# Application of the Tri-Square Method in Measuring Changes in Learner Performance: Illustrating Measurement via an Innovative Triostatistics Method and Statistical Procedure

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## Abstract

Measuring the impact of teaching on learning is necessary for discerning the relative effectiveness of different teaching models and methods. Frequently this determination is restricted to hypothesis testing involving the impact of a single variable on a specific performance measure. The common approach is to compare statistics for a treatment group versus a control group with a specified confidence level in order to accept or reject the hypothesis. While this approach may be adequate for clinical studies it is not very practical for a classroom environment where multiple input and output variables are in play. This paper presents the Tri-Square methodology from "Triostatistics" (Osler, 2014) for studying the interplay between a set of three input and three output variables within a culture or system to look for significance. This is a mixed methods model that can accommodate quantitative and/or qualitative variables. The value of mix methods statistical procedures was illustrated in a 2017 Academy of Process Education Workshop entitled, "Measuring The Impact of Teaching and Learning" conducted at the 2017 Academy of Process Education Conference. The power of the method is illustrated using student data from a recent Recovery Course. This paper illustrates the "PE: L2L" experiences, Triostatistics procedures, the PE philosophy, as well as models of the "Taxonomy of Process Education" first presented in the research article entitled, "AMOVA ["Accumulative Manifold Validation Analysis"]: An Advanced Statistical Methodology Designed to Measure and Test the Validity, Reliability, and Overall Efficacy of Inquiry–Based Psychometric Instruments". The authors provided a series of models from the book "Interactive Statistics Methods" (Osler, 2012) to illustrate the various statistical methods during the PE workshop. That data is provided in this narrative to further illustrate utility of the Tri–Squared methodology.

Keywords: Accumulative Manifold Validation Analysis (AMOVA), Conceptual Framework, Learning to Learn (L2L), Process Education: Learning to Learn (PE: L2L), Taxonomy of Process Education (PE), Tri–Squared Analysis, Tri–Squared Test, and Triostatistics.

## Introduction

Providing readily available procedures designed to measure the impact of teaching on learning is the goal and rationale for this paper. To first understand the need for a more adequate approach to teaching and learning measurement one must first comprehend "Process Education: Learning to Learn" (or "PE: L2L"). The next section defines and describes PE: L2L.

## Defining Process Education and Learning to Learn

Process Education, "Learning to Learn", and "Process Education: Learning to Learn

Experience" are each defined in detail to provide clarity:

1. Process Education: According to the "Academy of Process Educators" "Process Education" is defined in the following manner: "A performance-based philosophy of education which integrates many different educational theories, processes, and tools in emphasizing the continuous development of learning skills through the use of assessment principles in order to produce learner self-development." (Process Education, 2017)

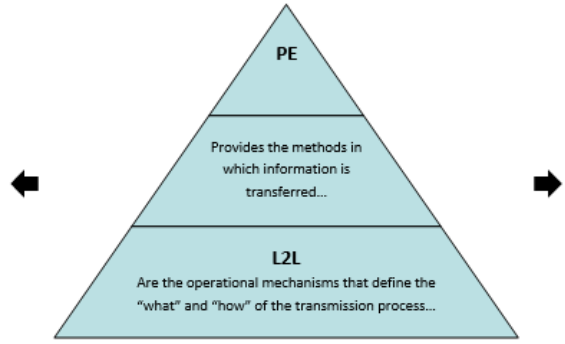
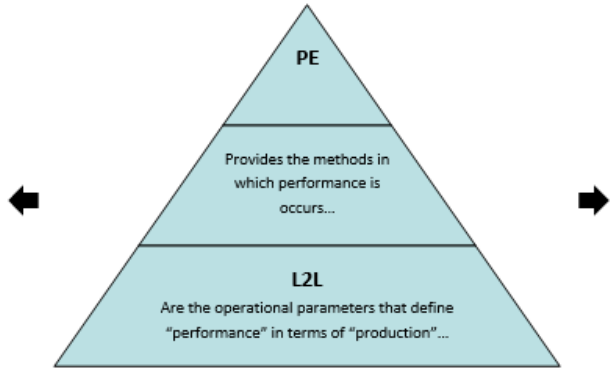
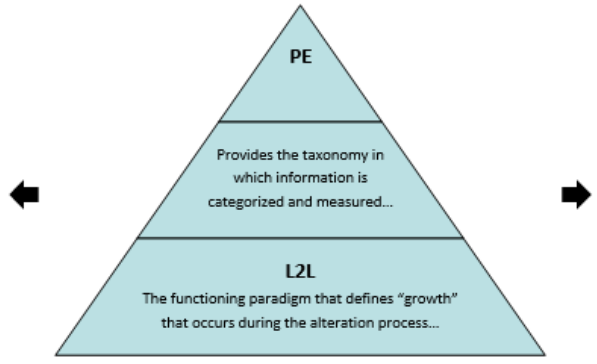
2. Learning to Learn: According to Rožman and Koren in their research work presented at the 2013 International Conference on Management, Knowledge and Learning "Learning to Learn" (or "L2L") is defined as follows:

> Learning to learn is the ability to pursue and persist in learning, to organise one's own learning, including through effective management of time and information, both individually and in groups. This competence includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles in order to learn successfully. This competence means gaining, processing and assimilating new knowledge and skills as well as seeking and making use of guidance. Learning to learn engages learners to build on prior learning and life experiences in order to use and apply knowledge and skills in a variety of contexts: at home, at work, in education and training. Motivation and confidence are crucial to an individual's competence. (Rožman & Koren, 2013, p. 8)

3. "Process Education: Learning to Learn" Experience: The arena of "Process Education: Learning to Learn" is the use of Learning to Learn through the lens of Process Education concepts, models, measures, and strategies. As such, "Process Education: Learning to Learn" or "PE: L2L" is best defined through a constructs model that highlights the exactly how L2L is used in PE between the two areas. Table 1 follows and provides a construct model of PE and L2L with the unifying utilization model and methodology diagram displayed between the two.

