AC 2009-428: ASSESSING CREATIVITY IN ARCHITECTURAL DESIGN: EVIDENCE FOR USING STUDENT PEER REVIEW IN THE STUDIO AS A LEARNING AND ASSESSMENT TOOL

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Assessing Creativity in Architectural Design: evidence for using student peer review in the studio as an assessment tool

Abstract
Creativity is a phenomenon that occurs in architectural design where there is no universal or authoritative definition. This presents a dilemma for both faculty and students in assessing student work because it asks the question, "How do we measure something that we have difficulty in defining?" This three-year study will present evidence that both students and faculty agree on levels of creativity when they *see it*, regardless of a set definition and without faculty stating their opinions during the design and critique process. Students were asked to apply a number of architectural design concepts to a simple one-day design problem. They then comparatively analyzed and critiqued the projects in group discussion that was moderated by the faculty. Students were also asked to privately journal their observations and select without discussion a set number of the most successful projects in the class. Successful projects were defined as ones that applied these concepts in a creative way to produce a solution. The problems were purposely left somewhat ill-defined with few constraints that allowed for a broad range of creativity. At the same time, faculty privately assessed and graded the students' projects. It was found that a comparison between faculty grades and collective student rankings revealed a strong correlation in identifying the most and least creative projects. Two different statistical methods are used to support this conclusion. It also indicated that the difference in priori experience between faculty and students did not play a role in assessment outcomes. The immediate implications for these findings is for faculty to use student peer review to justify a highly subject grading process. The broader findings will allow for the development of a number of learning and analysis tools in the classroom and beyond.

Introduction
Private student journals were introduced in my architectural design studio several years ago for two primary reasons: one, to keep students focused during group critiques of projects and two, as a tool for faculty to obtain feedback. In addition to learning about what students thought and how they understood the concepts that they were applying, they were asked to select the *best* three or four projects in the class in terms of being the most creative and successful overall. Interestingly enough, their collective rankings in this process and my independent assessment, as reflected in the project grades, paralleled each other. This correlation took place without me telling students which projects were the best. The idea was to have students discover this through a rigorous comparative critique process. The process was based on mapping concepts as a series of characteristics or facets. If enough points were mapped it gave a full summary of each project in terms of its individual strengths and weaknesses in addition to the entire ensemble. Several students at a time would debate the application of concepts in this context. The faculty moderated the discussion, without prejudice or preference for one project or another. One fascinating aspect to this correlation had to do with why both students and faculty can recognize the best projects without an explicit definition or weighted formula for creativity. The one day sketch problems given could be termed as new to students, very open, functionally unconstrained and ill-defined; the types of problems that tend to maximize creativity (Simon, Newell and Shaw 1962; Rowe 1982; Dillion 1982; Getzels 1982). The other aspect to this

correlation was that the students, who can be described as very novice and untrained designers, collectively came to the same conclusion as an experienced and highly trained faculty member as to which projects are the best.

Selection of the best projects by students was explicitly meant as the most successful interpretation and creative application of the concepts as presented in the theory lecture and reading. The concepts can be thought of as variables in which the problem exists. Some concepts or variables such as clarity of form and integration of form or mass and void or additive and subtractive process compete against each for expression when applied in a multidimensional, multivariable problem. Other intangible variables and relationships such as scale and proportion of objects relative to each other, in a complex field are more about recognition, and developing an eye for, as part of the ensemble rather than something that can be measured. The entire project is one of combinations and interpretation of conceptual variables and elements that generate and express new and novel solutions or unique relationships. Each of these student projects has a good, better and best solution and there is general agreement among the students and the instructor as to which project rank at the top and the bottom.

While working with a team of researchers on a grant proposal, a discussion came about among several colleagues on how to model experiments in creativity. The working hypothesis that was used stated the following: individuals are more creative than groups even though groups could generate many more ideas by brainstorming. The primary goal of group brainstorming is to generate a wide variety of ideas but people often refrain from acting on them. They think their ideas are too strange or unrealistic and they fear negative reactions from other group members (Diehl & Stroebe, 1987; Osborne, 1957). Individuals on the other hand can explore creative connections and combinations beyond the normative boundaries set by groups.[1] The net result may be that many creative ideas generated by groups are never expressed or acted upon (Goncalo & Staw 2006). The research seems counterintuitive at first since more ideas should lead to more creativity but historical evidence supports this hypothesis in that nearly all great creative works of literature, art and architecture usually bear the name of a single author. One could conclude that groups are better arbiters in defining creative boundaries, especially at the limits of where creativity becomes inappropriate for the solution or context, but not in generating creativity. Another hypothesis that was considered had to do with experience and creativity. Some research in cognitive psychology indicates that experience has little influence on creativity in general although other research suggests domain experience is an important predictor (Amabile 1983; Martinsen 1993).[2] This may give an insight as to a role experience may play in elementary creativity but not the kind that also relies on complex cultural associations with creativity. This idea is also counterintuitive in architecture where it’s widely believed that great architects don’t really mature and produce their best work until later in life.[3]

[1] There is research that suggests modifying the group idea generating processes can yield better results in creativity by promoting an individualistic culture within groups (Goncalo & Staw 2006).
[2] Yong, Chua & Iyengar (2008) argue that high prior experience in the domain task and explicit instructions to be creative produce more creative outcomes when given more choice.
[3] Experience in architecture also contributes to factors such as designers being more efficient, solutions being less risky and more appropriate but not being more creative. Some have theorized that creativity is equivalent to an intelligent quotient (IQ) but no successful tests have been developed to prove it. Lack of experience also has psychological effects on the individual i.e., feelings of incompetence at a creative task (Deci 2005).

The objective of this paper is to show that we can assess work that we cannot fully define but know it exists in an ideal form. The use of this assessment process extends beyond the architectural design studio to any course with a creative dimension for problem solving. This paper will examine why students and faculty can agree on which projects are the best in the class, without an explicit formula for measuring creativity or a more unambiguous definition for success beyond what has been presented here. It will present data, provide analysis and outline previous research on creativity to help to provide an explanation as to why this phenomenon occurs. Two different statistical methodologies are used to show that a correlation exists between the sets of data: a correlation statistic (Correl) and a non-parametric rank sum probability test (Mann–Whitney *U* test). It will develop a theory of why boundaries need to be mapped that allows for this type of agreement. The larger and more complex question here is how does this contribute to our understanding of the creative process in design? The more applied goal is to provide an assessment process of checks and balances that can be used as a valuable tool to publicly reinforce seemingly subjective grades to students when they think such decisions are unfair and as a tool for faculty to see if the class is collectively developing an insight as to defining what is best, successful and creative is in architecture. It also encourages faculty to test and replicate this process in their classrooms.

Background

There is no universal definition of what creativity is in architecture. The Oxford Dictionary of Architecture and Landscape Architecture has no listing for creativity at all. A Dictionary of Psychology defines creativity as: "**creativity n.** The production of ideas and objects that are both novel or original and worthwhile or appropriate, that is, useful, attractive, meaningful, or correct. According to some researchers, in order to qualify as creative, a process of production must in addition be heuristic or open-ended rather than algorithmic (having a definite path to a unique solution). See also convergence-divergence, multiple intelligences, triarchic theory of intelligence."[4] An encyclopedia definition is: "**creativity**. Ability to produce something new through imaginative skill, whether a new solution to a problem, a new method or device, or a new artistic object or form. The term generally refers to a richness of ideas and originality of thinking. Psychological studies of highly creative people have shown that many have a strong interest in apparent disorder, contradiction, and imbalance, which seem to be perceived as challenges. Such individuals may possess an exceptionally deep, broad, and flexible awareness of themselves. Studies also show that intelligence has little correlation with creativity; thus, a highly intelligent person may not be very creative."[5] A standard dictionary definition is: "**creativity – noun.** (1) the state or quality of being creative, (2) the ability to transcend traditional ideas, rules, patterns, relationships, or the like, and to create meaningful new ideas, forms, methods, interpretations, etc.; originality, progressiveness, or imagination: *the need for creativity in modern industry; creativity in the performing arts,* (3) the process by which one utilizes creative ability: *Extensive reading stimulated his creativity.*"[6] Ideas on creativity in architecture have historically developed from many prescriptive treatises and speculative

[4] "creativity." A Dictionary of Psychology. 2001. Andrew M. Colman, ed. (accessed March 3, 2009 Encyclopedia.com http://www.encyclopedia.com/doc/1O87-creativity.html)

[5] "creativity." Britannica Concise Encyclopedia. 2008. (accessed March 3, 2009 Encyclopedia.com http://www.encyclopedia.com).

[6] "creativity." Random House Dictionary. 2009. (accessed Feb. 06, 2009. Dictionary.com http://dictionary.reference.com/browse/creativity).

theories. This is in contrast to the work in the social sciences that is based on a scientific approach to understanding creativity with goals that range from discovery to increased productivity. A background discussion is presented on characteristics that play an important role in defining aspects of *where* creativity occurs in the architectural design process without actually trying to explicitly define the phenomenon.

