THE PSYCHOMETRICS OF EDUCATIONAL SCIENCE: DESIGNING TRICHOTOMOUS INVENTIVE INVESTIGATIVE INSTRUMENTS FOR QUALITATIVE AND QUANTITATIVE INQUIRY

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ABSTRACT

This monograph provides an active discourse on the novel field of "Educational Science" and how it conducts in–depth research investigations first presented in an article by the author in the i-managers Journal of Mathematics. Educational Science uses the innovative Total Transformative Trichotomy–Squared [Tri–Squared] Test as a means of informative inquiry. This novel approach to data analysis is a mixed methods research design that involves the holistic combination and comparison of qualitative and quantitative data. An example is provided on the psychometric process of creating trichotomous instruments that are an essential part of the Tri–Squared research investigative process.

Keywords: Data Analysis, Education Science, Eduscience, Instrument, Investigative, Psychometrics, Trichotomy, Tri–Squared, and Statistics.

INTRODUCTION

Defining the Field of Educational Science

The field of "Education Science" is also represented by the term "Eduscience" which is a portmanteau of the two terms "Education" and "Science" (Osler, 2012). Similar to the field of "Bioscience", Eduscience is the study of education wherein applicable sciences (such as ergonomics, statistics, technology, etc.) are applied to enhance and improve learning. The primary purpose of the field of Eduscience is the study and application of solutions to improve and enhance the learning environment and learning in general. Eduscience is solution–driven and is actively concerned with the transfer and dissemination of knowledge. Education Science is a broad field and its professionals are directly involved in the field. Those who are actively involved in Eduscience can be referred to as "Education or Educational Scientists". Educational Scientists or "Eduscientists" are multifaceted professionals who have a variety of areas of expertise. They can assume multiple roles in the educational environment and can serve in a variety of offices and in a multitude of capacities. The primary positions that Eduscientists assume are in the following areas: Administration (as Leaders, Organizational Heads, and Organizational Management Professionals), Instruction (as Teachers, Professors, and Facilitators), Practice (as Practitioners in a variety Specified Areas and Arenas), and Technology (as Educational Technologists, Instructional Technologists, and Information Technologists). In these positions Eduscientists effectively use, analyze, study, and deploy novel instructional learning theories, methodologies, strategies, solutions, tools, and techniques in both traditional or virtual (pedagogical and andragogical) settings to bring about learning (Osler, 2012).

Transitive Transformative Knowledge Transfer: The Ultimate Goal of Education Science

Educational Scientists strive to make the process of knowledge transfer both transitive and transformational. A transitive and transformative knowledge transfer process is as seamless and as harmonious as possible in an effort to empower, enhance, and improve learning. Eduscientists are masters of teaching who also are also highly proficient practitioners who are able draw from personal and professional experiences to make the learning environment more viable (Accessible), usable (Ergonomic), teachable (Instructional), engaging (Relevant), approachable (Adaptive), exploration–based (Discovery), and inspirational (Transformative). The Total

Transformative Trichotomy–Squared Test is a comprehensive multi–step research methodology that is employed by Eduscientists. It is especially designed to conduct qualitative and quantitative investigations in educational settings and the learning environment.

One of the most challenging areas of research in education involves the construction of specific instruments that are designed to measure qualitative outcomes and data. Although there are a great many measurement tools that analyze the cognitive and psychomotor domains, there remains a vacuum in the number of instruments especially designed to accurately measure the affective domain (the learning domain that contains attitudes, opinions, emotions, perception, and perspectives). This void is further expanded when the specific event under investigation is unique, specialized, has specific characteristics, serious legal constrictions, and issues regarding time. This often requires the research investigator to design an instrument that ideally measures the variables under investigation.