Table 1

*The "Process Education: Learning to Learn" Constructs Model*

| **Process Education (PE)** (Apple, Ellis, and Hintze, 2016) | **Defining Learning to Learn (L2L) Practices Utilized in Process Education (PE) in the Process of PE: L2L Experiences** | **Learning to Learn (L2L)** (Kelly, 1999 as cited by Priestley & Humes, 2010) |
|---|---|---|
| 1. Methodologies;<br>2. Learning Process Methodology;<br>3. Reflection/ Meta-Cognition |  | The curriculum as content, and education as transmission (reproduction) |
| 4. Self-Assessment;<br>5. Performance Criteria;<br>6. Self-Growth/ Growth Mindset |  | The curriculum as product, and education as instrumental (production); and |
| 7. Accelerator Model;<br>8. Performance Measures;<br>9. Performance Model; and<br>10. Classification of Learning Skills |  | The curriculum as process, and education as development (transformation). |

Summary of Table 1**:** Table 1 exhibits, "The PE: L2L Constructs Model". This model was created by the authors and refined via feedback by members of the "Academy of Process Educators". The Table is organized with a list of 10 PE outcomes and experiences on the far

right with a definitive set of triangular models in the midsection that connect PE with L2L and on the far left are the 3 L2L definitions that accurately define curriculum as reproduction, production, and transformation respectively. A list of Triostatistical Methods, Models, and Metrics for PE: L2L follows in Table 2.

## Support for Process Education and Learning to Learn

Process Education (or "PE") has been in some form or fashion on the educational landscape for approximately 26 years. Support for its concepts and ideology have gained widespread backing. Evidence of this can be seen in the 2016 research article entitled, "25 Years of Process Education: Commemorating 25 Years of Scholarship in Process Education and the 10th Anniversary of the Academy of Process Educators" by Apple, Ellis, and Hintze. They state the following in support for PE in "25 Years of Process Education":

> As of this writing, Process Education (PE) has been around for 25 years. If it were a person, we would expect to see it making its own way in the world — standing on its own two feet, as it were — in contexts that no longer necessarily involve those who brought it into being. And so it is. The life and growth of this philosophical approach to education consists of various stages of growth, important milestones, and noteworthy contributions and achievements. And as it has grown and evolved in clarity, organization and utility, its impact upon higher education has only increased. Over the last 25 years more than 50,000 faculty, staff, and administrators have been exposed to the principles and practices of Process Education, largely through professional development and scholarly efforts. While there is no way to accurately tally those who have adopted even some of what Process Education offers, a diverse community of serious practitioners has evolved over time. The genesis of this group began with a series of conferences entitled Problem Solving Across the Curriculum (1990–1996) and the community grew between 1999 and 2002 and became more coherent as a result of a major scholarship effort (The Faculty Guidebook: 2003–2007), eventually culminating in the Academy of Process Educators (2007 to present). This group is not definitive; there are Process Educators who are not members of the Academy and, thanks to the "stickiness" of many of the ideas in Process Education — that they have import, attraction, and utility that are obvious to many educators — there are surely individuals who could be termed "Process Educators" who may well have never heard the term Process Education." (Apple, Ellis, & Hintze, 2016, p.3 )

Support for "Learning to Learn" (or "L2L") is presented in the 2013 Oxford Review of Education research article by Pirriea and Thoutenhoofd (2013) entitled, "Learning to Learn in the European Reference Framework for Lifelong Learning" that states the following:

> The hallmark of L2L is the development of a fluid sociality rather than the promotion of fluent task-oriented behaviour. Moreover, we believe that the embodied, situated, affective and creative dimensions of L2L have previously been subordinated to the cognitive dimension, and have thus received insufficient attention. This is partly due to the fact that for the last 50 years human capital theory has served as a powerful steering mechanism across the European political landscape (Gillies, 2011, p. 240). This article is intended to redress this imbalance, and more importantly to begin to clarify the epistemological basis of L2L. This will entail wresting this concept from a narrow identification with self-regulated learning and meta-cognition." (p. 609)

**The Process Education: Learning to Learn (PE: L2L) Conceptual Framework**

There are critical components of implementing "Process Education: Learning to Learn" as dynamic and interactive learning experiences that foster and promote "self-growth". This process can best be illustrated in the form of a concept map. Concept mapping by nature inherently displays all the various aspects of an ideology or procedure. Jabareen (2009) in his work "Building a Conceptual Framework: Philosophy, Definitions, and Procedure" defines a conceptual framework as

> a network, or "a plane," of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena. The concepts that constitute a conceptual framework support one another, articulate their respective phenomena, and establish a framework-specific philosophy. Conceptual frameworks possess ontological, epistemological, and methodological assumptions, and each concept within a conceptual framework plays an ontological or epistemological role. The ontological assumptions relate to knowledge of the "way things are," "the nature of reality," "real" existence, and "real" action (Guba & Lincoln, 1994). The epistemological assumptions relate to "how things really are" and "how things really work" in an assumed reality (p. 108). The methodological assumptions relate to the process of building the conceptual framework and assessing what it can tell us about the "real" world." (Jabareen, 2009, p. 49).

Jabareen (2009) originally stated in his publication in the International Journal of Qualitative Methods entitled, "Building a Conceptual Framework: Philosophy, Definitions, and Procedure" the following*:*

> that the main features of conceptual frameworks are as follows:
> 1.) A conceptual framework is not merely a collection of concepts but, rather, a construct in which each concept plays an integral role. According to Miles and Huberman (1994), a conceptual framework "lays out the key factors, constructs, or variables, and presumes relationships among them" (p. 440);
> 2.) A conceptual framework provides not a causal/analytical setting but, rather, an interpretative approach to social reality (Jabareen, 2009);
> 3.) Rather than offering a theoretical explanation, as do quantitative models, conceptual frameworks provide understanding (Jabareen, 2009);
> 4.) A conceptual framework provides not knowledge of "hard facts" but, rather, "soft interpretation of intentions" (Levering, 2002, p. 38);
> 5.) Conceptual frameworks are indeterminist in nature and therefore do not enable us to predict an outcome. To support this notion Levering (2002) has suggested that "the idea that human behavior can be explained and predicted is roughly based on the concept of external factors being caught in an accidental cohesion, and the idea that human actions can be understood, but not predicted, is based on the concept of freedom (p. 38);
> 6.) Conceptual frameworks can be developed and constructed through a process of qualitative analysis (Jabareen, 2009); and lastly;
> 7.) The sources of data consist of many discipline-oriented theories that become the empirical data of the conceptual framework analysis. Although conceptual framework analysis generates theories or conceptual frameworks from multidisciplinary bodies of knowledge, metasynthesis, a systematic synthesis of findings across qualitative studies, seeks to generate new interpretations for which there is a consensus within a particular field of study (Jensen, & Allen, 1996; Nelson, 2006; Sandelowski, Docherty, & Emden,