Diversity of Attitudes

Within the discipline of architecture itself there are many attitudes toward design creativity. There is an attitude that views the architect as creative *artist* but they are criticized for ignoring certain functional and technical problems. There is another attitude that views the architect as *professional* problem solver but that is criticized for producing architecture that is too bureaucratic and boring (Garvin 1964). There are elitist attitudes that come from schools of architecture such as the French École des Beaux-Arts which advocated the use of the *parti* or big idea in conjunction with a systematic design process and aesthetic bias by highly trained architects. This is in contrast to much more populist attitudes such as the German Bauhaus that looked at creativity as a product with pragmatic and technological needs or even more extreme attitudes such as Christopher Alexander's Pattern Language (1977) that suggests that all human beings have the capacity to be creative without architects, who often have an agenda.

Arbiters of Architectural Creativity

There are several arbiters of architectural creativity: a group of professional peers recognized as experts and authorities used in judging competitions and awards; cultural critics, professional intellectuals and journalistic writers, usually for print media; academic architectural historians who recognize landmark works over the long periods of history; and the general public as end consumer. Professional peers are considered the best arbiters for cutting edge creativity among architects themselves. In addition to their social status, their training and experience allows them to implicitly know where the boundaries are and what is appropriate in a complex multidimensional and multivariable problem solving. Architectural historians and the general public, on the other hand, are considered better long term arbiters. Many of the buildings that receive architectural awards and recognition by professional peers sometimes fade, or in extreme cases are considered failures, by architectural historians and the general public. The Pruitt-Igoe Housing Project in St. Louis, designed in the early 1950's, which won many architectural awards but was ultimately demolished less than twenty years later was considered a failure by the general public and architectural historians alike (Jencks 1984). In some cases, the general public will recognize a building as a success before the professional establishment and cultural elite. The Eiffel Tower, part of the entrance gate to Paris Worlds Fair (Exposition Universelle) of 1889, is an example where the structure was criticized at first by most quarters but over time the general public came to love the building and it remains today one of the most recognizable icons of the city and country (Trachtenberg & Hyman 2002).

Research into Architectural Creativity

Architectural research on creativity is problematic in that the most celebrated architects tend to protect their creative secrets (Antoniades 1992). Frank Lloyd Wright was highly secretive and attributed his designs to genius (Wright 1943); which doesn't tell us much. Many other architects simply can't express how they actually arrived at a creative solution. Some theorists associate creativity with good judgment (Labatut 1956) while some argue that creativity is a process of creative abstraction and individual maturity (Bachelard 1969). There are other theorists that do offer more structured methodological approaches (Broadbent 1973; Koberg and Bagnall 1972) as a series of prescriptive processes for creativity but offer little in the way of measurement and definition beyond obvious characteristics.

Cross Disciplinary Attitudes
Theorists in other disciplines say creative designers are ultimately concerned with the production of socially-valued novel products (Albert 1975; Amabile1988; Bessemer & Treffinger 1981, Ghiselin 1963; Mumford & Gustafson 1988). Architects have been reluctant to mine in these social sciences for several reasons: one, a language barrier between the disciplines; two, a preference toward design as an art and not a science; and three, the architect's formal professional training generally does not give them the tools for conducting and implementing a design process that includes a scientific methodology. Theorists like Don Schön (1988) have suggested that designers should learn from what scientist do rather than try to interpret their language and findings. Other architectural theorists such as Alan Colquhoun (1967) have argued against deriving designs from overly scientific approaches at all, as a form of *biotechnical determinism,* because creativity is so complex that these models simply do not understand the mental processes designers experience during the architectural design process.

Where Creativity Occurs
High creativity usually occurs when a problem is ill defined (Simon, Newell and Shaw 1962; Rowe 1982; Dillion 1982; Getzels 1982) or so complex (too many unconstrained variables) that the problem becomes ill defined. In these problems, neither the solution nor method for obtaining the solution is apparent. Peter Rowe (1982) calls these "wicked problems" in that their ends and means are both unknown and there are many plausible solutions and strategies for solving the problem. This is in contrast to well defined problems that offer little opportunity for creativity and are usually easy to design, where the solution is obvious from the start, or offers a process that yields the same result all the time. Rowe argues that tackling a highly creative problem requires a starting point that involves speculating on one or more possible ideas of what the end form might look like to suggest a plausible set of design rules, strategies, techniques and processes as the means to get you there. These end solutions are characterized sometimes as analogies, metaphors, relationships and concepts as ideas, and hints, only to start the creative process; they are not solutions in themselves or developed prototypes which typically offer little creativity beyond modification.

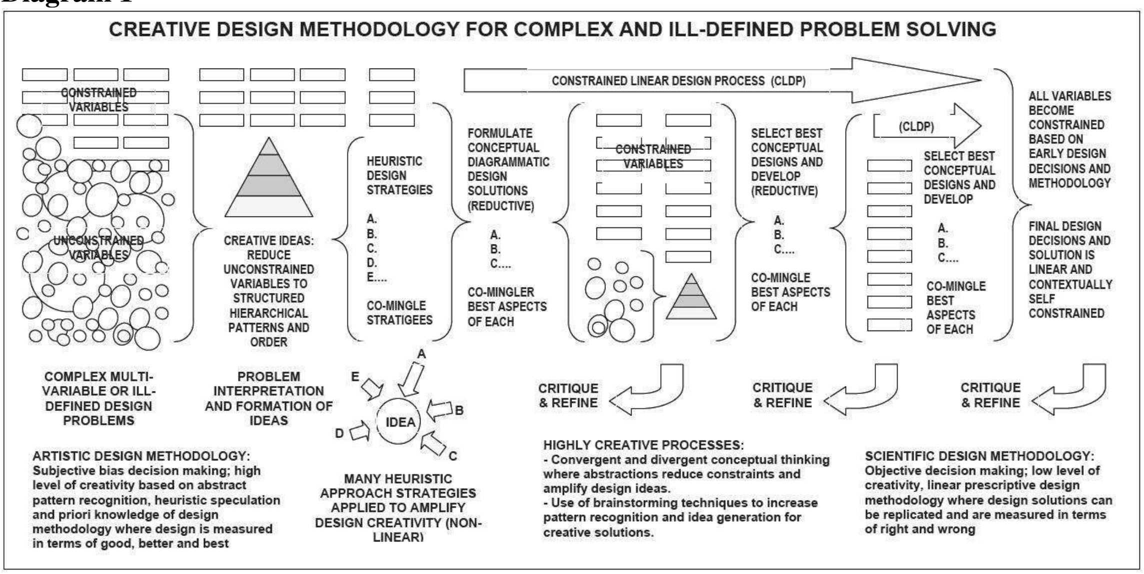
Creative Techniques in Architecture
Creative techniques are simple associative thought processes that allow new connections to be made or patterns recognized from a number of variables to generate ideas. These techniques cannot design a building and lack a comprehensive methodology to do so. They do form the building blocks for creativity. Some creative techniques used in architectural design include: convergent thinking (a diagram or reductive abstract) and divergent thinking (exploration of many possible solutions that fit); ranking variables into hierarchical patterns; sorting and segregating variables into likeminded categories and patterns; narratives to explore relationships and patterns; abstract geometric pattern matching and breaking; contextual analysis and pattern matching and breaking; analogies to quickly generate possible end solutions; transforming prototypes into workable solutions; metaphors, signs, symbols and aesthetic language patterns to

tell a narrative or give meaning, etc. Still other more informal techniques rely on using various shifts in perspective that allow the designer to see new relationships from different angles.

Design Methodologies in Architecture

Design methodologies are different than techniques in that that they include a broader philosophical and conceptual bias in addition to a comprehensive process. These design methodologies often have step-by-step approaches that can be characteristics as: linear, parallel, multipath, network, comingled, circular, continuous development and improvement, etc., with underlying global philosophies and relationships. The issue with using design methodologies is that many aspects are intertwined with problem solving that may not have a direct relationship to creativity but link one series of processes to another. They can be used to design a building. Diagram 1 illustrates a complex architectural design methodology for problem solving with many unconstrained variables.[7] The creative techniques are shown graphically as triangles that allow for hierarchical patterns, relationships or associations to form producing idea with a complex methodological system.

