The Interface Among Educational Outcomes and School Environment

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ABSTRACT

Linking measurements of the physical environment's physiognomies to human behavior and productivity is a rather new task in the fields of education, and social and natural sciences. In education; for example, how can a schoolhouse and its surroundings be measured such that valid and reliable comparisons can be made among student outcomes? For example, how do school environments influence student behavior and other outcomes? How do we quantify specific features of the physical environment of the school? Obviously, we already accept the quantification of student testing and other measurable outcomes based on our continual dependence on standardized tests for making decisions. The article approaches this issue through rules of consistent measurement and mapping practices. Three common measurement scales, nominal, ordinal, and interval scales are compared. The nominal scale is shown to be of unequivocally no value in making quantitative comparisons, beyond classifying and categorizing assigned values. The ordinal and interval scales may be considered as vectors having magnitude and direction, while the nominal scale does not fit into correlations, regression, and prediction equations because the nominal classification cannot show direction or specify magnitude. Examples of the use of ordinal and interval scales are presented with respect to comparisons of student outcomes and measured environmental variables having magnitude and direction.

INTRODUCTION

Almost 50 years ago Sommer wrote that, "… *The interface between education and design has remained relatively unexplored – educators being mainly concerned with student behavior and designers with aspects of the physical environment* (Sommer, 1969, p. 101). Only during the past 15 years has the complex endeavor of relating school environments to students' learning and behavioral patterns shown increased attention in the media and in research institutions.

This new prominence still finds measurement of school layout for the purpose of comparing it with student outcomes plagued by the view of skeptics who argue, "*you can't claim student outcomes have any causal relationship to a physical structure because measurement of a physical environment is not isomorphic to measurement of student achievement and behavior*." This disagreement has its basic foundation in issues of interface or boundaries, which include educational measures of achievement, psychological measures of behavior, aesthetic measures of physical structures and designs, and natural science measures of spaces, places and distances.

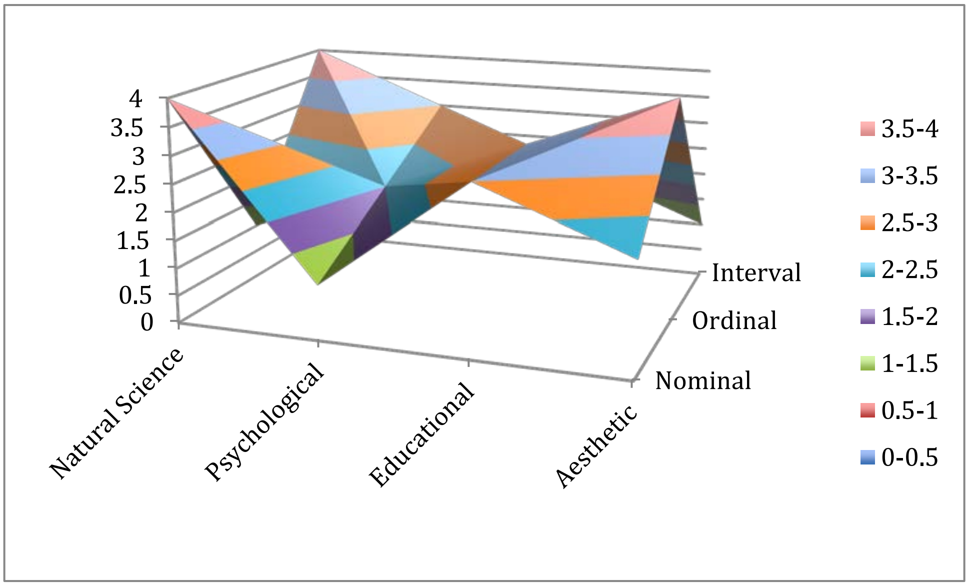
CONCEPTUALIZING THE CONSISTENCY OF MEASUREMENT

Before getting into the published research, it is important for us to consider the measurement issue noted in the introduction. Included in the science of measurement, where phenomena relate to quantities and objects relate to numbers, there exist rules for measurement, which are often presented in instrumentation such as standardized tests and questionnaires. This science is developing rapidly as a result of the push of advancing technology and the pull of changing requirements (Finkelstein, 2009). *The nature, scope, and organization of measurement as discussed in this article includes the identification of a common denominator among various forms of measurement, with and illustration and application pertaining to how the physical environment influences student achievement and behavior.* The concern here is can measurement in the natural sciences such as length width and volume and aesthetic preferences (Salkind & Salkind, 1974) be linked to educational and psychological measurements? To gain a better view of this idea three categories of measurement relevant to this discussion are depicted in Figure 1.

