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ABSTRACT

It is hypothesized that the use of an empirical indicator of a theoretical construct implies certain epistemic assumptions about the nature of the construct. In this study, the implications of assuming interval level of measurement using various isomorphic monotonically increasing epistemic alternatives to a commonly used occupational status index was investigated in the following manner. (1) Simulated samples of 100 Duncan's Socio-Economic Index scores were drawn by generating random independent samples from normally distributed populations with different means. (2) The simulated SEI scores were transformed to correspond to six alternate assumptions about the nature of the pattern of intervalization. This resulted in seven isomorphic, monotonically increasing measures of occupational status differing only in the pattern of intervalization. (3) The degree of divergency among epistemic models was determined by analyzing matrices of coefficients of epistemic error corresponding to the "mean epistemic error" between two given conceptualizations under the assumption that one conceptualization is used and the other conceptualization perfectly describes the theoretical construct. (4) The nature and magnitude of the measurement error introduced into path models by using different assumptions of intervalization was investigated by comparing simulated causal models involving occupational status using the alternative interval conceptualizations as one of the two independent variables. (Author/BJG)

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"An Assessment of the Degree of Isomorphism among Alternative Interval Scaling Approaches"[1/]

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by

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This is a continuation of our earlier effort (Brunn, et. al; 1974) to assess the amount of isomorphism among alternative scaling approaches. In summary our premise then and now is that the use of an empirical indicator of a theoretical construct implies certain epistemic assumptions about the nature of the construct. Unfortunately, these assumptions are not always recognized. And the selection of a particular indicator often varies considerably from, and is not consonant with, many alternate and equally plausible conceptualizations of the construct. We are investigating the comparability and acceptability of empirical conclusions based on alternative, even contradictory, epistemic assumptions. In this effort simulated scores of occupational status as measured by the Duncan SEI were subjected to monotonic transformations to represent patterns of intervalization isomorphic with plausible alternative conceptualizations of the epistemic relationship. The analysis consists of an assessment of the comparability and homogeneity of "coefficients of epistemic error" and standardized path coefficents based on these transformations.

As we have noted in the past, the problem of congruence between the measurement approach and the epistemic assumption is neither trivial nor esoteric. For example, in the case of occupational status there appears to be consensus among most empirical sociologists that the Duncan SEI represents an acceptable ranking of occupation categories. However, the appropriate intervalization of occupational differences is not so widely agreed upon. As a result empirical conclusions based on ordinal level analysis are not subject to epistemic error despite the existence of alternative isomorphic interval conceptualizations given the accepted ordinal conceptualization. Yet many sociological studies using interval level analytical procedures can be challenged in this regard because the use of product-moment correlations, analysis of variance, regression and path analysis requires at least implicit interval assumptions.

Epistemically we accept the tacit assumption that occupational status is an interval variable, i.e., the size of the status interval between occupations can be known. However, currently we lack isomorphism between our epistemic assumption and our achieved level of measurement. As we have suggested previously, this problem of isomorphism leads to a dilemma in research. If we utilize ordinal measurement, our assumption at the empirical level contradicts our assumption at the theoretical level. On the other hand, we cannot easily assume interval level of measurement because the exact intervalization is unknown. We hope to demonstrate methods which can assess the error introduced into empirical analysis when alternative epistemic models exist and could be used.

1/ We acknowledge the valuable criticisms of Stanley Wilson and Arthur Cosby on our approach to this problem; however the authors alone assume all responsibility for the paper. Development of this manuscript was partially supported by Texas Agricultural Experiment Station Research Project H2811, "Devlopment of Human Resource Potentials of Rural Youth in the South and Their Patterns of Mobility."

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The Approach

The implications of assuming interval level of measurement using various isomorphic monotonically increasing epistemic alternatives to a commonly used occupational status index were investigated in this study in the following manner:

(1) Simulated samples of 100 Duncan's Socio-Economic Index scores were drawn by generating random independent samples from normally distributed populations with different means.

(2) The simulated SEI scores were transformed to correspond to six alternate assumptions about the nature of the pattern of intervalization. This resulted in seven isomorphic, monotonically increasing measures of occupational status differing only in the pattern of intervalization.