> 1997). In "metasynthesis", which is both hermeneutic and comparative in nature, the researcher aims to expand our interpretation (Sandelowski, 1993) beyond existing qualitative studies from the same discipline (Paterson et al., 2009). Moreover, whereas conceptual analysis aims to produce concepts, metasynthesis produces metaphors, ideas, concepts, and more. Usually, metasynthesis initially selects studies and then identifies key metaphors, ideas, concepts, and relations in each one (Nelson, 2006; see also Campbell et al., 2003; Noblit & Hare, 1988 and Jabareen, 2009). (p. 51)

**Effective Implementation of the Process Education Conceptual Framework**

To facilitate effective learning experiences that are transformational in approach based on the way the curriculum is designed, how it is applied, and measured, requires an intentional engaged process (Mastery of the curriculum is critical for implementation). The process also involves developing the learning and growth environment that is transformational, affective, and effective in engaging the learner to a newly developed personal life vision. The facilitator has to create a public desire for a consistent measurement approach with clear performance criteria that challenges the learners to keep improving their performance. It also requires the facilitator to formally integrate methodologies.

There is a distinction that is important in facilitating learning that is transformational in order to produce designed learning outcomes. One of the aspects that is ignored is the experiential learning which involves active learning and training of the mind to think in a certain way that engages the learner to think and act. There are attributes to adult learning experience needed in fulfilling personal urgency and growing self-efficacy (non-cognitive leadership efficacy "Experiential learning" (Kolb, 2014) that also contribute to developing awareness on self-concept (Lynch & Chaves, 1975; Lynch, Norem-Hebeisem & Gergen, 1981). In the last 20 years (Apple, Ellis and Hintze (2016) have developed a L2L curriculum through the lens of Process Education that has been transforming the way higher education is done for over 25 years by focusing on growth and development. The PE: L2L curriculum development process has identified specific aspects that are effective in demonstrating change and a transformational learning environment that facilitators or learners have to apply in order to produce desired measurable learning outcomes in teaching and learning. However, there are eight institutional cultural and policy critical barriers that have been identified through teaching institutes and "learning to learn" camps by Pacific Crest that have been found to present challenges in the efforts of transforming teaching and learning. Table 2 that follows includes a list of those barriers that have been found to be critical in facilitating a culture of success in educational institutions that must be addressed in order to achieve the desired transformational and high quality learning environment and leadership (based upon the 14 aspects-Reds to Green presented in as "Figure 8 Scales used to describe red, yellow, and green performance in each aspect", Beyerlein, Burke & Hintze, 2012).

Table 2.

*Critical Cultural Barriers in Implementing Learning to Learn*

| **Barriers** | **Why are They Significant Barriers** |
|---|---|
| 1. Fixed Mind | Close to 100% of incoming students lean strongly to a fixed mindset vs. growth mindset |
| 2. Self-evaluation | Individuals are unaware of the power of self-assessment |
| 3. Not owning student failures | Most faculty are unwilling to fully accept the responsibility for facilitating success for all their students |
| 4. Disdain for use of methodologies | Few faculty believe in the generalization of process knowledge as a model and believe that it dumbs down the expertise |
| 5. The limited Focus on knowledge vs. Learner performance | Most faculty focus teaching knowledge level but not performance of the learner and themselves |
| 6. Non-transformational learning culture (Red to green culture) | Change and growth are impacted by the educational culture that is established and unfortunately the current culture is non-growth culture |
| 7. Limited facilitators tool set | Facilitating a Learning to Learn Camp/Course requires a strong set of skills in facilitation, assessment, mentoring (constructive interventions) |
| 8. Minimal believe in the value of Educational research | Most faculty teach the way they were taught and rarely use research to inform teaching (common practice is try and error approach) |

Summary of Table 2: Table 2 illustrates, “Critical Cultural Barriers in Implementing L2L”. The Table is organized with a list of barriers on the right with adjacent definitions to the left that explain in detail why the barriers are significant. Educational research and its contributions in terms of value can address all of the critical Cultural Barriers that can impede effective PE: L2L implementation. There is a virtual plethora of research (both continuing and ongoing) that can and will allow the facilitator of PE: L2L to ground their work in empirical evidence that supports the most positive aspects of PE: L2L. However, the facilitator must be aware of the notion of superiority complex which can and will defeat all of their efforts in PE: L2L. This phenomenon is better characterized by the Dunning–Kruger effect:

> The Dunning–Kruger effect is a cognitive bias wherein unskilled individuals suffer from illusory superiority, mistakenly assessing their ability to be much higher than is accurate. This bias is attributed to a metacognitive inability of the unskilled to recognize their ineptitude. Conversely, highly skilled individuals tend to underestimate their relative competence, erroneously assuming that tasks which are easy for them are also easy for others. As David Dunning and Justin Kruger of Cornell University conclude: "The miscalibration of the incompetent stems from an error about the self, whereas the miscalibration of the highly competent stems from an error about others. (Carlson, n.d.).

A profile of PE: L2L defeats and counters the Dunning–Kruger effect the next section

covers this topic in detail.

**A Profile of PE: L2L Facilitator's Responsibilities [an In-Depth Profile]**

Learning to learn experience requires the instructor as "PE: L2L Facilitator" to have specific set of instructional efficacy skills that informs practice and identifies the initial "self-growth learning conditions" to students. This set of PE: L2L skills includes: 1. How to help students identify their own learning risk factors; 2. How to develop student's ability to identify their own learning outcomes; and 3. Development of student growth goals in the learning environment as an ongoing process. As such, a PE: L2L Facilitator of (for example) a "PE: Learning to Learn Camp" or a "specified course that adheres to PE: L2L principles" must engage students through a PE: L2L pre-assessment process. It is this process which helps the students to do the following: A.) Identify their own individual's personal learning risk factors; B.) Obtain their own learning and growth goals; and C.) Build connectivity in at least three learning-related dimensions to aid them in building instructional-setting rapport. Subsequently, the PE: L2L Facilitator creates a "focused-on-self-growth" learning environment that holistically generates "a cultural desire for the transformational learning." Accordingly, the Facilitator must know which PE: L2L process, tool, technique, or strategy is effective in driving both the learner and the learning environment towards "dedicated constructive intervention" designed to produce growth and a high-quality learning environment. It is also understood that the Facilitator has to have a clear understanding of the specified curriculum and its design, sequencing, and synergistic qualities that will uniquely allow students to leverage (in timely manner) opportunities to consistently advance and promote self-growth.