The process of designing instruments for the purposes of assessment and evaluation is called "Psychometrics". Psychometrics is broadly defined as the science of psychological assessment (Rust & Golombok, 1989). The Tri–Squared Test pioneered by the author, factors into the research design a unique event–based "Inventive Investigative Instrument". This is the core of the Trichotomous–Squared Test. The entire procedure is grounded in the qualitative outcomes that are inputted as Trichotomous Categorical Variables based on the Inventive Investigative Instrument. The specific assessment of the variables is completely dependent upon the outcomes determined by the researcher's instrument. The creation, production, and deployment of the trichotomous Inventive Investigative Instrument requires that the research investigator adopt the role of a "Trichotomous Psychometrician". A "Trichotomous Psychometrician" is an Educational Scientist that uses trichotomous–based psychometrics to develop a qualitative Inventive Investigative Instrument specifically designed capture qualitative responses during a specific event. A description of the entire Tri–Squared research process follows and is described in detail to provide the reader of the precise steps undertaken in the process of developing, designing, and ultimately implementing an Inventive Investigative Instrument.

"Trichotomy" Origins

The term is pronounced ['trahy-kot-uh-mee'], spelled "trichotomy", and is a noun with the plural written form "trichotomies". A "Trichotomy" in terms of philosophy can be referred to as a threefold method of classification. Philosopher Immanuel Kant adapted the Thomistic acts of intellect in his trichotomy of higher cognition — (i) understanding, (ii) judgment, (iii) reason — which he correlated with his adaptation in the soul's capacities — (i) cognitive faculties, (ii) feeling of pleasure or displeasure, and (iii) faculty of desire — of Tetens's trichotomy of feeling, understanding, will. (Teo, 2005). In terms of mathematics, Apostol in his book on calculus defined "The Law of Tricohotomy" as: Every real number is negative, 0, or positive. The law is sometimes stated as "For arbitrary real numbers a and b, exactly one of the relations $a < b$, $a = b$, and $a > b$ holds" (Apostol, 1967).

It is important to note that in mathematics, the law (or axiom) of trichotomy is most commonly the statement that for any (real) numbers x and y, exactly one of the following relations holds. Until the end of the 19th century the law of trichotomy was tacitly assumed true without having been thoroughly examined (Singh, 2002). A proof was sought by Logicians and the law was indeed proved to be true. If applied to cardinal numbers, the law of trichotomy is equivalent to the axiom of choice. More generally, a binary relation R on X is trichotomous if for all x and y in X exactly one of xRy, yRx or $x = y$ holds. If such a relation is also transitive it is a strict total order; this is a special case of a strict weak order. For example, in the case of three elements the relation R given by aRb, aRc, bRc is a strict total order, while the relation R given by the cyclic aRb, bRc, cRa is a non–transitive trichotomous relation. In the definition of an ordered integral domain or ordered field, the law of trichotomy is usually taken as more foundational than the law of total order, with $y = 0$, where 0 is the zero of the integral domain or field. In set theory, trichotomy is most commonly defined as a property that a binary relation $<$

has when all its members <x, y> satisfy exactly one of the relations listed above. Strict inequality is an example of a trichotomous relation in this sense. Trichotomous relations in this sense are irreflexive and antisymmetric (Sensagent, 2012). It is from these logical and mathematical definitions that the author derives the definition of "Research Trichotomy" and applies it to the qualitative and quantitative analysis of the affective domain of learning (Osler, 2012).

The term "Trichotomy" is defined in Trichotomy–Squared in the following manner: "Trichotomy": is pronounced ['trahy-kot-uhmee'], spelled "trichotomy", and is a noun with the plural written form "trichotomies". "Trichotomy" has the following threefold definition: (i) Separation or division into three distinct parts, kinds, groups, units, etc.; (ii) Subdivision or classification of some whole into equal sections of three or "trifold segmentation"; and (iii) Categorization or division into three mutually exclusive, opposed, or contradictory groups, for example – "A trichotomy between thought, emotions, and action" (Osler, 2012).

