possess higher levels of environmental knowledge. While science course-taking significantly influenced environmental knowledge, the effect size demonstrates the importance of taking into account variables outside of formal classroom experiences. This suggests that although environmental problems are based in science, knowledge of environmental issues is influenced beyond formal scientific training.

The amount of informal science activities in which students participated had a positive influence on environmental knowledge. Students who engaged in more out-of-school science education had higher levels of environmental knowledge. This finding is important because it supports the contention that students who experience science activities outside of the classroom will acquire more information than students who lack these experiences. This suggests that environmental knowledge is the result of informal as well as formal science exposure.

The intervening variables (locus of control, level of science class, and informal science education) not only had the hypothesized significant direct influences on environmental knowledge, but they also mediated the effects of SES, gender, and previous environmental knowledge. While previous research found positive relationships among environmental knowledge and background variables such as SES and gender, this study indicates some variables that mediate the effects of those background variables.

The indirect effect of SES suggests that SES fosters earlier environmental knowledge, internal locus of control, advanced course selection, and exposure to informal science opportunities. Those factors in turn have a direct effect on twelfth-grade environmental knowledge.

As stated in the introduction, this preliminary model is designed to

explore some of the basic relationships among several different types of variables which have been found to be related to environmental knowledge or general forms of achievement. This model is meant to serve as a foundation for future studies which will develop and test additional models. Although this model has produced some valuable information in regard to some of the factors associated with the development of environmental knowledge, its primary function will be to act as groundwork upon which additional variables can be introduced and tested. Testing alternative models and cross-validating results will allow for more conclusive interpretations and applications.

Implications and Future Research

The findings in this study should be applied to programs which attempt to alter environmental knowledge. The results indicate that growth in environmental knowledge can be the result of a combination of internal thought processes, formal science education, and informal science experiences. This suggests that environmental education should be multifaceted and take into account affective, cognitive, and social factors when planning educational experiences.

I would like make two specific recommendations for future models and research in this area. First, studies should begin to investigate variables which can be manipulated by decision makers. It is important to understand the alterable factors that influence environmental knowledge in order to provide recommendations to educators, curriculum developers, and policy makers. For educators, these mediating variables are most important because they may be modifiable through instructional techniques. Second, researchers should develop and utilize improved measures of environmental knowledge. Environmental issues are becoming more popular and more important. In order to understand what individuals know about those issues relies largely on the scale which measures that knowledge. I suggest measures which break down the vast domain of environment issues into subtests. Potential topics for subtests include population, energy, the greenhouse effect, acid rain, and ecosystems.