Diagram 1



All methodologies are underpinned by some creative techniques. Theorist Peter Rowe for example has outlined five types of heuristic analogies, as stimuli, that are used as starting points in architectural design. They can be singularly used or comingled as needed and are defined as: anthropometric analogies (physical occupancy of space); literal analogies (borrow from existing forms) with subcategories iconic (broad from the natural world) and canonic (ideal from geometric patterns and shapes); environmental relations (natural and built context); typologies (proven prototypes); formal languages (sets of rules for design i.e., classical architectural language) (Rowe 1982, p.363). Anthony Antoniades (1992) has outlined three types of metaphoric (analogy) acts that are used as a starting points in the design process: one, attempt to transfer references from one subject (concept or object) to another; two, attempt to "see" a

[7] This diagram represents my own thinking on creative problem solving in architecture.

subject (concept or object) as if it were something else; and three, displace the focus of our scrutiny from one area of concentration or from inquiry into another (in the hope that by comparison or thought extension we can illuminate our contemplated subject in a new way (Antoniades 1992, p.29). In both cases, each theorist is attempting to define boarder methods of association between the problem, and the solution to the problem, and both advocate commingling combinations of each. Many other theories rely on the use of analogies or metaphors to provide speculative clues, and act as the creative spark to illuminate, as to what parts of the solution might look like. This analogy search through a problem space involves the sequenced generation and evaluation solutions by which the designer can take the next step within a more complex process than a creative technique. The goal is to allow one to quickly see if patterns within the solution fit the problem. The selection of the analogy will in the end constrain large groups of unconstrained variables allowing the designer to structure the problem in a way that the final solution it easier to obtain.

Architectural Concepts and Creativity

Architectural concepts are patterns, relationships, ordering and organizing elements but they are not in themselves creative techniques or methods. Examples of these include: concepts on form and space, relationships between spaces and paths; circulatory patterns and prototypes; formal ordering principles such as elements to make a datum and rules for hierarchies. They are treated as variables in architectural problem solving. The selection of which concepts are used has a creative dimension to it since it relies on making associations or connections to existing contextual patterns. The course textbook, *Architecture: Form, Space & Order* by Ching (2007), is an assembly of concepts but does not explicitly present creative techniques or design methodologies. The concepts used in this paper are the most introductory and fundamental of form, volume and space. See the General Procedures in the Method section of this paper and the referenced Appendix for a description of the problem and concepts used.

Creative Boundaries in Architectural Design

There are boundaries to creativity in architecture that usually include the limits of acceptable norms and values, aesthetic patterns and ability to fit cultural, social, economic and technological systems. Characteristics such as weird, bizarre, flashy and over the top may be highly creative but inappropriate. In this respect, how much creativity is used is difficult to define and measure beyond saying that architects generally recognize levels of creativity when they “see” it and sense the boundaries of inappropriateness. This may explain why the focus is on the methods and techniques to encourage creativity while letting the market economy and professional peers judge the amount of creativity rather than try to define it in absolute terms.

Method

Subjects

The studies were conducted over a three year period, from 2005 to 2008 in the fall semester in the Architectural Design I; the students first introductory design course in the curriculum. The course focused on the fundamentals of architectural design. The students were sophomores and the class size varied as follows: one section fall 2005 of 23 students; fall 2006 of 23 students; fall 2007 of 25 students; and two sections in fall 2008 of 18 and 13 students.

General Procedures
Students were given a series of three one-day three-dimensional sketch model problems where they would apply and explore various elementary architectural concepts. The concepts and materials applied were: form, using sugar cubes; volume, using dowels; and space, using planes, respectively. See project outlines in Appendix A1 - A3 for detailed descriptions. A reading assignment was given in advance and a classroom lecture presented the concepts. Students were then instructed through the use of materials to apply, test and explore the concepts. In addition to a detailed list of concepts, simple rules and constraints were given. No formal design methodology was presented other than a simple trial and error strategy, i.e., try something, if you don't like it take it apart and try it again. The projects had no functional requirements, only conceptual applications. Some constrained variables such as the size of the 15" x 15" foam core base and the material used allowed for comparative analysis of the concepts applied as independent variables. The students were told that the more creative and original the design solutions, the higher the grade would be. Since the problem was something very new to students, with few constraints given and no functional dimension to the problem, it can be considered ill-defined and extremely open ended as to what the solution would look like; a wicked problem.

Creative Techniques Used
The creative technique used by the students in the design process relied on various shifts in perspective that allow them to see new three dimensional relationships from different angles.[8] After a lecture was presented outlining the concepts, students worked on their projects for approximately two hours in studio before finishing the projects at home. Most of the projects were less that a quarter complete when the class ended. During this studio design and build exploratory time, students built small components and tested the relationships of the concepts. As instructor, I would go around the room and encourage students to think outside the box, turn things on their side, literally, to see things in a new way, and try something new or creative. If their exploratory components were unique, dynamic, exciting, and innovative, I'd call the class over and have everyone take a look; the same was true with components that were flat or boring. This was all done very early on in developing a solution. In the end, the emphasis was on developing a value for an innovative and unique application of the concepts and approach to developing a solution.

Studio Critique Process of Boundaries
Students presented their projects comparatively in groupings of four or five. A simple one minute presentation was made on each project and then those students sat quietly and listened to student peer criticism and debate. Three students at a time were called upon by the instructor and asked which project had the most and least application of various concepts. For example on the form project, typical questions would be: (a) which project has the most and least clearest forms, or (b) which projects has the most and least integrated forms, etc. See project sheets A1-A3 in Appendix for detailed list on questions applied. The questions ultimately defined the boundaries of concepts, in terms of most and least, but did not try to gradate each project. Usually five characteristics or facets of a concept were explored through these questions. Some questions were diametrically opposed to concepts in other questions, i.e., clarity of form is

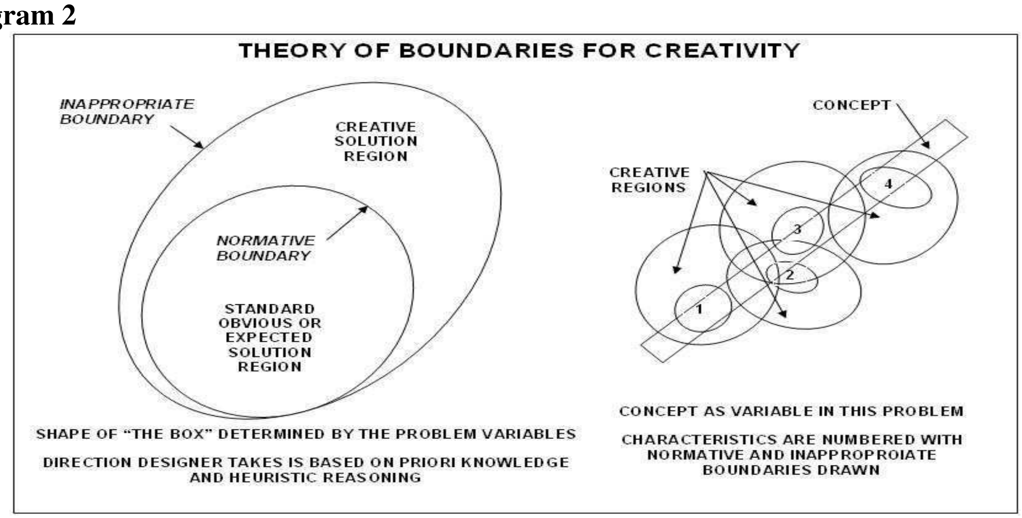
[8] Since this paper is not measuring creativity directly, a general technique was used. It's measuring a correlation between two groups only and outlining where creativity occurs; not defining it.

usually at the expense of integrated forms, so one project could be very successful in one area but be unsuccessful in another. The focus was on the rational and not just a selection. The instructor moderated the debate but gave no indication as to whether or not the students were correct in their selection. This was a process of analysis and discovery and not one where the instructor imposed a unilateral value. The class was also allowed to engage in the debate if no clear consensus was reached, often through a show of hands a potential consensus was developed; the instructor remained a neutral referee. The final question of which projects in the class were the best in terms of the most successful interpretation and creative application of the concepts applied to the project were never publically discussed or debated. Students made their selections from the numerous boundaries they collectively debated and defined.

Student Journals and Selection Criteria
Students were also asked to journal for each project the ways in which the concepts were applied. After all of the students presented their projects, the students were asked to select the four best projects in the class as earlier defined. This was reinforced in the project description sheet where students explicitly told that, "The more creative and original the design solution, the higher the grade."

Hypothesis
Theory of Boundaries
The primary difference between professional peers and the general public in determining creativity is that their training and experience allows them to implicitly know where the boundaries are and what is appropriate in complex multidimensional and multivariable problem solving. If we remove appropriateness of function as a variable, have a problem with no socio-cultural or economic dimension and if the student, who in this case resembles the general public because of their lack of formal training and experience, can collectively establish boundaries based on characteristics of concepts; then their findings should correlate with those of a well trained and experienced architect. Recognizing creativity here is a factor of boundary setting that results in a particular or local definition of creativity that can be applied to assessing the problem solution as the major determinant.

Diagram 2



This hypothesis is based on a more general idea that creativity occurs beyond the norm but not past the inappropriate boundaries in problem solving.[9] We understand this as an outside the box solution although the term is paradoxical.[10] Without the context of a problem with its own level of definition and constrained and unconstrained variables, the definition of creativity itself remains an implicit idea and not an explicit one. Once the problem is applied, boundaries of creativity are formed but not entirely set. Diagram 2 presents a graphic representation of this idea although it lacks a multidimensional complexity of the phenomenon. The types of variables, techniques and methodologies also contribute to creating additional boundaries in which the problem solution is allowed to exist in. Each of these boundaries can be thought of as being mapped by plotting characteristics as points with each having its own internal boundaries.