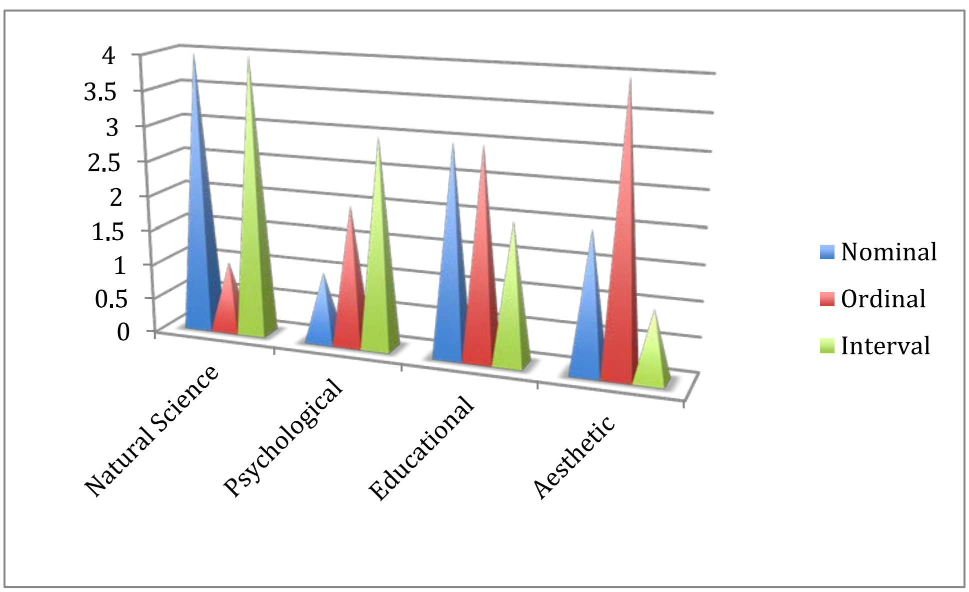
Figure 1. Scales and Measures

Measures	Nominal Classification	Ordinal Scale	Interval Scale (%)
Natural Science	4	1	4
Psychological	1	2	3
Educational	3	3	2
Aesthetic	2	4	1

Graph A



Graph B



In Figure 1 each of the four identified measures was assigned symbols or numerals (1 to 4) on the nominal classification. There is no difference in the value between the symbol 4 for natural science measures and the symbol 1 assigned to psychological measures on the nominal scale. The nominal classification is not a vector, since nominal classifications or identifiers have neither direction nor magnitude. These are just identifiers (identifier or descriptive symbols). When the ordinal scale is considered, for example, a subjective value was attached to each type of measurement by the author, thereby indicating direction and magnitude.

Moving to the other two scales, and in order of importance (one rater's viewpoint as seen on the ordinal scale), we have natural science (1), psychological (2), educational (3), and aesthetic measures (4). The reverse subjective values are applied to the interval scale so that we may see how these rules of measurement apply. By holding the nominal scale constant (since we have no other choice because it lacks magnitude and directional qualities) where measurement is concerned, we may plot the interval and ordinal values on Cartesian coordinates and show an isomorphism as seen in graphs A and B.

Although the concern about comparing the physical environment to educational and behavioral outcomes exists, there is some agreement that the conversion of subjective information about a school facility to an objective descriptor is possible. Even the most complex measurement system morphed from subjective items to objective criteria. Sophisticated standardized tests have their beginning in the subjective arena. Test items are identified subjectively before any numerical value is placed on them.

Measurement of anything begins with the identification and classification of items under consideration. Objects or phenomena as candidates for evaluation or measurement may be represented by symbols or numerals as noted in the nominal scale in Figure 1. Measurement is the assignment of numerals to physical objects or human performance according to rules (Kerlinger, 1967). Thus, in Figure 1, we have natural science measures representing objects such as school buildings, educational and psychological measures tied to standardized tests, behavior, and human performance, and aesthetic measures linked to the physical environment.

To assess a school's physical environment for the purpose of comparing it to educational outcomes in clusters (see for example, Tanner & Lackney, 2006, pp. 295 – 306) we ask a person (or persons) trained in school facility planning and design to tour a school's physical environment and rate various design characteristics on a validated questionnaire. Based on work by Likert (1932) the questionnaire containing Likert items describes various school design characteristics. Then, with numerals, the individual specifies where, in their judgment, the design characteristic falls on a set of Likert items that are later converted to a Likert scale (which may also be a percentage or interval level data – see discussion below).