(3) The degree of divergency among epistemic models was determined by analyzing matrices of coefficients of epistemic error corresponding to the "mean epistemic error" between two given conceptualizations under the assumption that one conceptualization is used and the other conceptualization perfectly describes the theoretical construct.

(4) The nature and magnitude of the measurement error introduced into path models by using different assumptions of intervalization was investigated by comparing simulated causal models involving occupational status using the alternative interval conceptualizations as one of the two independent variables.

Alternative Epistemic Model:

The following epistemic models of occupational measurement were used:

1) OCC1: This is Duncan's Socio-Economic Index (SEI) ranging from 1 to 100, (Duncan, 1961). This index reflects the concept of a constant and perfectly uniform linear increase in status as the socio-economic occupational ranking increases.

2) OCC2: This index was constructed according to the transformation: $OCC2 = SEI^{0.5} \times 10$. For this model the interval between adjacent scores decreases gradually as socio-economic rank increases. This epistemic model reflects the proposition advanced by Carter (1971) that a given increase in income will have a greater relative impact on social position at the lower portion of the social system. This is isomorphic with the epistemic assumption of diminishing marginal utility of income.

3) OCC3: The transformation $OCC3 = (SEI)^{1.1} / 100^{0.1}$ was used to construct an index corresponding to the conceptualization that status increases at an increasing rate.

4) OCC4: The transformation $OCC4 = (SEI)^{1.5} / 10$ represents a scaling approach similar to OCC3 except that interval distances increase at an even greater rate.

5) OCC5: Similarly $OCC5 = (SEI)^2 / 100$ represents the concept of rapidly increasing marginal utility of income.

6) OCC6: This transformation corresponds to a Marxian conceptualization of two widely separated classes with little status differentiation within each class. Specifically OCC6 = $\bar{x}$ + 0.25 (SEI-$\bar{x}$) when $\bar{x}$ = 25 for SEI 50 and $\bar{x}$ = 75 for SEI $\geq$ 50. Thus the within-class interval between adjacent scores is 0.25 the between class interval is 38.75 between SEI scores of 49 and 50.

7) OCC7: This index approximates a six class stratification system similiar to that advocated by Warner (1941). The transformation was:

$$OCC7 = \bar{x} + 0.9\,(SEI-\bar{x})$$

where
$\bar{x}$ = 6 for SEI $\leq$ 11
$\bar{x}$ = 18 for 12 $\leq$ SEI $\leq$ 24
$\bar{x}$ = 29 for 25 $\leq$ SEI $\leq$ 34
$\bar{x}$ = 43 for 35 $\leq$ SEI $\leq$ 50
$\bar{x}$ = 40 for 51 $\leq$ SEI $\leq$ 69
$\bar{x}$ = 85 for SEI $\geq$ 70

With this epistemic model the within class interval is 0.9 and the between class intervals range from 1.9 to 3.4.

While these alternative epistemic models are products of transformations applied to Duncan SEI scores, they represent plausible, independent scaling approaches. Figure 1 graphically compares these alternative models using Duncan's SEI as a base for comparison. Thus Duncan's SEI appear as a 45° line. OCC3, OCC4, and OCC5 appear below that 45° line representing differing increasing rates of interval change. The Marxian and Warner transformations cross the 45° line at the class median points. It is important to note that the OCC1, OCC2, OCC3, OCC4 and OCC5 conceptualizations agree that the highest occupation should have a status value of 100. However, there is no common status value assigned to the lowest occupation.

The Data

The 100 SEI scores used for OCC1, and later transformed into indicators isomorphic with the other epistemic models, were generated by a random number APL computer program and arranged in ascending order.