Further additional essential knowledge areas that are needed by the PE: L2L Facilitator include using the guiding principles of Process Education that are generally adhered to in one's daily professional, family, and personal life (these are also considered to be "empowerment processes"). Indeed, the Facilitator of PE: L2L must know how to elevate his/her own practices in all the key PE processes in order implement the planned curriculum through PE: L2L effectively. This knowledge thereby aids the Facilitator in modeling "quality performance" in each of the following PE transmission of information processes: a.) facilitation; b.) assessment; c.) mentoring; d.) collaborating; e.) evaluating; f.) problem solving; g.) leadership; and h.) self-growth. Knowledge in each of the aforementioned eight PE information processes also requires the facilitator to have a very clear distinction between the two operative PE parameters of: 1.) Assessment [or "the arena of measurement"]; and 2.) Evaluation [or "the arena of judgment"]. The PE: L2L Facilitator thereby models their personal experiences and curriculum expertise in both of these operational arenas with their students. Thus, an effective PE: L2L Facilitator is also an engaging "PE: L2L Mentor" who then guides performance to advance assessment (via the practice) for the specific purposes of providing empowerment in the learning environment to enhance overall self-concept and in this manner elevate self-growth throughout the learning process. There are 10 primary characteristics that a PE: L2L Facilitator as a PE: L2L Mentor must have to both promote and sustain the process of self-growth in the learning environment they are:

1. Have a very strong belief in each learner's potential for success, convey this clearly to each student consistently, and share personal experiences and results of previous students' successes;

2. Are very caring individuals who connect with their students, build rapport and express this caring in a productive and meaningful way by putting student's interests first;
3. Have emotional toughness (strong affective skill set) that allows them to carry out tough love – holding their students accountable for their commitment and performance given very difficult personal factors and circumstances;
4. Consistently self-assess their own performance, learn and grow from these performances so their future PE: L2L performance continually improves and thusly they are much more successful for a greater percentage of the students under their care;
5. Continuously model a set of productive professional behaviors that students will and can emulate and use "a language of success" that produces positive reinforcement, encourages, and thereby creates an environment for productive growth;
6. Mentor the growth of their student's learning skills by letting learners do for themselves, learn by discovery, and provide constructive interventions when learners struggle with specific learning skills;
7. Put in extra effort to reach out to students who are having difficulties and are about to withdraw from the process and bring them back successfully;
8. Produce an enriching and engaging learning environment where there is a high expectation, a strong shared commitment, adventurous risk taking, inspiration and encouragement, temporary failure, quality assessment, reflection and documentation of growth, and steadily increasing challenges;
9. The facilitator also takes the responsibility for the performance and success of each learning team and member within the learning community by preparing facilitation plans for each activity and effectively implements a focus on higher levels of learning through critical thinking and having students teach each other through communication skills to learn intra-group and inter-group communication. Facilitation with improvisation must be used when necessary. This process then motivates via counsel, creates collaboration, sustains professional development, and gives quality feedback to grow the performance of each learning team; and
10. The Facilitator diagnoses key individual learning issues and in collaboration with each student come up with customized growth plan that addresses these learning issues. The Facilitator also challenges each student daily to help keep improving their performance by assessing work products, assessing the reflective and assessment produced by the students, and assessing student's self-assessments.

## Practical Measurement of PE: L2L Using Statistics

The authors provided an in-depth workshop on statistical measurement during the 2017 Academy of Process Education Conference. The conference workshop to place in the following manner using the framework illustrated in Appendix A.

## Measurement of Process Education: Learning to Learn for Assessment and Continuous Growth

Measurement is essential to Process Education: Learning to Learn. It is very evident in the assessment methodology, process, and procedures. There are two primary and very valuable tools that are essential to the measurement of PE: L2L and its outcomes. They are a vital part of

the science of “Triostatistics” which is the measurement field adjacent to PE: L2L. The Triostatistics assessment measurement procedures that have direct application to PE: L2L are Tri–Squared Analysis and Accumulative Manifold Validation Analysis or “AMOVA”. They are defined as follows: 1.) Triostatistics: The science and field of Triostatistics is comprehensively defined as follows: “The word “Triostatistics” is a portmanteau of the terms: “Triochotomous” and “Statistics”; that can also be referred to as “Triostat”, “Advanced Trichotomy” or “The Science of Trichotomy”. More definitively Triostatistics is descriptively defined as

> a branch of the science statistics that is the specific application of statistical methods, techniques, and strategies to a wide range of topics that are concerned with primary and post hoc measurements, the mathematics of trichotomy, innovative statistical measures, and in many cases the outcomes of the Tri–Squared Test. (Osler, 2014, p. 33)

At the heart of this statistical discipline is the application of the mathematical “Law of Trichotomy”.

The science of Triostatistics encompasses the design of Tri–Squared experiments, especially in education and social behavioral settings. However, the utility and flexibility of Triostat as a body statistical metrics allows it to be applied to a variety of sciences (through the use and application of the mathematical “Law of Trichotomy”) (Osler, 2014). Tri–Squared Analysis: The Total Transformative Trichotomous–Squared Test provides a methodology for the transformation of the outcomes from qualitative research into measurable quantitative values that are used to test the validity of hypotheses. The advantage of this research procedure is that it is a comprehensive holistic testing methodology that is designed to be static way of holistically measuring categorical variables directly applicable to educational and social behavioral environments where the established methods of pure experimental designs are easily violated.