As an example of linking the measurement scale to objects of interest we will consider attributes such as *space for movement, fenestration, and architectural design. Movement* is defined as easy to find relations among spaces, pathways with goals, and ample room to move about freely. *Fenestration* may be described as windows for daylight and views overlooking green areas. *Architectural design*, which might also include some aspects of movement patterns and fenestration, is expressed as the school building's point of reference, friendly entrance, intimacy gradients, variation of ceiling heights, and scale.

Professional educational facility planners, using a numerical format and a list of objects to look for, give the estimates in terms of numerals or symbols on various Likert items that correspond to school design characteristics. For example, a specific school may receive a numerical score on a Likert scale of 9 on space for movement, an 8 on fenestration, and 7 on architectural design.

The assessment is first tabulated on Likert items having a ranking scheme of 1 (a low degree of a specific characteristic is present) to 10 (a high degree of a specific characteristic is present) and converted to percentages on a Likert scale, indicating the degree that the characteristics are present. The estimates may be given by several people and then aggregated to establish a per item score leading to total Likert scale scores across categories. *The key to measurement in this example is that the planners, serving as judges, assign numerals to objects according to rules.* The list of objects is presented in questionnaire form, where close attention was paid to reliability and validity constraints (Tanner & Lackney, 2006, p. 278).

According to Flygt (2009), a measurement should include objective-subjective assessments representative of both the functional/technical and the ethical/aesthetical dimensions of a facility. The objects, numerals, and rules are specified as illustrated in Table 1. The numerals, based on the Likert items, are placed next to each descriptor, the objects are the school design items identified in the questionnaire, and the rules are contained in the instructions given in the questionnaire. For example, the instructions might read as follows: *Please score the design patterns below on a numerical scale from 1 to 10, where the numeral 1 indicates dysfunctional and the numeral 10 denotes functional. Design includes the way the schoolhouse is made, how it is arranged, and how the outside areas near the school complement the curriculum.* Here we have given meaning to numerals thus allowing them to become numbers such as percentages.

Table 1. Objects and Rules of Assignment

(Likert Scale: 24/3 = 8) Movement Patterns

The school's design may be judged regarding its ability to enable students and teachers to enter and move freely within and around a facility.

1- ____7___ **Promenade –** Outside walkways linking main areas; ideally placing major activity centers at the extremes.

Ambiguous *Likert Item* Distinct
< -- >
0 1 2 3 4 5 6 7 8 9 10

2-___8___ **Pathways** - Clear and comfortable pathways that allow freedom of movement and orientation among structures. These play a vital role in the way people interact with buildings. This pattern defines the overall philosophy of the layout.

Ambiguous *Likert Item* Clear
< -- >
0 1 2 3 4 5 6 7 8 9 10

Circulation Patterns - Indoors spaces for circulation. The passages should be broad and well-lit allowing for freedom of movement.

3- ____9____ Within learning environments .

Poor *Likert Item* Excellent
< -- >
0 1 2 3 4 5 6 7 8 9 10

According to Brown (2011), When considering Likert items … "we must think about individual Likert items and Likert scales (made up of multiple items) in different ways. Likert items represent an item format not a scale. Whether Likert *items* are interval or ordinal is irrelevant in using Likert *scale* data, which can be taken to be interval. If a researcher presents the means and standard deviations (interval scale statistics) for individual Likert items, he/she should also present the percent or frequency of people who selected each option (a nominal scale statistic) and let the reader decide how to interpret the results at the Likert-item level. In any case, we should not rely too heavily on interpreting single items because single items are relatively unreliable." (p. 13)

Brown (2011) concluded, "Likert scales are totals or averages of answers to multiple Likert items." Likert scales contain multiple items and are therefore likely to be more reliable than single items. Naturally, the reliability of Likert scales should be checked using Cronbach's alpha or another appropriate reliability estimator. Likert scales contain multiple items and can be taken to be interval scales so descriptive statistics can be applied, as well as correlational analyses, factor analyses, analysis of variance procedures, etc. (if all other design conditions and assumptions are met). (p.13)

Since we are relating characteristics of a school layout to student outcomes, the last aspect of measurement is defined. At this point the item describing a certain characteristic of school layout with an assigned rank on the questionnaire is converted to a Likert scale or percentage. In measurement terminology this is known as *mapping.* In summary, a number is a numeral that has been assigned a quantitative meaning (Likert scale) and implicitly includes magnitude and direction. The percentages representing school design characteristics are now ready for comparison to test scores and behavioral measures that are also presented as percentages. Hence, we have a rule of correspondence that assigns or maps aesthetic measurements, and natural science measurements onto educational and psychological measurements. The mapping functions, assumed to be one-to-one, are isomorphic since they are represented as percentages and have special rules of assignment and correspondence. Now that the issue of measurement has been addressed, we may apply our instrumentation to the evaluation of a physical structure.