The Coefficient of Epistemic Error

An adaptation of the Gini coefficient, called the coefficient of epistemic error, or C, was used as a heuristic device to analize the relative amounts of variation between competing pairs of occupational indices constructed under different assumptions of intervalization. Figure 2, illustrates the principle on which this coefficient is constructed. In this figure the point (X,Y) represents the "true"or ideal score for an observation and the point (X,Y') represents the score actually used. The difference between the two scores, $\Delta Y = Y' - Y$, is the magnitude of epistemic error, incurred in this instance. The size of the epistemic error is dependent on the scale used, so the effects of the scale are removed by expressing the magnitude of the error relative to

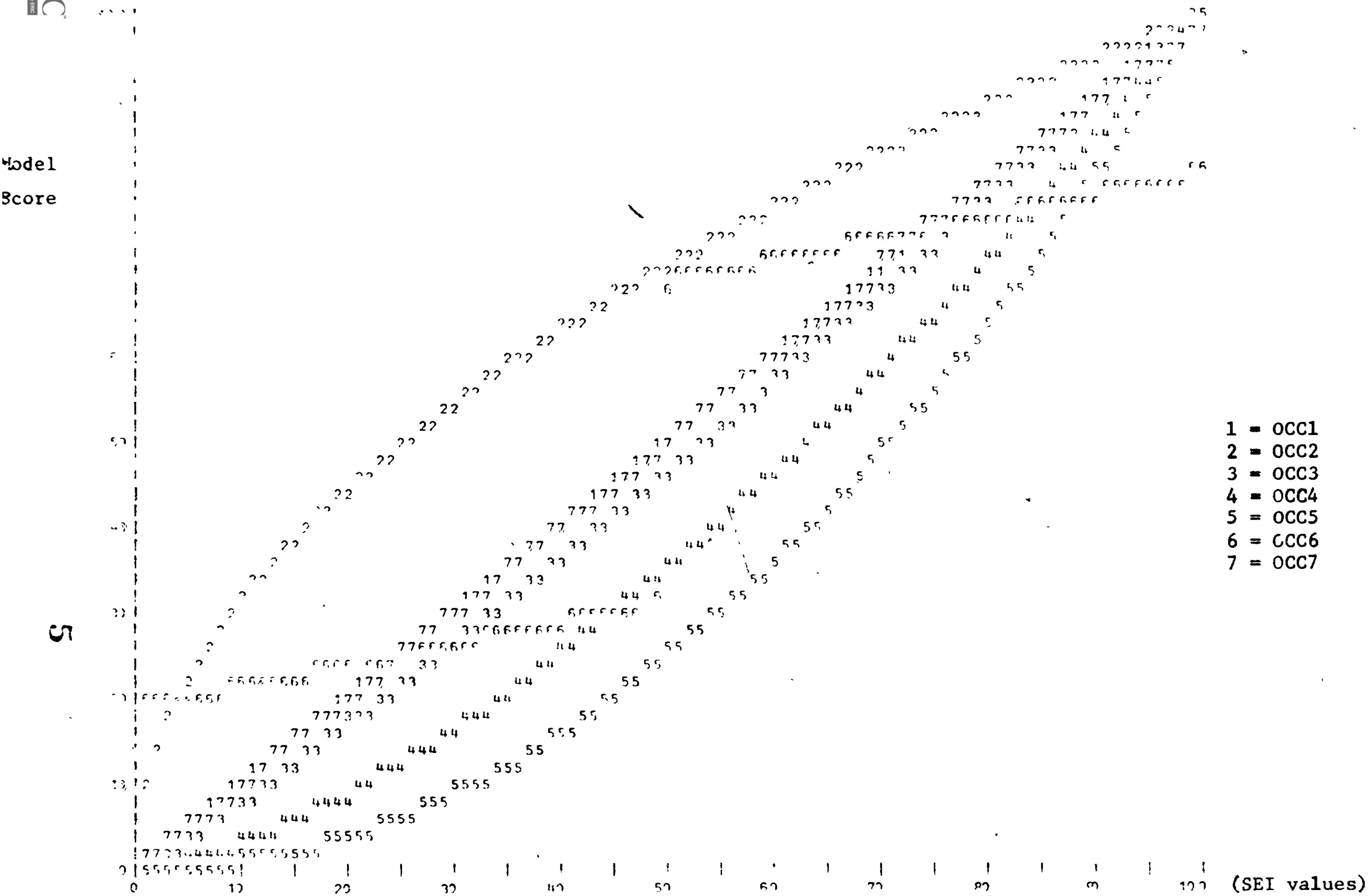

Figure 1: Illustration of 7 Alternative Epistemic Models[1]

1. Where models overlap, highest number is shown.

the magnitude of the true score. Thus $\Delta Y/Y$ represents the epistemic error as a proportion of the true score.