The unchanging base of the Tri–Squared Test is the 3 × 3 Table based on Trichotomous Categorical Variables and Trichotomous Outcome Variables (see Table One Sample Research Report Table in the Appendices on p. 8). The emphasis the three distinctive variables provide a thorough rigorous robustness to the test that yields enough outcomes to determine if differences truly exist in the environment in which the research takes place. As it states in the IGI Global book entitled, Handbook of Research on Educational Technology Integration and Active Learning (Keengwe, 2015):

> The Tri–Squared  research procedure uses an innovative series of mathematical formulae that do the following as a comprehensive whole: (1) Convert qualitative data into quantitative data; (2) Analyze inputted trichotomous qualitative outcomes; (3) Transform inputted trichotomous qualitative outcomes into outputted quantitative outcomes; and (4) Create a standalone distribution for the analysis possible outcomes and to establish an effective—research effect size and sample size (see Figures 3 and 4 in the Appendices p. 11, respectively) with an associated alpha level to test the validity of an established research hypothesis (Osler & Mutisya, 2013, p. 14)

AMOVA which was first defined by Osler in 2015 in the research publication entitled “AMOVA [“Accumulative Manifold Validation Analysis”]: An Advanced Statistical Methodology Designed to Measure and Test the Validity, Reliability, and Overall Efficacy of Inquiry–Based Psychometric Instruments”, as follows

> AMOVA: Accumulative Manifold Validation Analysis [“AMOVA”] is a specialized statistical methodology designed to test the internal and external validity of uniquely designed psychometric instruments. AMOVA uses a mathematically specialized form of

> inquiry that is an arithmetic form of natural mean optimization that is parallel to the discipline of linear stochastic modelling. AMOVA is an in–depth statistical procedure for the internal testing of research instruments based on the metrics from a novel taxonomy based on and grounded in “Process Education”. This new taxonomy is referred to as the “Taxonomy of Process Education” (or “TPE”). (Osler, 2015, p. 20)

Osler further states in the 2015 research article “AMOVA” published in the 2015 the following:

> The TPE is based off of the Process Education (or “PE”) four–level measures designed to measure self–growth. The Taxonomy of Process Education (TPE) is based off of the Process Education [PE] (Pacific Crest, 2015) four–level measures designed to measure self–growth. The PE four levels in particular are viewed as sequential stages (as levels and/or phases) of professional development. The four–level measures are also constructed to build towards the highest level of content knowledge or subject matter expertise and are: 1.) Emerging (the lowest level); 2.) Developing (the next stage that arises from Emerging and illustrates a higher level of self–growth and authentically-based learning); followed by 3.) Proficient (the next level and second highest level of growth displaying the ability to adequately implement the task and/or skillset); and lastly followed by 4.) Accomplished (the highest level demonstrating mastery of the topic, concept, task, skillset, and/or requirement). The PE four levels in particular are viewed as sequential stages (or phases) that through the TPE ideally measure “professional development” (Osler, 2015). Table 5 immediately follows and details the 0 through 4 metrics of TPE by providing a logical sequence of definitive categories, scalar characterizations, assigned weights, calculative outcomes, and data type descriptions. (Osler, 2015, p. 20)

Table 3.

*The AMOVA Measurement Comprehensive Continuum of Self–Growth Table*

| Repetitively Assigned Mathematical Weight | Equal to | Measurement of Self-Growth Scale | Identical to | Repetitive Weight Assignment Based on the Taxonomy of Process Education$_{Self–Growth}$ | Identical to | Taxonomy of Process Education $_{Self\text{-}Growth}$ Weighted Accumulative Outcome | Parallel to | Mathematical Measurement Data Type Scalar Level |
|---|---|---|---|---|---|---|---|---|
| 0 | = | Empty | ⟷ | None | ≡ | Non–Existent | ‖ | *Self-Growth* in terms of Learning is at the Vacant Level = Void |
| 1 | = | Weak | ⟷ | Seldom | ≡ | Emerging | ‖ | *Self-Growth* in terms of Learning is at the Nominal Level = Name Only |
| 2 | = | Mild | ⟷ | Occasionally | ≡ | Developing | ‖ | *Self-Growth* in terms of Learning is at the Ordinal Level = Rank Only |
| 3 | = | Strong | ⟷ | Often | ≡ | Proficient | ‖ | *Self-Growth* in terms of Learning is at the Interval Level = Equidistant or Balanced in Area |
| 4 | = | Perfect | ⟷ | Consistently | ≡ | Accomplished | ‖ | *Self Growth* in terms of Learning is at the Ratio Level = Ideal from the Source or Starting Point |

Summary of Table 3**:** The defined in the Journal of Educational Technology (Osler, 2015) publication entitled, "AMOVA" stated the following that applies to the above table:

> The AMOVA Continuum of Self–Growth provided above is designed to displays the sequential (left to right) relationship between the instrument values for the purposes of validation. In this manner the individual weighted outcomes have a multiple manifold applicable rubric that illustrates how scores were obtained, their relative value, and their expression in terms of the Taxonomy of Process Education in terms of Self–Growth. Table

4 follows and highlights “The Accumulative Crosswise–Validation Analysis Table.” (Osler, 2015, p. 24)

This Table expands the scope of AMOVA and measures learning by defining it through a self-growth categorization methodology. Through this categorization the “Taxonomy of Process Education” defines statistical data types as categories of learning that build upon one another that at the highest level illustrate that learning can be defined from a self-growth perspective. For example, as a maximum score of the integer “4” = “Perfectly Consistent Accomplished Ideal Learning from the Source” (that is at a Ratio Level and exemplifies a statistical “Ratio” data type). Figure 1 follows and details the “Taxonomy of Process Education” models.