Results

Descriptive Findings

The raw data showing the student initials, the total student peer votes received and the instructor grades is presented in the Appendix, Tables 3-6. The data was then reordered based on the total student votes received from high to low and then the corresponding instructor letter grade, translated to a grade point average (GPA) equivalent and then scaled, using a scale factor, where the high grade equaled the highest total student peer votes received. The scale factor is based on setting the grade of C to a value of zero and scaling the maximum grade of A to the maximum total student votes received. Setting the value of C to zero was based on the fact that less than five percent of the time students selected a project with a grade of C or less with a maximum of four votes received in one case. The equation for determining the scale factor (F) was F = (GPA (max.) - 2) x PV (max) where PV is the peer votes received. The scaled grade, located under the scale factor F, is equal to the GPA x F. Each of the total student peer votes received and scaled grades were graphed, see Appendix Graphs 3-6.

Table 1 below presents the correlations among the total peer votes and scaled instructor grades for each year, project number and section, if more than one, where X = PV (Total Student Peer Votes Received) and Y = Scale Grade = GPA x F. The formula for generating the Correlation Coefficient (Correl) is show below; as Correl (X,Y). Next to the Correl is the Number of student projects reviewed. Table 2 presents the Descriptive Statistics for all Correl values; the mean is 0.791 and the median is 0.806. There is some degree of interpretation when using correlation coefficients in a social statistic, rather than a physical science, but as the numbers approach 1.0 the degree of correlation increases; values below 0.5 are problematic. Graph 2 illustrates the one low Correl value on Project 1 in Fall 2006 of .0535 as the lone exception to the norm.

Graph 1 presents the Correl and the number of student projects/peer reviewers. It shows that when the number of projects is less, the correlation between total student peer votes and instructor grades increases. This is not surprising since the less choice students have the less dispersion of total votes will occur.

[9] It is eluded here that inappropriateness in many problem solutions is connected to functional, socio-cultural or economic deficits and experience plays a major role in determining where these boundaries lie.

[10] The problem of thinking “outside the box” is it promotes unconventional thinking and solutions which may be inappropriate and therefore also outside the box. This paper argues that the correct analogy is really two boxes and not just one where creativity occurs outside one but inside the other.

Table 1: Correlation Coefficient (Correl) of Total Student Peer Votes and Scaled Instructor Grades

Term/Year and Section	Project 1		Project 2		Project 3	
	Correl	N	Correl	N	Correl	N
Fall 2005	0.6989103*	23	0.76094	23	0.776885	23
Fall 2006	0.534901*	23	0.733586	25	0.806266	25
Fall 2007	0.771984	24	0.874453	25	0.75104	25
Fall 2008 S1	0.88528	18	0.837935	17	0.892474	16
Fall 2008 S2	0.839343	13	0.874774	13	0.828375	11

Out of the fifteen sample groups only two have Correl values between .5 and .7 (*** shown in red**), the rest are above .73. Each Correl is also comparatively graphed in the Appendix Graphs A3-A6. The highest Correl is .89. Since the Correlation Coefficient is highly interpretative, the Mann–Whitney *U* test will be used as a robust statistical method to determine if the sample groups are significantly different.

The equation for the correlation coefficient (Correl) is:

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

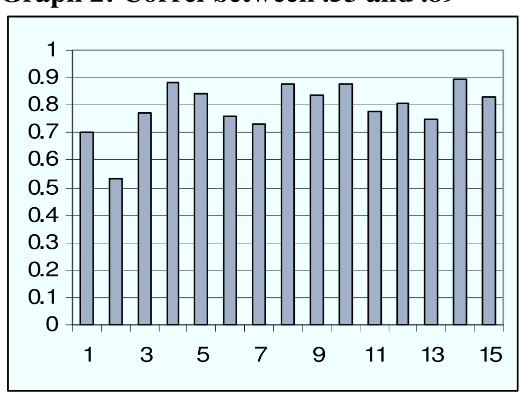
where ***X*** and ***Y*** are the sample means AVERAGE(array1) and AVERAGE(array2).

X = PV (Total Student Peer Votes Received)
Y = Grade Scale factor GPA x F
F = (GPA (max.) - 2) x PV (max)
N = Sample size

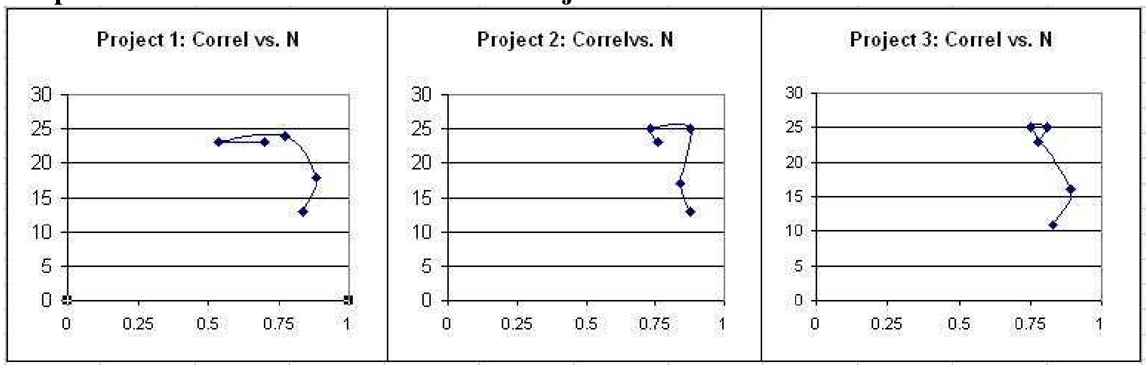
Table 2: Descriptive Statistics for Correl

Mean	0.791143
Standard Error	0.023881
Median	0.806266
Mode	N/A
Standard Deviation	0.09249
Sample Variance	0.008554
Skewness	-1.5203
Range	0.357573
Minimum	0.534901
Maximum	0.892474
Count	15

Graph 2: Correl between .53 and .89



Graph 1: Correl and Number of Student Projects/Peer Reviewers



Non-Parametric test

The paper will use the Mann–Whitney–Wilcoxon rank-sum test, (herein called the Mann–Whitney *U* test) for assessing whether the two samples, total student peer votes and instructor grades, are drawn from a single distribution and therefore that their probability distributions are equal (Conover 1980).

The Mann Whitney U statistic is defined as:

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n_1+1}^{n2} R_i$$

Where samples of size n1 and n2 are pooled and Ri are the ranks. U is the number of times observations in one sample precede observations in the other sample in the ranking.

The P value or calculated probability is the estimated probability of rejecting the **null hypothesis (Ho)** of the two samples when that hypothesis is true, "no difference." The choice of significance level at which you reject H_0 is arbitrarily set at 5% (less than 1 in 20 chance of being wrong). The two samples are not significantly different when P >= 0.05 for the two-tailed test. The U and P values are shown below in Table 1A.

Table 1A: Mann–Whitney *U* test calculations where the two samples are not significantly different (P >= 0.05, two-tailed test); *significantly different samples are shown in red.

Term/Year and Section	Project 1		Project 2		Project 3	
	U	P (two-tailed)	U	P (two-tailed)	U	P (two-tailed)
Fall 2005	361	0.03444*	336	0.119402	310	0.324678
Fall 2006	362	0.031908*	395	0.112624	405	0.0741
Fall 2007	366	0.111034	395	0.112042	426	0.027358*
Fall 2008 S1	194	0.323896	157	0.682496	154	0.342408
Fall 2008 S2	108	0.242784	101	0.418412	74.5	0.365308

Out of the fifteen sample groups only three are significantly different and correlate to the first, second and fourth lowest Corell values. Twelve of the sample groups are not significantly different. There are two different reasons that explain why these three sample groups are significantly different. Project 1 in the Fall 2005 and Fall 2006 was the very first design problem students were given along with a new journal selection process and a large class size. In Project 3 in Fall 2007, the instructor gave out a abnormally number of higher grades on average in relation to the other samples while the students selected the same number of best projects.

Discussion

Pedagogical Tools

The results obtained herein have important implications for assessing student projects based on the correlation between total student peer votes and instructor grades. One of these implications is for a quantitative *test* for subjective instructor grades. Developing a system of checks and balances to a seeming subjective faculty assessment decision has a perceived element of psychological fairness for students. Two, having students as part of a larger assessment process has a real pedagogical value for faculty because it gives insight into what students are thinking and their collective value system. Three, making students aware of what the assessment criteria is by having them peer review each other has the effect of empowering them in the learning process itself. They will know which projects are the best in the class and where their project lies in relation to their peers.