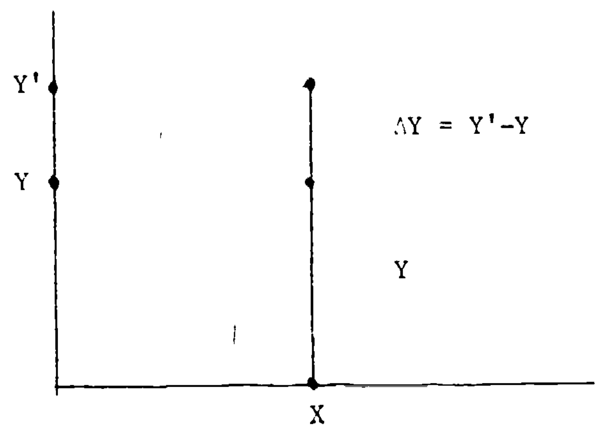

Figure 2. Illustration of the Epistemic Error

We suggest the use of a coefficient, C, to measure the percent of the mean amount of epistemic variation between pairs of competing indices for a given set of observations. For a set of observations, the coefficient of epistemic error, C, is given by the formula

$$C = \frac{1}{N}\sum_{1}^{N} \left| \frac{Y'_N - Y_N}{Y_N} \right| \times 100 = \frac{1}{N}\sum_{1}^{N} \left| \Delta Y_N / Y_N \right| \times 100$$

where N is the number of observation, Y'_N is the empirical score for the n^{th} observation, and Y_N is the ideal score for the N^{th} observation. The lower bound of the coefficient of epistemic error is zero. The coefficient assumes this value when there is perfect correspondence between a pair of indices. There is no theoretical upper bound for C, since there is no theoretical limit to the amount of epistemic error that can exist between two interval measures. Thus, the range of the coefficient of epistemic error is $0 \leq C \leq \infty$. The larger the value of C, the greater the amount of epistemic error between the two indices being compared.

Analysis of the Coefficients of Epistemic Error

Data sets were constructed in order to examine the nature and magnitude of the inherent variation in the occupational scores obtained by the different interval transformations. Each data set consists of simulated scores constructed by using a random number generator to draw integer samples from a normally distributed, infinite population. Two different groups of samples were drawn, simulating differing assumptions about the frequency distribution of occupational prestige in society. The first group of data consists of 100 scores individually drawn from a normal population with a mean in the middle of the SEI index ($u=50$). This master sample was then divided into three subsamples consisting of the observations in the lower third, the middle third, and the upper third of the SEI index, respectively. This procedure simulates data obtained from sampling the lower, middle, and upper strata of a normally distributed, prodominantly "middle class" population. This is to determine if epistemic differences have differential impact over conceptually significant value ranges.

Table 1 depicts the matrix of coefficients of epistemic error calculated for the set of four samples derived from the single "middle class" population. The coefficients in this matrix are generally quite small, ranging from a low of 0.04% to a high of 6.69%. Of the 80 values in this matrix, 11 have values representing errors of greater than 1 percent. Only one coefficient, that for $SEI^2/100$ vs. OCC2 (C=6.69) represents a mean error greater than 5 percent.

Because all the indices except the Warner and Marxian conceptualization converge at 100 as the highest occupational ranking, the variation, or mean epistemic error, between any pair of scales is very small for high occupational rankings. On the other hand, the greater proportional differences among "lower class" occupational scores is reflected in higher coefficients of mean epistemic error for that range of values. This is primarily due to the contrasting characteristics of the alternative epistemic models. However, to determine the effect of sample size and distribution, two additional sets of simulated SEI scores were generated and transformed. Collectively they represent samples drawn from three different normal populations where the mean of the occupational status distribution is in the lower, middle, and upper class SEI value ranges. Then a set of coefficients of mean epistemic were calculated for each sample. Those coefficients are presented in comparative form in Table 2.