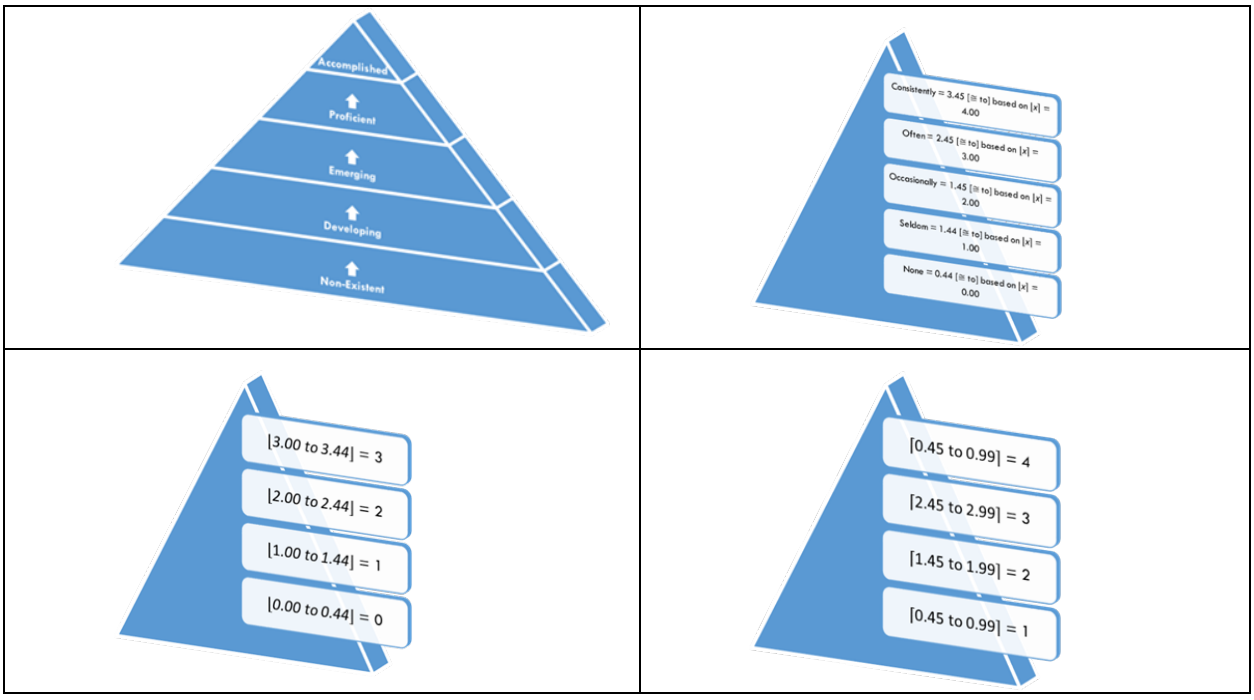



*Figure 1*. The Primary Model of the Taxonomy of Process Education in Terms of Self–Growth as Used to Measure All Types of Learning as Pure Forms of Professional Development

Summary of Figure 1: Image 1. The Accumulative Manifold Validation Analysis (AMOVA) Figure above is the “Taxonomy of Process Education in Terms of Self–Growth”. It is designed to illustrate the sequential hierarchal (from bottom to top) steps that one matriculates through from “No Experience” (i.e. “Non–Existent”) to a maximized “Accomplished” Level indicating the penultimate level of achievement of “Professional Development”. This particular taxonomy has universal applicability. The terms and associated values can be used to assess growth, disposition, content mastery, level of expertise, value of particular items, analysis of skill sets, the power relative to performance, the building of a specific set of measurement data (as in the course design “*4A* Metric” from Techtonics) (Osler, 2010), the creation of implicit goals and objectives, and the amount of assigned value to a particular criterion. The quantitative numerical equivalent of these “indices” or “indicators” can be found in Table 5 which displays the holistic “Taxonomy of Process Education: Learning to Learn Continuum Measurement Rubric” specifically for the Itemization of Accumulative Crosswise–Validation Analysis for the purposes of research instrumentation psychometric analysis. (Osler, 2015, p. 24)

## Summary and Conclusion

The use of advanced triostatistics such as the Tri–Squared Test and that AMOVA triostatistical procedures can very efficiently and effectively measure novel methodologies such as Process Education: Learn to Learn. PE: L2L (effectively in the landscape of education K–20+) has the ability to transform all of education (in a multiplicity of sectors)—from the elementary classroom to the halls of higher education from the unique perspective of "learning as present, past, and future professional development". The conceptual framework, metrics, measurement, strategies, and "Taxonomy of PE: L2L" can not only shed light on innovation in academia, but it can also greatly aid in the producing the next generation of educators who will shape and formulate how education will impact learners right now and in the near future.

The implementation of the triostatistics measurement analytics presented in this narrative (AMOVA and Tri–Squared Analysis in particular) can greatly enhance the understanding of "education as a science" as the active development of the comprehensive field of "Eduscience" (Osler, 2013) as comprehensive field. The implications are great and truly expansive for the growth and sustainable future of academicians as leaders in the academy. It is these leaders who seek to address, "the challenges and social change that demands a reconceptualization of education as a process to emphasize entrepreneurship and leadership throughout the academy" (Osler & Mutisya, 2013, p. 21). The measurable contextual texture of this change in education begins with the paradigm shift brought on by the measurement of learning (via novel statistical measures such Tri–Squared and AMOVA) and the implementation of comprehensive learning models such as PE: L2L. The measurement of PE: L2L directly addresses "transformational change" by thereby providing an acceptable data analysis conceptual framework that is grounded in years of research and training from both Europe and the United States. The advent of the PE: L2Lconceptual framework measurement methodology now provides PE with a researchable acumen of credentials and metrics that allows educational researchers to further interpret the in–depth and rich complexities of learner self-growth through the lens of self-concept. The widespread use of measurable PE: L2L in this context creates a uniquely empowering and dynamically engaging learning methodology that has a professional development perspective that is both approachable and plausible. This ultimately will push the body of knowledge in education (and all of the related fields that it both nurtures and touches) into new and vast expanses of creative learning environments established through energetic innovation that is focused on proprietary student development, authentic professional development, and capacious self-growth.

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## Appendix A

**Title: "Measuring Impact of Teaching and Learning"**

**Facilitators: James Osler and Masila Mutisya (North Carolina Central University)**
**Steve Beyerlein (University of Idaho)**

**Description:** Beginning with principles of educational research, methods for validating effectiveness of teaching/learning in different venues will be explored. These include specific teaching/learning practices, course design and delivery, and degree programs. Added value from quantitative and qualitative methods will be outlined along with applications for mixed methods studies. Building from this foundation, strategies for acquiring evidence of educational effectiveness of Process Education theory will be examined. It is hoped that this workshop will create a core group committed to research teaching/learning methods that explore personal and professional development implied by the Profile of the Collegiate Learner.

**Session Outcomes:**

1. Clarify the role of Measurement, Assessment, and Evaluation in Educational Research.

2. Overview statistical models used to examine educational research questions.
3. Identify personal applications for mixed method tools in Educational Research related to Process Education.

**Materials:**

- Overview of Measurement module from Faculty Guidebook (1.4.1)
- Visual Taxonomy of Educational Research Methods (derived from pages 88, 89, 91 in James Osler's Interactive Statistics Methods text);
- Video on the Tri-Squared Method https://www.youtube.com/watch?v=n7q5_9-LsEE;
- Shared Governance article from IJPE that illustrates use of Tri-Squared Analysis; and
- Profile of the Collegiate Leaner and associated rubrics.