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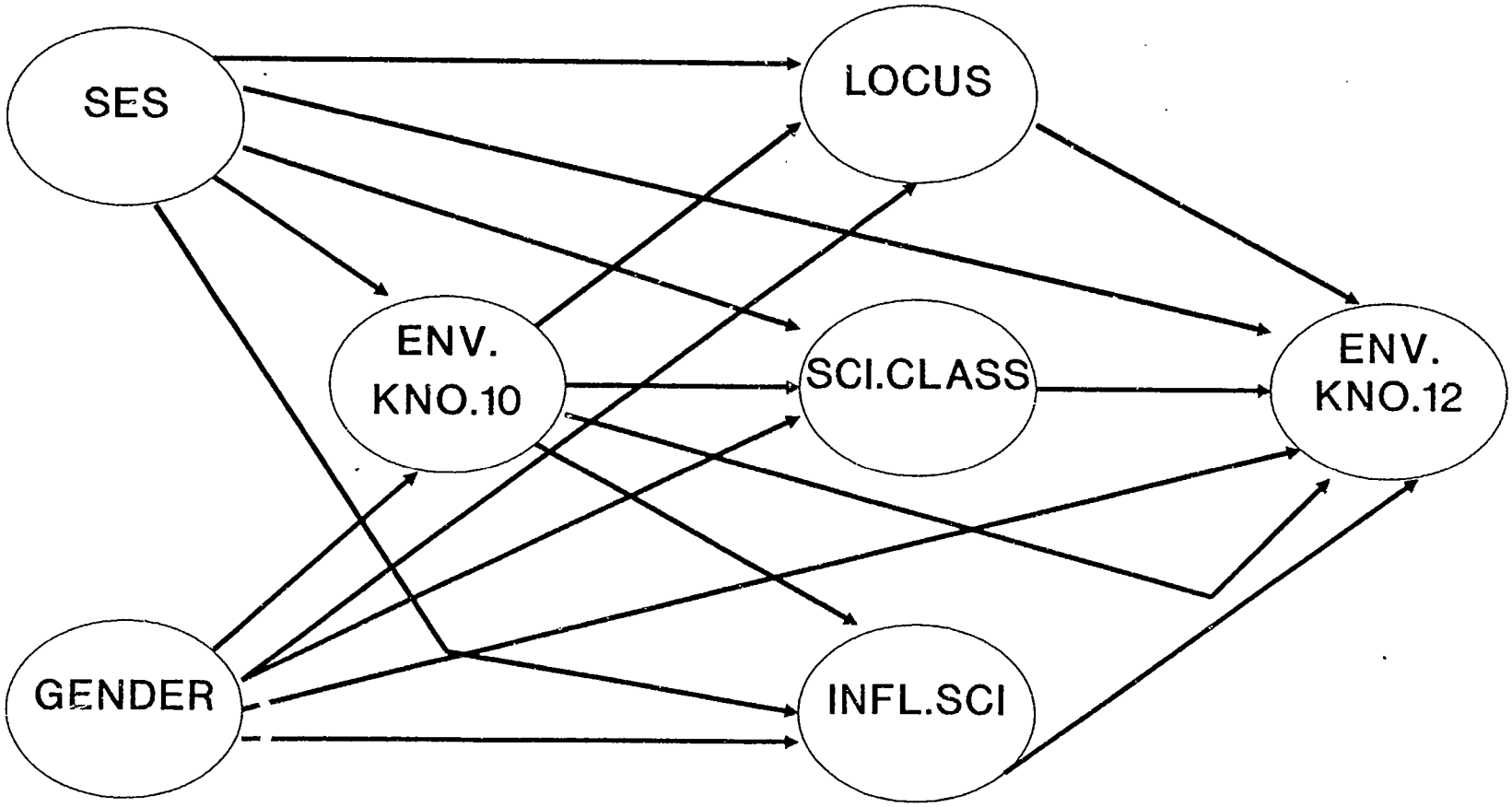
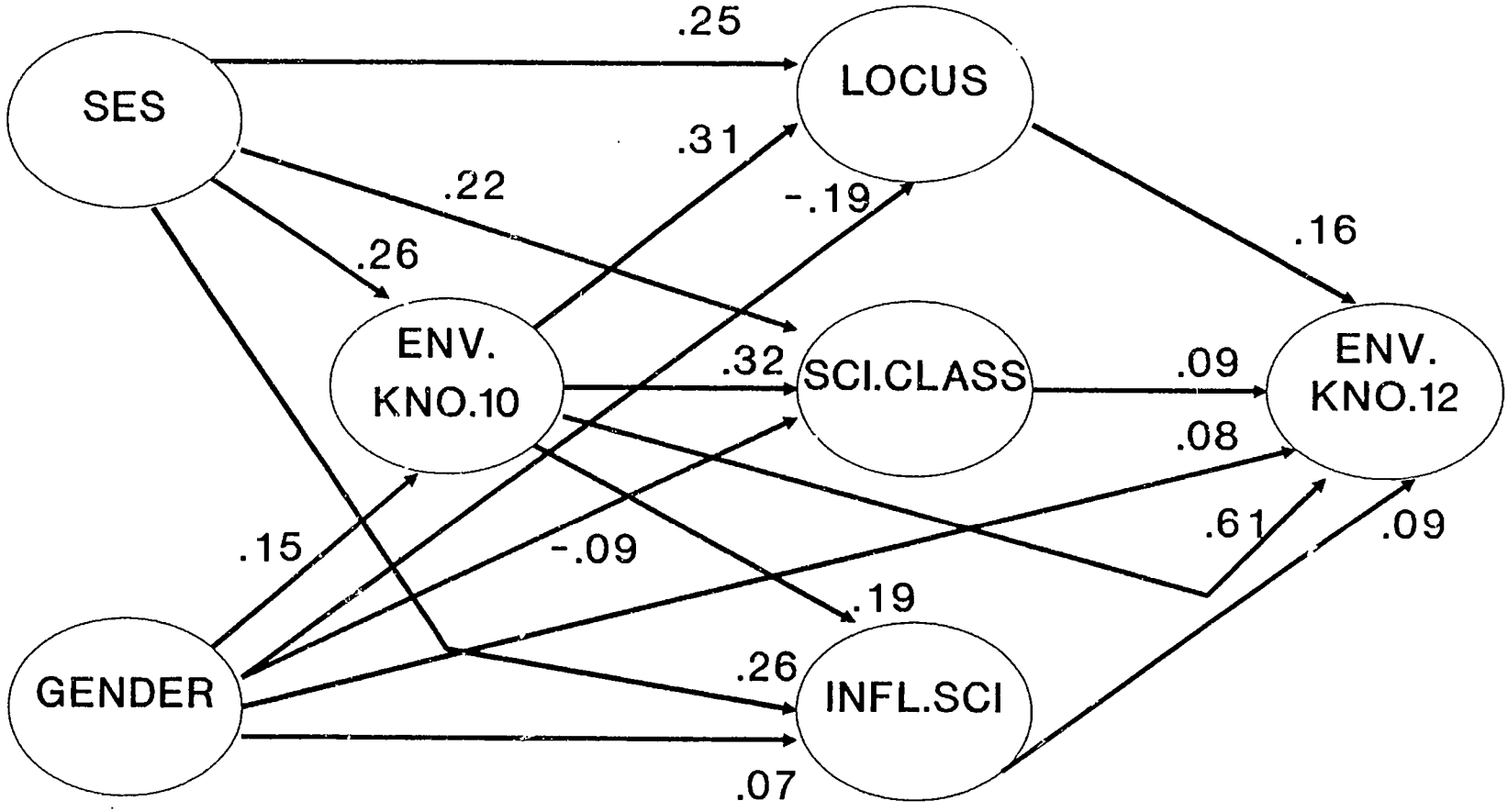
Figure 1. A Model of Environmental Knowledge



Key. SES = socioeconomic status, Gender (coded males=1, females = 0), Env.Kno.10 = grade 10 environmental knowledge, Locus = locus of control, Sci.Class = level of science class taken, Infl.Sci. = informal science activities, Env.Kno.12 = grade 12 environmental knowledge.

Figure 2. A Model of Environmental Knowledge



Key. SES = socioeconomic status, Gender (coded males=1, females = 0), Env.Kno.10 = grade 10 environmental knowledge, Locus = locus of control, Sci.Class = level of science class taken, Infl.Sci. = informal science activities, Env.Kno.12 = grade 12 environmental knowledge.
Note. Standardized regression coefficients: $t > 1.96$ or $p < .05$.