For the practicing researcher, perhaps the most interesting vectors are the first columns in Tables 1 and 2 where Duncan's SEI as the empirical index is compared with the other indices as the ideal. With this vector we can approach the question, if we use the SEI in research and the true theoretical construct corresponds to any of the alternative scaling models, how large is the epistemic error, on the average? As can be seen, the coefficients for SEI as the empirical index are quite small. The largest coefficient for SEI occurs in Table 2 where SEI is compared to $SEI^2/1a$ for a lower class population. In this instance, C=3.1 represents a mean error of 3.1 percent. These small coefficient scores for SEI seem to indicate the Duncan's index is compatible with all the conceptualizations of social class as represented by the particular transformations made in this paper.

The matrix of coefficients of epistemic error calculated for the set of three samples drawn from different normal populations is shown in Table 2. Examination of these coefficients reveals the same pattern as in Table 1 but with smaller epistemic error in all cases, except for the lower class where the mean error is always greater with the larger sample size. The smallest mean variation is 0.02 percent between the values of the SEI index and the comparable values of the presumed true $SEI^{1.1}$ index. The largest mean variation is 11.9 percent between the values of the $SEI^{0.5}$ indice and $SEI^2/100$ model. Of the 60 coefficients in the matrix, only 39 have values representing mean errors of 1 percent or greater. Thus, the degree of epistemic error is affected by sample characteristics. Whether the error, however accentuated, affects the comparability of empirical conclusion remains to be determined.

Table 1: Coefficients of Mean % Epistemic Error Comparing Alternative Epistemic Models for Different Subpopulations from a Normal Population with $\overline{SEI}$ = 50 and s.d. = 15

"TRUE" MODEL		EMPIRICAL INDICATOR OCC1	OCC2	OCC3	OCC4	OCC5
SEI	All	0	.42	.07	.28	.48
	L	0	1.0	.13	.49	.74
	M	0	.46	.07	.31	.52
	U	0	.22	.04	.18	.32
$SEI^{0.5} \times 10$	All	.30	0	.34	.50	.63
	L	.50	0	.57	.75	.87
	M	.31	0	.36	.53	.67
	U	.18	0	.21	.32	.44
$SEI^{1.1}/100^{.1}$	All	.07	.52	0	.23	.44
	L	.15	1.30	0	.42	.70
	M	.08	.57	0	.26	.48
	U	.04	.27	0	.14	.29
$SEI^{1.5}/10$	All	.39	.98	.30	0	.27
	L	.97	2.97	.72	0	.48
	M	.45	1.10	.34	0	.30
	U	.21	.48	.17	0	.17
$SEI^2/100$	All	.91	1.72	.79	.37	0
	L	2.80	6.69	2.30	.94	0
	M	1.10	2.03	.93	.44	0
	U	.47	.79	.41	.21	0
$\sum_{1}^{100} Y$	All	4795	6813	4480	3439	2508
	L	241	484	210	122	63
	M	3277	4774	3042	2264	1575
	U	1277	1552	1228	1052	870

All: N = 100 L: N = 11 M: N = 71 U: N = 20

Table 2: Coefficients of Mean % Epistemic Error Comparing Alternative Epistemic Models for Different Normal Distributions.

"TRUE" MODEL		EMPIRICAL INDICATOR OCC1	OCC2	OCC3	OCC4	OCC5
SEI	L	0	1.44	.16	.57	.81
	M	0	.42	.07	.28	.48
	U	0	.10	.02	.09	.16
$SEI^{0.5} x 10$	L	.59	0	.66	.83	-.92
	M	.30	0	.34	.50	.63
	U	.09	0	.10	.17	.24
$SEI^{1.1}/100^{.1}$	L	.19	1.91	0	.49	.78
	M	.07	.52	0	.23	.44
	U	.02	.12	0	.07	.15
$SEI^{1.5}/10$	L	1.34	4.72	.97	0	.56
	M	.39	.98	.30	0	.27
	U	.09	.90	.07	0	.08
$SEI^2 /100$	L	4.28	11.9	3.44	1.25	0
	M	.91	1.72	.79	.37	0
	U	.20	.31	.17	.09	0
$\sum_{1}^{N} Y_N$	L	1580	3860	1330	674	299
	M	4795	6813	4480	3439	2508
	U	8231	9020	8083	7523	6888