Education–Based Inquiry: Using the Tri–Squared Research Methodology as a Four Step Process to determine an appropriate research Effect Size, an ideal Sample Size, and an effective Alpha Level for Education–Based Experiments in the Learning Environment

The Tri–Squared research procedure consists of a four step approach designed to provide the researcher with a clear and precise set of data to conduct research, analyze data, and determine the level of significance required to either validate or reject the initial research hypothesis. The four Tri–Squared steps are as follows

- Design of an Inventive Investigative Instrument that has Trichotomous Categorical Variables and Trichotomous Outcome Variables.
- Establish the Research Effect Size, Sample Size with associated Alpha Level.
- Establish Mathematical Hypotheses.
- Use the Tri–Squared Test as the Data Analysis Procedure following implementation.

Sample research questions from an actual trichotomous research study have been provided as an ideal example of how the qualitative trichotomous Inventive Investigative Instrument is produced and ultimately implemented.

Trichotomous Categorical Variables as Research Questions for the Formulation of the Inventive Investigative Instrument Items

- What is the relationship between participation in a ninth grade academy, ninth grade centers or similar models and the graduation rate for minority students?
- What is the relationship between participation in a ninth grade academy, ninth grade center, or similar models and dropout rates for minority students?
- What is the relationship between participation in a ninth grade academy, ninth grade center, or similar models and minority student retention rates?

Trichotomous Outcome Variables as Qualitative Output for the Formulation of the Inventive Investigative Instrument Item Responses

- Yes
- No
- Missing

The Inventive Investigative Instrument Extracted from the initial Trichotomous Research Questions and Associated Categorical and Outcome Variables Used in the Research Study

In this sample research study the researcher Inventive Investigative Instrument items were derived from the aforementioned research questions and outcome variables. The instrument was used to obtain data from administrators as responses to research questions relating to the impact of Ninth Grade Centers, Academies or similar models on minority ninth grade students. The purpose of this instrument was to provide data from 9th Grade Academies, Centers, and Center Models for non–parametric Tri–Squared analysis. Data that was not responded to was reported as "Missing" (a separate Categorical Variable designed to report all research results). The Inventive Investigative Instrument was a qualitative method of data collection designed to accurately provide responses to carefully answer research questions. Ultimately, the research data analysis methodology (Tri–Squared) qualitatively and quantitatively

determined the academic success of ninth grade students who participated in ninth grade centers or similar models at four year high schools in North Carolina based upon the research hypothesis. A sample Inventive Investigative Instrument containing all three outcome variables is provided to illustrate how the 3 × 3 Trichotomous Table is constructed from the Inventive Investigative Instrument (Osler, 2012). A Sample Inventive Investigative Instrument is shown in Appendix section.

The Tri–Squared Research Design Using the Inventive Investigative Instrument

Step One: Design of an Inventive Investigative Instrument that has Trichotomous Categorical Variables and Trichotomous Outcome Variables.

To effectively use Tri–Squared in a research investigation the researcher must first develop a series of trichotomous categorical variables based on associated trichotomous outcome variables. This is the first initial and crucial step to using Tri–Squared as a valid, reliable, and objective means of analyzing data. Second, an "Inventive Investigative Instrument" must be created and implemented in a manner compliant with the initial trichotomous categorical variables and outcomes stated at the outset of the research investigation. This insures that the research investigation is consistent throughout the study and that the later Tri–Squared computations are validly reporting what actually took place in the research environment during the time period in which the actual study was conducted. As previously stated the "Inventive Investigative Instrument" can be psychometrically delivered as a test or qualitatively delivered in the form of a research questionnaire, survey, interview or another type of metric. As long as the trichotomous categorical variables are measured according to the established associated trichotomous outcome variables then the research has merit within the confines and strict requirements of the Tri–Squared Test.

Step Two: Establish the Research Effect Size, Sample Size with associated Alpha Level.

The Tri–Squared Effect Size Formula

$$Tri^2_{Eff} = \left[T_{CR} - \left(T_C T_R : n_{Tri^2}\right)\right] : C_S R_S \left(n_{Tri^2} - 1\right)$$

Results

The Effect Size Table for the calculated Tri–Squared Effect Size Formula for the study was determined based off of the Standard 3 × 3 Tri–Squared Table calculated to be 0.125 (or small in overall effect size). The total number of participants that were identified in the study from the outset was $n_{Tri} = 17$. Thus, an alpha level of 0.975 is best for this small sample size from a corresponding small effect size according to the calculated effect size for the Standard 3 × 3 Tri–Squared Table (specifically identified as 17 to 33 participants for $\alpha = 0.975$). This is further illustrated in Tables 1 to 3.