Differences between Student and Instructor Assessment

One of the difficulties in trying to correlate the total student peer votes and instructor grades is that each has its own strategic goals. Students were limited to selecting the four best projects in the class and the instructor has no artificial boundaries set on grades. The maximum number of "A" grades that was given out on any one project was nine and the minimum was four. The instructor also had additional motives for grade distributions that include factors such as classroom morale, or reward and encouragement for significant improvement, that probably accounted for a half letter grade play in the assignment of grades. Students on the other hand may have collective favorites or may have wanted to try to get the selection right to win favor with the instructor, etc. There were also a very small minority of students who sometimes failed to cast the maximum of four votes, say only three projects selected; there were one or two instances where a student failed to cast any vote in their journal at all.

Convergent Selection and Thinking

One of the interesting findings here is the ability of a group to collectively agree on the most successful projects without actually discussing the summation of the boundary characteristics. Defining the best projects here is a convergent form of thinking without the social constraints that occurs in group brainstorming; this is opposite of what we consider to be the more creative divergent form of thinking.[11] Convergent thinking based on setting boundary characteristics to narrow the solution. Here it acts as the arbiter for selecting creativity; not generating it.[12]

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[11] Divergent thinking is typically considered to be an important precursor to creativity because creative solutions are unique and original in nature and not commonly arrived at (Amabile, 1983).

[12] Some theorists such as Larey & Paulus (1999) and Mobley, Doares & Mumford (1992) have focused on measuring convergent thinking and creativity using category tests but I would suggested that what they are really

Experience and Selection
Another important finding here is that experience apparently played little role in the selection of the best projects. All of the highest total student peer vote projects received an "A" grade from the instructor. There were three cases over the entire time where the instructor gave a project an "A" grade where the project received no student peer votes. This difference here can probably be accounted in how the instructor individually weighted some qualities differently than the students collectively.[13] Another reason that experience probably played little role in the selection of the best projects was the type of creativity used in the problem solving here. Creativity that involves simple geometric patterns and three dimensional relationships is different than that which involves complex cultural associations and social connections and does not require a high degree of experience.[14]

Inherent Interpretation Dilemmas
Any paper on creativity has inherent problems in defining and measuring this phenomenon. The strategy of this paper is to use a process that defines characteristic and boundaries of creativity, similar to the way it would be done in any social system that tries to select problem solutions with these qualities; architectural competitions, creative writing competitions, academic papers selections, etc. In this respect, there is a parallel consistency here. There are many questions that the reader will be challenged to face: How much creativity is in this project and how can we isolate creativity as a singular variable that can be better correlated? What are the students and instructor really interpreting in terms of best, is creativity the major component? How much were the instructor's grades influenced by the student peer critique comments? How does one interpret the correlation results without context to other data or a control group and is this methodological approach correct? In this defense, this paper is based on correlations of observations on creativity and not in directly measuring creativity itself. It used the Mann–Whitney *U* test to verify the correlations in lieu of having a contextual comparison. It is not as concerned as to whether or not the collective student peer votes or the instructor grades are accurate in their selection of creativity, only whether they *see* the same phenomenon in determining the *best* projects. One could argue that the characteristics are subjectively selected but if this model is correct then the results can be replicated using new other characteristics to define boundaries.

Future Experiments
Unlike most papers, this paper explains a phenomenon behind the data collected versus developing a theory and test to prove it. The next step will be to establish a control and experimental group. The control group will be one that does not use the critique process to set boundaries and the experimental group will be one that does. It will measure whether the control group and experimental groups correlate with each other or the instructor's grades. If it does, it would indicate that there is something about the student peer critique process that allows them to

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measuring is convergent correlations between groups of experts who assess creativity and not necessarily creativity itself.

[13] No explicit weighted formula was given for determining the best projects.

[14] Some creative problem solving requires just abstract recognition and uniqueness of a solution whereas other creative problem solving requires a dimension of cultural appropriateness in addition to abstract recognition and uniqueness to the solution.

collectively *see* the best projects in the class. An additional test would be for the instructor to have the project independently graded by an instructor outside the student peer critique process to determine what, if any, effect the students have on the instructor.

Conclusion

What did we learn here as educators who promote creativity as a valued commodity in design problem solving? Once we promote it, we are faced with the dilemma of trying to assess a phenomenon that we cannot neither authoritatively define nor measure but we know exists when we *see*. Based on this premise, this paper puts forth a process for correlating two types of assessment: collective total student peer votes and instructor grades. It relies on a rigorous critique process based on collective boundary setting. Through this process, it is possible to agree on this phenomenon. It leads us to further investigate what additional analytical tools can be developed to assess creativity and to develop new methods for correlating the results. Most importantly, it challenges us to reflect on how we come to determine grades if the students are unable to collectively concur with our assessment process. The concluding question asks, is this proposed model correct and if so, does it have the necessary pedagogical components for more mature student centered higher learning in the classroom?

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Appendix: A1

ARCHITECTURAL DESIGN I
Project 1: The Creation of Form

In the beginning God created the heaven and the earth.
And the earth was without form, and void;...
And God said, Let there be light: and there was light (and light gave form).
Genesis, Chapter 1

Theory:
Form is one of the basic building blocks in architecture. We rely on our universal recognition of basic shapes and forms to allow the viewer to understand the architect's intent. Three dimensional variations of the circle, triangle and square undergo additive and subtractive transformations and interactions to reflect program and contextual needs. Designers also think of form in terms of its mass (solid) and void (volumetric) properties. This project will explore the relationship of how form work together to clearly express the designer's intent and understanding.

Methodology & Analysis:
Since no formal methodology is given to explore these design issues, the emphasis will be on the analysis of the projects. Students will introduce their individual project (usually 3-5 projects at a time) and then the class will comparatively analyze them. Each student will keep a journal and record various aspects of each project. At the end of the entire critique, place a check next to what you think are the four (4) best projects in terms of the most successful interpretation and creative application of the concepts (do not share your opinion with any other students). Students will be asked in groups of three to evaluate the projects on the following criteria, usually most and least. Additional comments may come from the gallery at large but not from the designers whose projects are being critiqued.

Project 1 (Form) will be critiqued on the following concepts/criteria:
1. Clarity of form (select the most and least).
2. Additive and subtractive (select the most additive and subtractive project)
3. Interaction of form (select the most and the least)
4. Mass and void (select the most mass and void oriented project)
5. Overall set of rules or game plan the designer used (select the most and least).

Rules/Constraints for making the forms:
1. No symmetrical projects
2. No "forts" or 2-D projects

Material:
1 - layer of 15" x 15" x 1/4" foam core
2 - 16 oz. boxes of large sugar cubes
1 - hot glue gun

Assignment:
Using the principles of form, as outlined in the class lecture, construct one or more of the following: an additive form, a subtractive form, and a form that is both additive and subtractive. Each of the forms must be related to one another. They may not be separate, independent objects, on a plane; rather they must interact, interlock and create spaces and objects. The more creative and original the design solution, the higher the grade. Projects shall have a minimum of 9 forms.

Procedure:
A series of three dimensional constructions shall made exploring the design principles of form using the sugar cubes. No glue shall be used during this exploration stage. After several design investigations, the student will glue together his or her final design solution onto the 15" x 15" base.

Project Due Date: One week from date given.

Bibliography/Reading: Francis Ching, Architecture: Form, Space & Order, pp.:33-58.

Appendix: A2

ARCHITECTURAL DESIGN I
Project 2: Volume and Space

Theory:
Space and Volume are one of the basic building blocks in architecture. We rely on our universal recognition of basic spaces and volumes to allow the viewer to understand the architect's intent. Three dimensional variations of the circle, triangle and square undergo interactions to reflect program and contextual needs. There are 3 spatial relationships: (a) space within a space; (b) space overlapping a space; (c) space abutting a space. Students will also explore the issue of economy in design. Dowels are one of the most minimal architectural elements for creating spaces and volumes. One can make a square space with four dowels and one could use a thousand. What is the minimum one needs to express clarity? This project will explore the relationship of how spaces and volumes work together to clearly express the designer's intent and understanding.

Methodology & Analysis:
Since no formal methodology is given to explore these design issues, the emphasis will be on the analysis of the projects. Students will introduce their individual project (usually 3-5 projects at a time) and then the class will comparatively analyze them. Each student will keep a journal and record various aspects of each project. At the end of the entire critique, place a check next to what you think are the four (4) best projects in terms of the most successful interpretation and creative application of the concepts (do not share your opinion with any other students). Students will be asked in groups of three to evaluate the projects on the following criteria, usually most and least. Additional comments may come from the gallery at large but not from the designers whose projects are being critiqued.

<u>Project 2 (Volume and Space) will be critiqued on the following concepts/criteria:</u>
1. Clearly defined spaces
2. Economy of elements to make the spaces
3. Integration of spaces; having 3 spatial relationships:
   (a) space within a space; (b) space overlapping a space; (c) space abutting a space.
4. Rules for using the dowels
5. Overall pattern or idea

<u>Rules/Constraints for making the spaces with the dowels:</u>
1. Must have a minimum of 9 spaces
2. All must be integrated
3. All dowels must be vertical
4. Do not draw the spaces on the foam core
5. No symmetrical projects

<u>Material:</u>
1 - layer of 15" x 15" x 1/4" foam core
2 - 1/2" diameter x 3'-0" wood dowels
2 - 1/4" diameter x 3'-0" wood dowels
2 - 1/8" diameter x 3'-0" wood dowels
1 - hot glue gun.