L = Lower Class	$\bar{X}$ = 16	s.d.= 7	N = 100
M = Middle	$\bar{X}$ = 50	s.d.= 15	N = 100
U = Upper Class	$\bar{X}$ = 83	s.d.= 7	N = 100

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Impact of Epistemic Differences in Path Analysis

To assess the impact of these differences a path analytic model was tested; an X variable, measuring occupational status, and a Y variable, measuring some other theoretical construct were specified as determinants of a simulated dependent variable Z. For the purposes of this analysis Y was also a vector of randomly generated numbers with a mean of 50 and a standard deviation of 15; however, the values were not arranged in ascending order. The dependent variable, Z is the sum of Y and the simulated SEI_2 scores. Therefore, the model OCC1 + Y = Z is a perfect path model with $r^2 = 1.0$. The standardized path coefficients are .695 SEI + .793 Y = Z, where $r_{xy} = -.10$. Table 3 shows the impact on the standardized path coefficients when occupational status is measured according to the alternative suggested epistemic models. The results indicate that only the Marxian interval conceptualization significantly alters the magnitude of the standardized path coefficients and of the r^2 value. With this single exception the path coefficients and the r^2 value are remarkably stable. The very low correlation between the independent variables eliminates the confounding effect of multicollinearity on the magnitude of the path coefficients.

As we noted earlier, many data analysis procedures are more responsive to the occurrence of certain values and the frequency of certain values in a data set. Because we are investigating the comparability of alternative epistemic models of occupational status, we again analized the homogeneity of standardized path coefficients within certain class intervals. Those path coefficients are depicted in Table 4. Again we see that with few exceptions the within class standardized path coefficients and r^2 values are very able. In particular the Marxian conceptualization significantly differs from the other models only for middle class samples or distributions. For the upper class sample all the epistemic models are comparable with the principal path differences occurring significantly when Duncan's SEI is compared with the other six epistemic models. For the lower class sample, there is no significant difference among the alternative epistemic models in terms of the standardized path coefficient for occupational status. However, the path coefficient for the other independent variable does vary, decreasing as the exponential nature of the transformation increases. This did not occur using middle or upper class samples.

The differences among these epistemic models as measured by the coefficients of epistemic error were most acute for the lower class value range (SEI<34). Therefore, we examined the homogeneity of these path coefficients using transformations of a larger lower class sample of 100 SEI simulated, normally distributed, scores with a mean of 15 and a standard deviation of 7. The path coefficients using the alternative epistemic models appear in Table 5. Again there is little variation in the r^2 values, all being practically 1.00. The OCC1, OCC3, Marx and Warner conceptualization have virtually identical path coefficients. OCC5, the $SEI^2/100$ transformation, varied most with both OCC1 and OCC3 according to both the coefficients of epistemic error and the path coefficients. Use of OCC2 and OCC4, instead of OCC5, epistemic models moderates slightly these results primarily because their degree of nonlinearity is not as acute as that of OCC5.

Clearly the larger sample size has elucidated better the divergences among the epistemic models. In the lower class value range, the contrasting degrees of linearity affect more significantly the heterogeneity of path coefficients.

Table 3: Standardized Path Coefficients Comparing Alternative Epistemic Models

	Independent Variables			
	X	Y	r^2	r_{xy}
X=SEI	.695	.793	1.00	-.10
$X=SEI^{.5}$ x 10	.691	.794	.99	-.10
$X=SEI^{1.1}/100^{.1}$	.694	.793	1.00*	-.0996
$X=SEI^{1.5}/10$	.691	.792	.995	-.0997
$X=SEI^{2}/100$	.682	.790	.983	-.0987
X=(MARX MODEL)	.595	.782	.873	-.0997
X=(WARNER MODEL)	.695	.797	.999	-.107
X=SEI	.615	——	.378	
	——	.723	.523	

N=100

SEI=50,

X Variable: s.d.=15, arranged in ascending order

Y Variable: Y=50, s.d.=15, randomly distributed

Table 4: Standardized Path Coefficients Comparing Alternative Epistemic Models with Samples Representing Different Class Groupings