HOW THE SCHOOL LAYOUT MIGHT CONTRIBUTE TO STUDENT OUTCOMES

The research documented here conducted at the School Design and Planning Laboratory (SDPL) attempts to tie aspects of the interplay of knowledge, beliefs, behaviors, and actions in reference to a place (the school environment) to cognition or acquisition of knowledge (measured by standardized scores on tests for cognition). Other researchers independent of the SDPL have linked these two areas, simultaneously. For example, Rollero and De Piccoli (2010) report that affective and cognitive dimensions, defined as place attachment and identification, characterize *the relationship between people and places*. Their timely study shows that the affective and the cognitive dimensions (1) are directly predicted by different demographical and psychosocial variables and (2) are strictly associated with the perception of the place and its inhabitants. Furthermore they contend that cognitive and affective dimensions are two distinct but correlated components.

Beginning in 1997, the SDPL associates discovered that no valid and reliable measurements existed that would indicate if or how much the school's physical environment contributes to or influences the student's cognitive learning and behavior. Hence, we set out, tolerating colleagues' pointed skepticism as presented in the introduction, to explore a way to link place and cognitive learning and behavior. Up until then, we discovered that school environments were usually built on whims, standardized codes, and unsupported "best practices," or hearsay evidence among educational planners and decision-makers. To strengthen our argument, we encouraged educators to examine the issue of "best practices in building schools," which often goes unchallenged regarding whose best practices and what, when, where, and how they might influence various educational and cultural settings (Tanner & Lackney 2006, pp. 263 - 322). Our conclusion was to avoid, or at least beware, of using best practices as a basis for planning and designing schoolhouses and educational environments.

Early studies at SDPL began with identifying aspects of places where students learn (these are called 'design patterns,' after Alexander, Ishikawa, and Silverstein (1977), from their masterwork entitled *A Pattern Language.*) Table 1 shows an example of design patterns used in our instruments. Our primary assumption was that design patterns in the school's physical environment influence student achievement; therefore, "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (Alexander et. al. 1997, p. x). That is, *we assumed that place and cognitive dimensions are related in various ways.* Readers interested in more detail on the physical environment, as we have defined it may refer to additional works such as Sommer (1969), Tanner and Lackney (2006, pp. 263 -322), and Tanner (2009).

More than 100 characteristics of design patterns were identified and debated among educational leaders attending graduate level classes offered in the SDPL, beginning as early as 1997. The purpose of these discussions was to validate each "education related design pattern" based on need and relevance to teaching and learning. Representing a very small fraction of our findings, three broad areas are identified below (Tanner, 2012).

1. Movement Classifications

Research on movement classifications, described as links to main entrances, pathways with goals, circulation pattern, density or freedom of movement, personal space, and social distance has been of interest to researchers in the field of environmental psychology for many years. In our validation process we always asked questions about too much or too little space and then referred to issues of social and personal distance to develop a stem for a measurement scale to be used in assessing existing places and spaces for learning.

Regarding personal and social distance, Wohlwill and Van Vliet (1985) summarized the effects of high student density as a hindrance to movement. "It appears as though the consequences of high-density conditions that involve either too many children or too little space are: excess levels of stimulation; stress and arousal; a drain on resources available; considerable interference; reductions in desired privacy levels; and loss of control" (pp. 108-109). Works such as this have led to the assertion that a high-density school influences achievement negatively (Weinstein & David, 1987). Our decision about freedom of movement has been consistent: An overcrowded school is not conducive to teaching and learning. *It is not the size of the school that plays the positive or negative role in student achievement as much as it is the density - number of students per square and cubic unit of measurement.*

Some other major conclusions from our research at the SDPL are summarized as follows: The issue of density may be viewed through psychological implications implied in "territoriality of place." Since the school is a social system within the cultural environment, social distance (as defined by Hall, 1966) relates to crowding and density, which are functions of school design. This course of reasoning should be made for school size and the size of classrooms. Special attention should be given to circulation classifications that permit student traffic to flow quickly from one part of the building to another. Movement within the school should be a conscious and perceptible environmental exchange; and complex structures that cause crowding should be avoided. School design should include pathways both inside and outside of the building. Pathways may link structures together and lead into the natural environment.