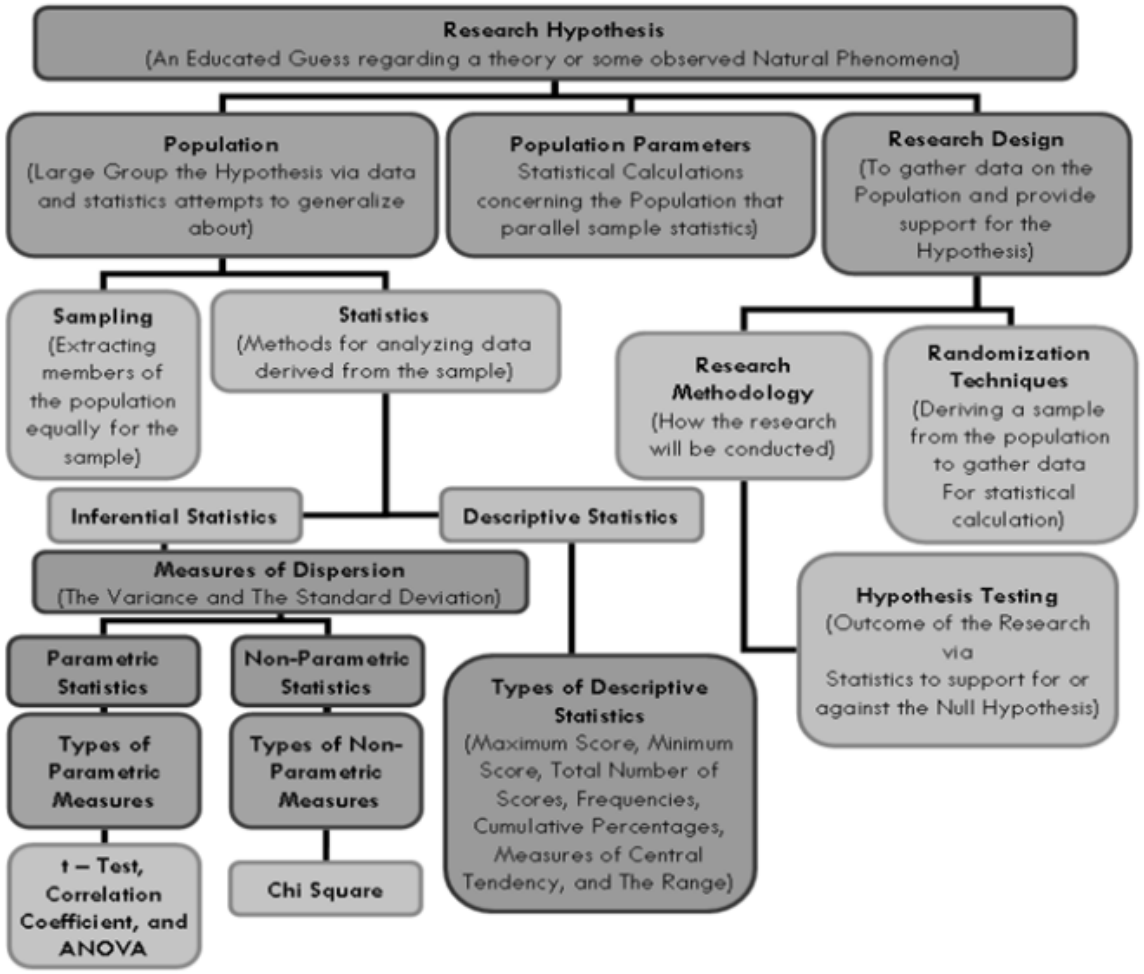
**Session Timeline:**

- **Pre-Workshop Critical Thinking Questions (posted on Academy Forum**
  a) What principles of measurement do you find most intuitive? What principles do you find most confounding/challenging? Why?
  b) What are the strengths and liabilities of quantitative, qualitative, and mixed methods in educational research?
  c) Which of the educational research methods shown in the Visual Taxonomy have you used previously? How did you apply these?
  d) What are the benefits of using the Tri-Square method in the IJPE shared governance article? What questions do you have about its application?
- **Synthesis of Academy Forum postings (30 minutes)**
- **Group Processing of a case study (30 minutes)**
  - Steps in applying the Tri-Square method
    - Literature Review on academic leadership/shared governance
    - Frame compelling Research Questions/Hypotheses
    - Design quantitative and qualitative instruments for collecting data
    - Select categorical variables and outcome variables
    - Choose effect size, sample size, and desired alpha level
    - Formulate mathematical hypotheses about interactions between variables
    - Use Tri-Square to quantify significance of hypothesized interactions
      - Alternative categorical variables and outcome variables (Masila)
  - Q/A and participant discussion (all)
- **Tools for Process Education Research (25 minutes)**
  - Profile of the Quality Collegiate Learner and associated rubrics (Steve)
  - Examples of student work associated with measuring growth (L2L examples)
  - Brainstorming collaborative PE research topics related to the L2L (all)
- **Workshop Assessment (5 minutes)**

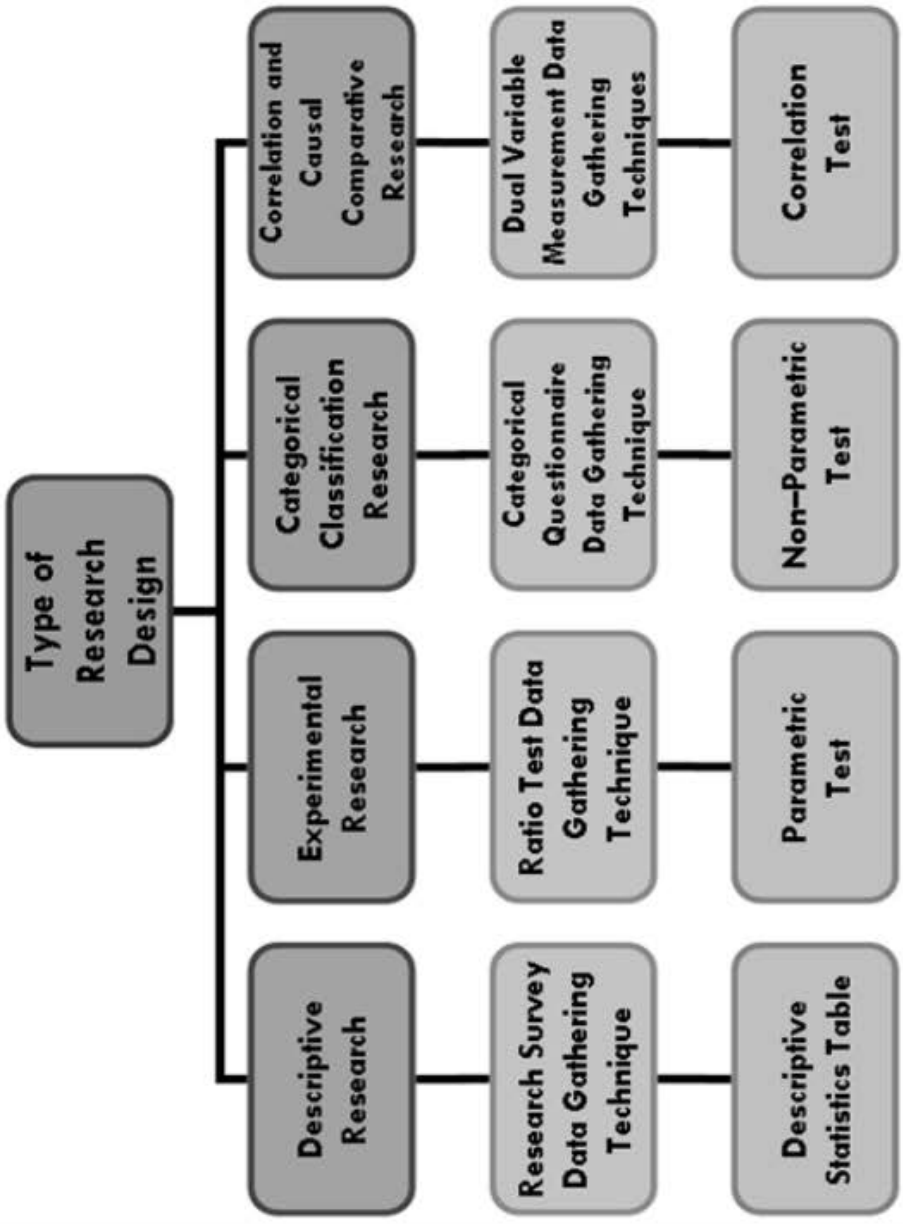
**Explaining Visually the Value of Mixed Methods Research**