		Independent Variables			
		X	Y	r^2	r_{xy}
X=SEI	All	.695	.793	1.00	.101
	L	.344	.952	1.00	-.037
	M	.500	.850	1.00	.032
	U	.312	.921	1.00	.08
$X=SEI^{.5} \times 10$	All	.691	.794	.99	-.105
	L	.344	.960	1.00*	
	M	.500	.851	1.00*	
	U	.331	.922	1.00*	
$X=SEI^{1.1}/100^{.1}$	All	.694	.793	1.00*	-.0996
	L	.344	.950	1.00*	
	M	.500	.850	1.00*	
	U	.332	.921	1.00*	
$X=SEI^{1.5}/10$	All	.691	.792	.995	.0997
	L	.344	.943	1.00*	
	M	.500	.849	1.00*	
	U	.332	.920	1.00*	
$X=SEI^2/100$	All	.682	.790	.983	-.0987
	L	.343	.935	.999	
	M	.498	.849	.998	
	U	.332	.919	1.00*	
X=(MARX MODEL)	All	.595	.782	.873	.0997
	L	.344	.952	1.00*	
	M	.440	.880	.944	
	U	.332	.921	1.00*	
X=(WARNER MODEL)	All	.695	.797	.99	-.107
	L	.345	.956	1.00*	
	M	.499	.880	.994	
	U	.328	.912	.997	
X=SEI	All	.615	——	.378	
	L	.319	——	.096	
	M	.527	——	.278	
	U	.395	——	.156	
	All	——	.723	.523	
	L	——	.939	.882	
	M	——	.866	.750	
	U	——	.944	.891	

All: N=100

L = Lower Class (SEI≤35), N=22

M = Middle Class (35≤SEI≤67), N=72

U = Upper Class (SEI≥67), N=6

X is arranged in ascending order, $\bar{x}$=50, s.d.=15

Y is randomly distributed $\bar{Y}$=50, s.d.=15

* Approximately

Table 5: Standardized Path Coefficients Comparing Alternative Epistemic Models (x) Using a Lower Class Sample from a Population with SEI=15, and $S_{SEI}=7$

	X	Y	r^2	r_{xy}
X=SEI	.434	.907	1.00	-.014
X=SEI$^{.5}$x 10	.427	.898	.994	
X=SEI$^{1.1}$/100$^{0.1}$	.434	.908	1.00	
X=SEI$^{1.5}$/10	.429	.913	.995	
X=SEI^{2}/100	.415	.916	.983	
X= (MARX MODEL)	.434	.907	1.00	
X= (WARNER MODEL)	.437	.907	.999	
X=SEI	.421	——	.178	
	——	.901	.812	

N=100

X scores are arranged in ascending order,

Y is a randomly distributed score; $\bar{y}$=50, s.d.=15

Among classes in Table 5 we see that the r^2 value is relatively unaffected but the average path coefficient for occupational status varies considerably. It is highest for the whole sample of 100 SEI scores, less for the middle class sample and the lower class sample, and very much reduced for the upper class sample. This demonstrates clearly the "class" bias of occupational status scores on the magnitude of the path coefficients. This leads us to suggest that criticisms about the irreconcilability of alternative epistemic assumptions may be unwarranted because they may be based on variations in sample characteristics.

Discussion

We have examined selected alternative epistemic models premised on assumptions about the appropriate theoretical intervalization of occupational status categories. The coefficients of epistemic error have elucidated the varied, and often contradictory, nature of these models. Yet the analysis of the homogeneity of path coefficients affirms our earlier conclusion (Brunn, *et. al.*, 1974) that the impact of epistemic error is not only small but often insignificant. That conclusion is of course tentative based as it on the use of a small selection of empirical models which are monotonically isomorphic with each other. Other epistemic models may prove less compatible with the models we have investigated, and other empirical techniques may be more sensitive to epistemic differences.

Despite these qualifications we have attempted to demonstrate the applicability and efficiency of certain procedures, in particular the coefficient of epistemic error in the assessment of the comparability of alternative epistemic models. These procedures can be used to indicate over which value range, and how, alterantive epistemic models differ, and to what extent these differences are important.

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