2. Architectural Design

Fiske (1995) indicated the organization of space has a profound effect on learning, and students feel better connected to a building that anticipates their needs and respects them as individuals. When children attend a school obviously designed with their needs in mind, they notice it and demonstrate a more natural disposition toward respectful behavior and a willingness to contribute to the classroom community (Hebert, 1998). Collaboration among stakeholders in planning and designing a school is a significant step in achieving the right design. Both the planner and the stakeholders (including parents and students) learn from each other. Participation can lead to the ultimate agreement about what the future should look like and includes awareness and perception. Awareness involves persuading participants to speak the same language, perception takes awareness a milestone forward – it facilitates an understanding of the physical, social, cultural, and economic ramifications for the project outcomes (Sanoff, 1994).

The need exists for the development of spaces that engage, challenge, and arouse a student's imagination. Brain-compatible learning requires much more interaction with the environment than current facilities allow. Taylor and Vlastos (1975) suggested that educational architecture is a "three-dimensional textbook." This means that the learning environment is a functional art form, a place of beauty, and a motivational center for learning. School buildings are visual objects, and as such they can be stimulating both in terms of their intrinsic design and their use.

Architectural design should include a friendly entrance that is age appropriate and highly visible. Huge, overpowering entrances are intimidating to young children, for example. The entrance should evoke a welcome feeling (Alexander et al, 1977), not instill fear. To stakeholders, the school administrative offices should be centralized for convenience and connection. Main buildings have an obvious reference point, a feature that heightens the sense of community. *Variation of ceiling heights and intimacy gradients help blend public and private places in schools and give the effect of drawing people into an area.*

The issue of scale must be emphasized in planning the school layout. Meek (1995) contributed to the understanding of scale when she wrote about Crow Island School: " Then you are at the front door, and what you notice is that the door handler is too low. Too low for you, just right for children." (p. 53)

3. Fenestration, Daylight, and Views

The presence of natural light in classrooms improves student learning. An extensive research effort, including a controlled study of over 21,000 students in California, Washington, and Colorado found that students with the most "day lighting" in their classrooms progressed 20 percent faster on mathematics and 26 percent faster on reading tests over a period of one year than students having less daylight in their classrooms (Heschong Mahone Group, 1999). "We also identified another window-related effect, in that students in classrooms where windows could be opened were found to progress 7-8% faster than those with fixed windows. This occurred regardless of whether the classroom also had air conditioning." (p. 62). Rather than being a distraction, an argument often used from the "conventional wisdom" side, which disrupts the learning process, windows provide a necessary relief for students (Kuller & Lindstern, 1992). As a general rule, being able to see at least 50 feet or more allows students to rest their eyes by changing focal length.

According to Wurtman (1975) light is the most important environmental input, after food and water, in controlling bodily functions. Different colors of lights affect blood pressure, pulse, respiration rates, brain activity, and biorhythms. Full-spectrum light, required to influence the pineal gland's synthesis of melatonin, which in turn helps determine the body's output of the neurotransmitter serotonin, is critical to a child's health and development (Ott, 1973). To help reduce the imbalances caused by inadequate exposure to the near ultra-violet and infrared ends of the spectrum, full-spectrum bulbs that approximate the wavelengths provided by sunshine should replace standard bulbs. Ample evidence exists indicating that people need daylight to regulate "circadian rhythms" (Alexander et al 1977, p. 527). Poorly lit and windowless classrooms can cause students to experience a daily form of "jet lag," while forms of florescent lighting may affect some students and teachers by causing mild seizures.

CONCLUSIONS

Following the logic presented in this article, we may hypothesize that measurement of educational and psychological outcomes can be compared with measures of the physical environment. That is, given isomorphic measures including magnitude and directional vectors, school layout can be compared to student outcomes. From the literature and SDPL research we can conclude that ample space for learning where overcrowding is avoided improves student outcomes. Likewise ample circulation patterns, appropriate scale, and plenty of natural light in the classroom improve student performance. The relationship between people and places is a significant and sound topic for further research.

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