<u>Assignment:</u>
Using the principles of making space and volume, as outlined in the class lecture, construct one or more of the following: an additive space, a subtractive space, a space that is (a) space within a space; (b) space overlapping a space; (c) space abutting a space. All three primary shaped volumes must be used. Each of the volumes and spaces must be related to one another. They may not be separate, independent places; on a plane rather they must interact and create a series of spaces and places. The more creative and original the design solution, the higher the grade. Projects shall have a minimum of 9 spaces and volumes.

<u>Preparation:</u>
Cut all of the 3'-0" dowels into 1'-0" lengths. Then divide all 1'-0" lengths into 2", 4" and 6" lengths. Each 3'-0"

dowel should yield six 2" long pieces, three 4" long pieces or two 6" long pieces of a particular diameter dowel.

Procedure:
A series of three dimensional constructions shall made exploring the design principles of volume and space using the dowels. Create several small prototypes during the exploration stage; you may use tape or small amounts of hot glue during this stage to hold the dowels together. The majority of the dowels must be placed vertically, but some dowels may be placed horizontally and diagonally. No post and beam construction is allowed. After several design investigations, the student will glue together their final design solution onto the 15" x 15" base.

Project Due Date: One week from date given.

Bibliography/Reading: Francis Ching, Architecture: Form, Space & Order, pp.: 121-129

Appendix: A3

ARCHITECTURAL DESIGN I

Project 3: Defining Space with Planes

"Architecture is the thoughtful making of space.
The continual renewal of architecture comes from the changing concepts of space."
Louis I Kahn, 1957

Theory:
Planes are one of simplest architectural elements that can create spaces. Spaces had three dimensional properties that include: length, width and height. We rely on our universal recognition of basic spaces and volumes to allow the viewer to understand the architect's intent. Three dimensional variations of the square undergo interactions to reflect program and contextual needs. There are 3 spatial relationships: (a) space within a space; (b) space overlapping a space; (c) space abutting a space. Students will also explore the issue of economy in design. One can make a square space with four walls, a roof and floor slab and one could explore other more creative ways of defining a space. What is the minimum one needs to express clarity? This project will explore the relationship of how spaces and volumes work together to clearly express the designer's intent and understanding.

Methodology & Analysis:
Since no formal methodology is given to explore these design issues, the emphasis will be on the analysis of the projects. Students will introduce their individual project (usually 3-5 projects at a time) and then the class will comparatively analyze them. Each student will keep a journal and record various aspects of each project. At the end of the entire critique, place a check next to what you think are the four (4) best projects in terms of the most successful interpretation and creative application of the concepts (do not share your opinion with any other students). Students will be asked in groups of three to evaluated the projects on the following criteria, usually most and least. Additional comments may come from the gallery at large but not from the designers whose projects are being critiqued.

<u>Project 3 (Planes and Spaces) will be critiqued on the following concepts/criteria:</u>
1. Clearly defined spaces
2. Economy of elements to make the as many spaces
3. Integration of spaces; having 3 spatial relationships: (a) space within a space; (b) space overlapping a space; (c) space abutting a space.
4. Three clear spatial size definitions (relative sizes vs. the use of shapes in the last project)
5. Rules for using the planes
6. Overall pattern or idea

<u>Rules/Constraints for making the spaces with the planes:</u>
1. Planes may not abut end to end; "T" and "L" connections.
2. The entire project must be a min. of 15" high (think of this as a three dimensional chess game).
3. All spaces must flow (no 4 wall dead ends)
4. No layer caking of planes are allowed (like stories in a building)
5. Have a min. of 10 spaces and use the majority of planes
6. No symmetrical projects

<u>Material:</u>
1 - layer of 15" x 15" x 1/4" foam core
As required - white mat board
As required - black mat board
1 - hot glue gun

<u>Assignment:</u>
Using the principles of defining space with vertical planes, as outlined in the class lecture, construct one or more spatial volumes using: a vertical plane, an "L" shaped plane, parallel planes, a "U" shaped plane, and a space defined by 4 sides. In addition, the following spatial constructions shall include small objects constructed from the cardboard that create having one or more of the following 3 spatial relationships: (a) space within a space; (b) space overlapping a space; (c) space abutting a space. Each of the spaces should be related to one another as either a

sequence of spaces. The more creative and original the design solution, the higher the grade.

Procedure:
Cut the mat board into pre-defined shapes as noted by the instructor. A series of three dimensional constructions shall made exploring the design principles of space. These constructions shall be prototypes. After several design investigations, the student will glue together his or her final design solution onto the 15" x 15" base.

Project Due Date: One week from date given.

Bibliography/Reading: Francis Ching, Architecture: Form, Space & Order, pp.: 99-120, 130-157, 166-169

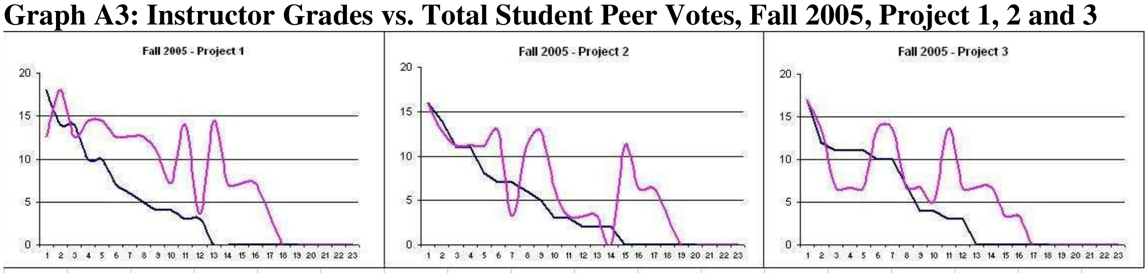
Appendix:

Table A3: Fall 2005 - Raw Data, Ordered Data, GPA equivalent and Scale Factor

Architectural Design I								Ordered by Peer Vote (PV) & Grade (high to low)													
Fall 2005 (Raw Data)								Project 1					Project 2					Project 3			
Name	PV.1	Gr.1	PV.2	Gr.2	PV.3	Gr.3		PV 1	Gr.1	GPA	F=7.2		PV 2	Gr. 2	GPA	F=6.4		PV 3	Gr. 3	GPA	F=6.8
A, B	5	A-	16	A+	10	A		18	A-	3.75	12.6		16	A+	4.5	16		17	A+	4.5	17
A, A	3	A	3	C+	0	D		14	A+	4.5	18		14	A	4	12.8		12	A	4	13.6
B, E	10	A	7	A	3	B		14	A-	3.75	12.6		11	A-	3.75	11.2		11	B	3	6.8
C, C	0	C	11	A-	0	C-		10	A	4	14.4		11	A-	3.75	11.2		11	B	3	6.8
C, J	14	A+	5	A	11	B		10	A	4	14.4		8	A-	3.75	11.2		11	B	3	6.8
G, L	7	A-	3	B	7	B		7	A-	3.75	12.6		7	A	4	12.8		10	A	4	13.6
H, T	4	B+	0	C	0	B		6	A-	3.75	12.6		7	C+	2.5	3.2		10	A	4	13.6
H, W	3	C+	6	A-	3	A		5	A-	3.75	12.6		6	A-	3.75	11.2		7	B	3	6.8
J, A	0	D	0	D+	0	C+		4	B+	3.5	10.8		5	A	4	12.8		4	B	3	6.8
J, D	0	C	0	B	0	C+		4	B	3	7.2		3	B	3	6.4		4	C-	2.75	5.1
K, A	4	B	2	C+	0	D		3	A	4	14		3	C+	2.5	3.2		3	A	4	13.6
K, A	6	A-	2	C+	11	B		3	C+	2.5	3.6		2	C+	2.5	3.2		3	B	3	6.8
L, S	18	A-	0	C	0	C		0	A	4	14.4		2	C+	2.5	3.2		0	B	3	6.8
L, R	14	A-	14	A	10	A		0	B	3	7.2		2	C	2	0		0	B	3	6.8
M, D	0	D	8	A-	4	C-		0	B	3	7.2		0	A-	3.75	11.2		0	C+	2.5	3.4
M, J	0	C	0	C	4	B		0	B	3	7.2		0	B	3	6.4		0	C+	2.5	3.4
M, J	10	A	0	B	17	A+		0	C+	2.5	3.6		0	B	3	6.4		0	C	2	0
O, R	0	C+	0	A-	11	B		0	C	2	0		0	C+	2.5	3.2		0	C	2	0
R, B	0	C	11	A-	12	A		0	C	2	0		0	C	2	0		0	C	2	0
R, R	0	B	2	C	0	D		0	C	2	0		0	C	2	0		0	C-	1.75	0
T, J	0	A	7	C+	0	B		0	C	2	0		0	C	2	0		0	D	1	0
V, A	0	B	0	C+	0	C		0	D	1	0		0	C	2	0		0	D	1	0
W, J	0	B	0	C	0	C		0	D	1	0		0	D+	1.5	0		0	D	1	0
Note: had to receive 2 or more votes to count																					