The authors provided **"A Visual Taxonomy of Educational Science Statistical Measurement Methodology"** from the Osler (2012b) book, "Interactive Statistics Methods ©" used During the 2017 Academy of Process Educators Workshop (the Visual Taxonomy follows on the next three pages).

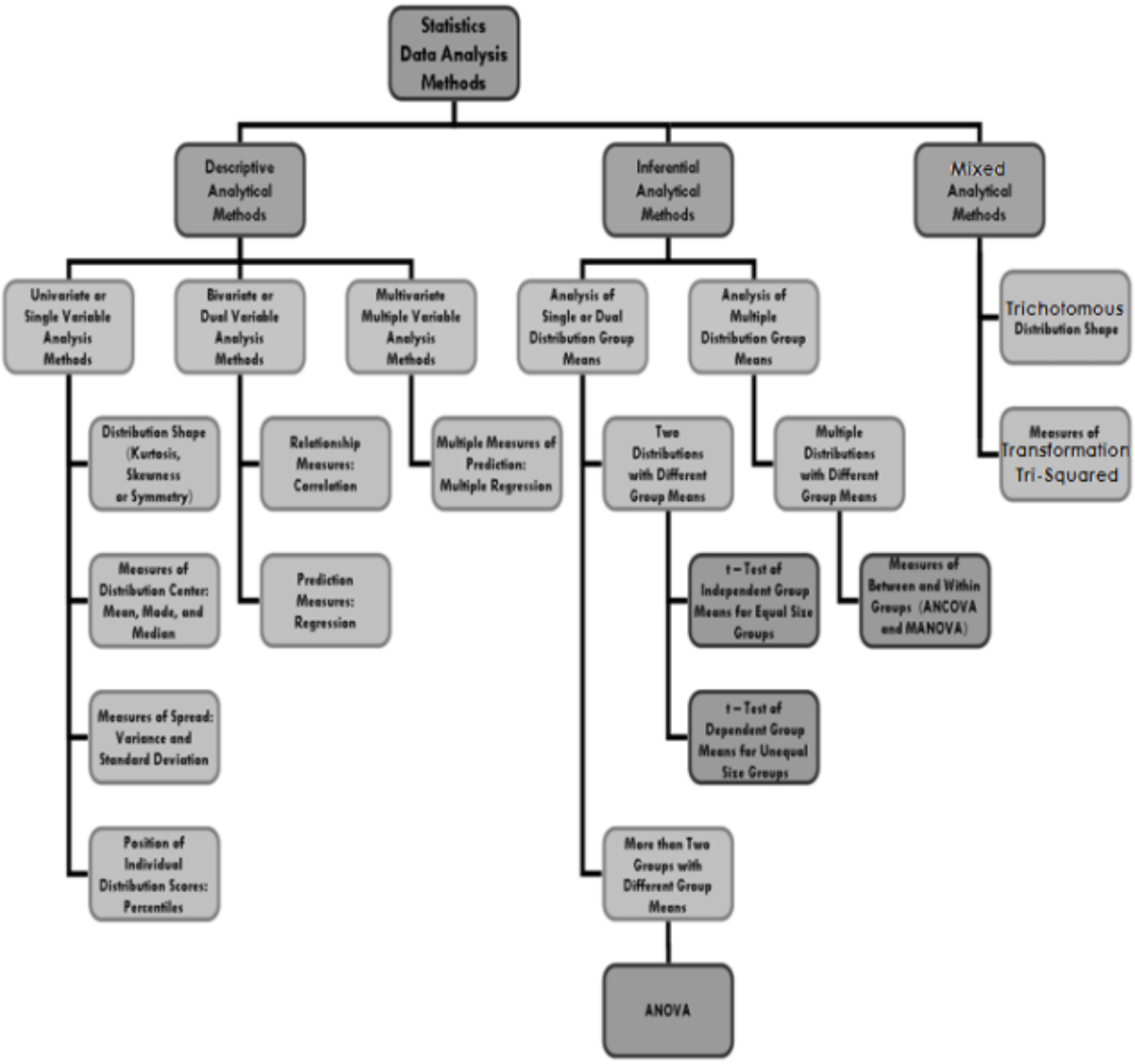
## A Visual Taxonomy of Educational Science Statistical Measurement Methodology: From the Book Entitled, "*Interactive Statistics Methods* ™ ©" by James E. Osler II



**The Research Design Model Illustrating the Four Major Types of Investigations Typically Conducted by Researchers with the Associated Types of Research and Data Gathering Methods**



## The Statistical Data Analysis Methods Model Illustrating Data Analysis Methodology Based upon the Selection of the Type of Data




***91*** [Modified]