PV = Total Student Peer Votes Received
Gr. = Student Grade Received by Instructor
GPA = Grade Point Average
F = (GPA (max.) - 2) x PV (max)
X = PV (Total Student Peer Votes Received)
Y = Scale Grade = GPA x F

Graph A3: Instructor Grades vs. Total Student Peer Votes, Fall 2005, Project 1, 2 and 3



Correl: 0.6989103 | Correl: 0.76094 | Correl: 0.776885

Red line = Instructor Grades; Black line = Total Student Peer Votes

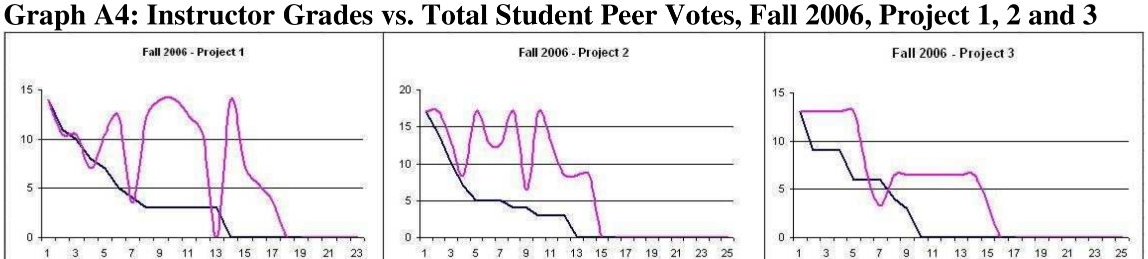
Appendix:

Table A4: Fall 2006 - Raw Data, Ordered Data, GPA equivalent and Scale Factor

Architectural Design I							Ordered by Peer Vote (PV) & Grade (high to low)											
Fall 2006 (Raw Data)							Project 1				Project 2				Project 3			
Name	PV.1	Gr.1	PV.2	Gr.2	PV.3	Gr.3	PV 1	Gr.1	GPA	F=7	PV 2	Gr. 2	GPA	F=8.5	PV 3	Gr. 3	GPA	F=6.5
A, J	3	A-	7	B	0	C-	14	A	4	14	17	A	4	17	13	A	4	13
B, R	0	F	0	C	0	B	11	B+	3.5	10.5	14	A	4	17	9	A	4	13
B, A	0	C+	0	B	0	D+	10	B+	3.5	10.5	10	B+	3.5	12.8	9	A	4	13
C, S	14	A	0	D	0	B	8	B	3	7	7	B	3	8.5	9	A	4	13
C, P	0	D-	0	C	3	B	7	B+	3.5	10.5	5	A	4	17	6	A	4	13
D, N	0	C	0	F	0	D+	5	A-	3.75	12.3	5	B+	3.5	12.8	6	B	3	6.5
E, R	3	A	3	A	6	B	4	C+	2.5	3.5	5	B+	3.5	12.8	6	C+	2.5	3.3
F, D	3	C	17	A	9	A	3	A-	3.75	12.3	4	A	4	17	4	B	3	6.5
G, E	abs.	0/F	0	C	0	C-	3	A	4	14	4	B-	2.75	6.4	3	B	3	6.5
G, K	11	B+	0	D	0	B	3	A	4	14	3	A	4	17	0	B	3	6.5
H, B	0	D	0	C	0	C	3	A-	3.75	12.3	3	B+	3.5	12.8	0	B	3	6.5
K, C	5	A-	5	B+	0	C	3	B+	3.5	10.5	3	B	3	8.5	0	B	3	6.5
K, R	3	A-	0	B	6	A	3	C	2	0	0	B	3	8.5	0	B	3	6.5
L, S	0	B	4	A	13	A	0	A	4	14	0	B	3	8.5	0	B	3	6.5
M, D	abs.	0/F	3	B	4	B	0	B	3	7	0	C	2	0	0	C+	2.5	3.3
M, H	10	B+	5	A	9	A	0	B-	2.75	5.3	0	C	2	0	0	C	2	0
M, P	0	C	14	A	0	B	0	C+	2.5	3.5	0	C	2	0	0	C	2	0
M, T	3	A	3	B+	0	C	0	C	2	0	0	C	2	0	0	C	2	0
P, M	3	B+	0	D	0	C	0	C	2	0	0	C	2	0	0	C	2	0
S, V	0	B-	0	C	0	C	0	D	1	0	0	D+	1.5	0	0	C	2	0
S, F	0	A	10	B+	0	C-	0	D	1	0	0	D	1	0	0	C-	1.75	0
S, M	0	D	4	B-	0	B	0	D-	0.75	0	0	D	1	0	0	C-	1.75	0
S, W	7	B+	0	D+	9	A	0	F	0	0	0	D	1	0	0	C-	1.75	0
T, R	8	B	5	B+	6	C+	abs.	0/F			0	D	1	0	0	D+	1.5	0
T, G	4	C+	0	D	0	C+	abs.	0/F			0	F	0	0	0	D+	1.5	0
Note: had to receive 3 or more votes to count																		

PV = Total Student Peer Votes Received
Gr. = Student Grade Received by Instructor
GPA = Grade Point Average
F = (GPA (max.) - 2) x PV (max)
X = PV (Total Student Peer Votes Received)
Y = Scale Grade = GPA x F

Graph A4: Instructor Grades vs. Total Student Peer Votes, Fall 2006, Project 1, 2 and 3



Correl: 0.534901 Correl: 0.733586 Correl: 0.806266

Red line = Instructor Grades; Black line = Total Student Peer Votes

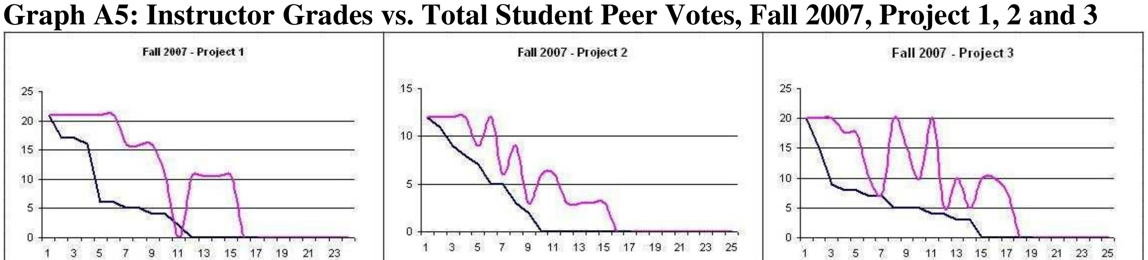
Appendix:

Table A5: Fall 2007 - Raw Data, Ordered Data, GPA equivalent and Scale Factor

Architectural Design I							Ordered by Peer Vote (PV) & Grade (high to low)											
Fall 2007 (Raw Data)							Project 1				Project 2				Project 3			
Name	PV.1	Gr.1	PV.2	Gr.2	PV.3	Gr.3	PV 1	Gr.1	GPA	F=10.5	PV 2	Gr. 2	GPA	F=6	PV 3	Gr. 3	GPA	F=10
C, A	5	B+	0	C	15	A	21	A	4	21	12	A	4	12	20	A	4	20
D, J	21	A	12	A	3	C+	17	A	4	21	11	A	4	12	15	A	4	20
D, I	2	C	0	C+	3	B	17	A	4	21	9	A	4	12	9	A	4	20
F, D	4	B+	0	C+	4	C+	16	A	4	21	8	A	4	12	8	A-	3.75	17.5
F, W	abs.	0/F	0	F	0	C	6	A	4	21	7	B+	3.5	9	8	A-	3.75	17.5
G, A	0	B	5	A	5	B+	6	A	4	21	5	A	4	12	7	B	3	10
H, R	0	F+	0	C	0	C-	5	B+	3.5	15.8	5	B	3	6	7	B-	2.75	7.5
K, D	0	D+	8	A	0	C	5	B+	3.5	15.8	3	B+	3.5	9	5	A	4	20
L, S	0	D	3	B+	8	A-	4	B+	3.5	15.8	2	C+	2.5	3	5	B+	3.5	15
L, W	0	C	0	D	5	B	4	B	3	10.5	0	B	3	6	5	B	3	10
L, D	0	D	0	C	0	D+	2	C	2	0	0	B	3	6	4	A	4	20
M, L	0	C	2	C+	0	D+	0	B	3	10.5	0	C+	2.5	3	4	C+	2.5	5
M, J	16	A	11	A	4	A	0	B	3	10.5	0	C+	2.5	3	3	B	3	10
M, B	0	D	0	C	7	B-	0	B	3	10.5	0	C+	2.5	3	3	C+	2.5	5
P, Z	6	A	0	B	0	C	0	B	3	10.5	0	C+	2.5	3	0	B	3	10
P, B	0	D	0	B	0	C-	0	C	2	0	0	C	2	0	0	B	3	10
R, J	0	B	0	C	0	C	0	C	2	0	0	C	2	0	0	B-	2.75	7.5
R, A	17	A	7	B+	5	A	0	C	2	0	0	C	2	0	0	C	2	0
R, B	0	B	0	C	7	B	0	D+	1.5	0	0	C	2	0	0	C	2	0
S, S	0	B	0	C+	0	B	0	D	1	0	0	C	2	0	0	C	2	0
S, M	5	B+	0	C	9	A-	0	D	1	0	0	C	2	0	0	C	2	0
S, S	4	B	0	C+	0	B-	0	D	1	0	0	C	2	0	0	C-	1.75	0
S, J	6	A	0	C	8	A	0	D	1	0	0	C	2	0	0	C-	1.75	0
T, B	17	A	5	B	20	A	0	F+	0.5	0	0	D	1	0	0	D+	1.5	0
V, J	0	C	9	A	0	B	abs.	0/F			0	F	0	0	0	D+	1.5	0
Note: had to receive 3 or more votes to count																		

PV = Total Student Peer Votes Received
Gr. = Student Grade Received by Instructor
GPA = Grade Point Average
F = (GPA (max.) - 2) x PV (max)
X = PV (Total Student Peer Votes Received)
Y = Scale Grade = GPA x F

Graph A5: Instructor Grades vs. Total Student Peer Votes, Fall 2007, Project 1, 2 and 3



Correl:	0.771984	Correl:	0.874453	Correl:	0.75104

Red line = Instructor Grades; Black line = Total Student Peer Votes

Appendix:

Table A6: Fall 2008 - Raw Data, Ordered Data, GPA equivalent and Scale Factor

Architectural Design I																		
Fall 2008 (Raw Data)							Ordered by Peer Vote (PV) & Grade (high to low)											
Section 1							Project 1				Project 2				Project 3			
Name	PV.1	Gr.1	PV. 2	Gr. 2	PV. 3	Gr.3	PV 1	Gr.1	GPA	F=7	PV 2	Gr. 2	GPA	F=5.5	PV 3	Gr. 3	GPA	F=6.5
B, M	0	C	0	C+	0	C	14	A	4	14	11	A	4	11	13	A	4	13
B, E	9	A	8	B	9	A	12	A	4	14	10	A-	3.75	9.6	12	A-	3.75	11.4
B, K	0	B	0	F	0	C	11	B+	3.5	10.5	8	B	3	5.5	10	A	4	13
C, L	7	A-	0	D+ r	0	C-	9	A	4	14	8	B+	3.5	8.3	9	A	4	13
D, A	0	C	10	A-	10	A	7	A-	3.75	12.3	6	B+ r	3.5	8.3	9	A	4	13
J, P	0	C	abs.	0/F	0	C-	6	A	4	14	6	A	4	11	3	A	4	13
K, D	0	B-	0	D-	0	C+	0	B	3	7	4	A	4	11	0	C+	2.5	3.3
L, R	14	A	6	B+ r	abs.	med	0	B-	2.75	5.3	4	C- r	1.75	0	0	C+	2.5	3.3
L, E	0	D+	0	C- r	0	C	0	C+	2.5	3.5	3	B	3	5.5	0	C	2	0
L, M	0	C+	6	A	abs.	0/F	0	C	2	0	0	C+	2.5	2.3	0	C	2	0
M, E	0	C–	0	C	3	A	0	C	2	0	0	C	2	0	0	C	2	0
M, P.	0	C	8	B+	12	A-	0	C	2	0	0	C	2	0	0	C	2	0
P, M	0	C	0	C	0	C+	0	C	2	0	0	C- r	1.75	0	0	C	2	0
P, E	0	C	0	D+ r	0	C	0	C	2	0	0	D+ r	1.5	0	0	C	2	0
Q, J	0	C	4	A	9	A	0	C	2	0	0	D+ r	1.5	0	0	C-	1.75	0
R, J	6	A	4	C- r	0	C	0	C	2	0	0	D-	0.75	0	0	C-	1.75	0
S, M	11	B+	3	B	0	C	0	C-	1.75	0	0	F	0	0	abs.	0/F		
S, A	12	A	11	A	13	A	0	D+	1.5	0	abs.	0/F			abs.	med		
Section 2																		
Name	PV.1	Gr.1	PV.2	Gr. 2	PV.3	Gr.3	PV 1	Gr.1	GPA	F=6	PV 2	Gr. 2	GPA	F=5.5	PV 3	Gr. 3	GPA	F=4
A, R	0	C	0	C	0	C+	12	A	4	12	11	A	4	11	8	A	4	8
B, M	12	A	7	A	4	B	10	A	4	12	9	A	4	11	8	A-	3.75	7
D, A	0	B	3	B-	3	A	9	A	4	12	7	A	4	11	7	A-	3.75	7
D, B	8	A	5	A	3	B	8	A	4	12	5	A	4	11	4	B	3	4
G, J	10	A	5	B	8	A-	5	C+	2.5	3	5	B	3	5.5	3	A	4	8
L, E	0	B	3	B	8	A	3	B	3	6	5	C+	2.5	2.8	3	B	3	4
K, J	0	B	0	C+	0	D+	0	B	3	6	3	B	3	5.5	0	B	3	4
M, R	5	C+	11	A	abs.	med	0	B	3	6	3	B	3	5.5	0	C+	2.5	2
P, J	0	C	0	C	0	B	0	B	3	6	3	B-	2.75	4.1	0	C+	2.5	2
R, J	0	C-	0	C	0	C+	0	C	2	0	0	C+	2.5	2.8	0	C	2	0
S, A	0	C	3	B	abs.	legal	0	C	2	0	0	C	2	0	0	D+	1.5	0
T, A	9	A	9	A	0	C	0	C	2	0	0	C	2	0	abs.	med		
Z, A	3	B	5	C+	7	A-	0	C-	1.75	0	0	C	2	0	abs.	legal		
Note: had to receive 3 or more votes to count																		

PV = Total Student Peer Votes Received
Gr. = Student Grade Received by Instructor
GPA = Grade Point Average
F = (GPA (max.) - 2) x PV (max)
X = PV (Total Student Peer Votes Received)
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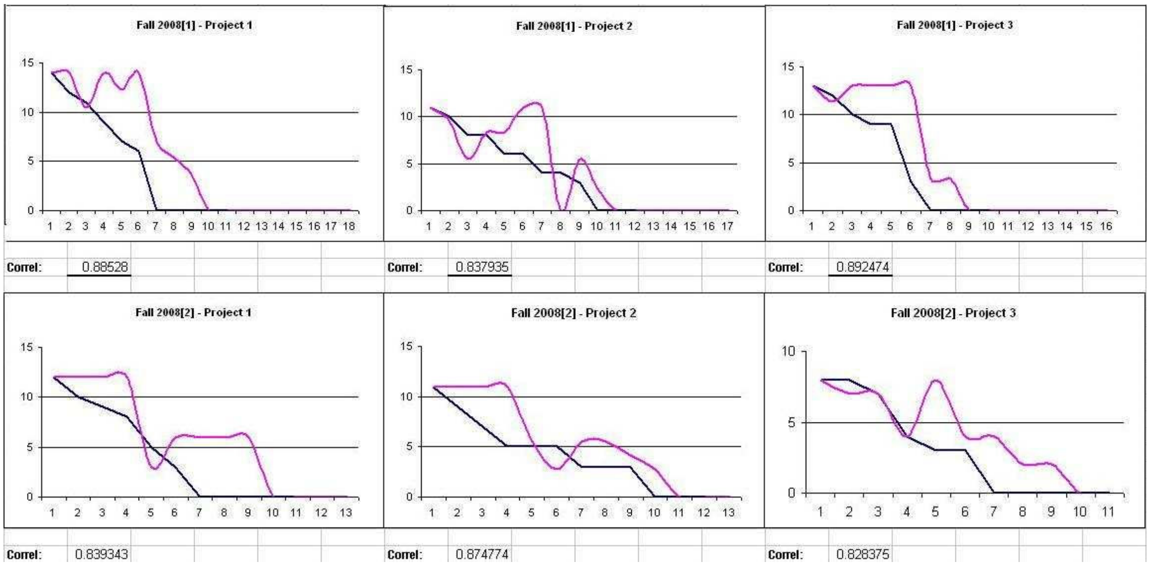
Graph A6: Instructor Grades vs. Total Student Peer Votes, Fall 2008, Project 1, 2 and 3, Section 1 and 2



Red line = Instructor Grades; Black line = Total Student Peer Votes