Step Three: Establish Mathematical Hypotheses.

Sample Research Hypotheses

The following were the research hypotheses for the example study:

H_0: There are significant differences in the perception of the success of Ninth Grade Academy Models in terms of graduation rates, dropout rates, high stakes testing, retention, and attendance by high school administrators.

H_1: There are no significant differences in the perception of the success of Ninth Grade Academy Models in terms of graduation rates, dropout rates, high stakes testing, retention, and attendance by high school administrators.

The aforementioned hypotheses yielded the following mathematical hypotheses using the Tri–Squared Test as the data analysis procedure:

An Example of Two–Tailed Mathematical Hypotheses

H_0: $\boldsymbol{Tri^2 = 0}$

H_1: $\boldsymbol{Tri^2 \neq 0}$

Step Four: Use the Tri–Squared Test as the Data Analysis Procedure following implementation.

Report the Results of the Research Data Analysis: Sample Historic Research Table, Qualitative, and Quantitative 3 × 3 Tri–Squared Tables

Quantitative Research Data Analysis Procedure: Results of the Tri–Squared Test

The Tri–Squared Test statistical analysis procedure was used to analyze data in the study. An alpha-level of 0.10 was considered in light of the research context that was

evidence-based in the prescribed schools that had restricted and controlled learning environments that allowed for very few chance factors to affect the outcomes of the research investigation ($n_{Tri} = 17$ with $17 \times 3 = 51$ items per the outcomes of the Trichotomous Variables on the Inventive Investigative Instrument). This was coupled with the data gathered from administrators that allowed for minimal chance factors to affect research outcomes. The 0.10 estimate was reasonable for this particular study based on the calculated Tri–Squared Effect Size. In addition, due to the exploratory context and nature of the research investigation (in an area where little previous research has been done regarding 9th Grade Academies, Centers, and Center Models) a less stringent level of significance of 0.10 best fit the research study (Osler & Waden, 2012). The study yielded the following final results using the Tri–Squared analysis procedure is presented in Appendix II section.

Appendix II illustrates the qualitative mathematical application of the Trichotomous–Squared ("Trichotomy–Squared", "Tri–Squared" or "Tri–Square") statistical analysis procedure. "Tri–Squared" is the mathematical transformation of qualitative data into quantitative data for the purpose of validating a research hypothesis. The Appendix II shows 3×3 Table reports the qualitative outcomes based on the Inventive Investigative Instrument Trichotomous Categorical Variables according to participant responses as the Trichotomous Outcome Variables. Appendix II shows that participants primarily and overwhelmingly selected the "Yes" Categorical Variable ($a_1b_1 = 48$, $a_2b_1 = 43$, and $a_3b_1 = 38$) rather than the alternative Categorical Variables of either "No" or "Missing" (the "Missing" C. V. indicated unselected or inapplicable responses to an item). The mathematical formula for the Tri–Squared is reported illustrating the final outcome of the research hypothesis test: the null hypothesis (H_0) is rejected at $p > 0.975$ is 0.484. Appendix II follows and provides the outputted quantitative outcomes of the Tri–Squared Test (Osler, 2012).

Appendix II also illustrates the quantitative mathematical application of the Trichotomous–Squared ("Trichotomy–Squared", "Tri–Squared" or "Tri–Square") statistical analysis procedure. "Tri–Squared" is the mathematical transformation of qualitative data into quantitative data for the purpose of validating a research hypothesis (clearly illustrated in this Appendix). Appendix II illustrates and validates the process of transforming qualitative data into quantitative data as a means of in–depth mixed methods for the purposes of discrete data analysis. The Appendix II 3×3 Table reports the transformed quantitative outcomes based on the Inventive Investigative Instrument Trichotomous Categorical Variables according to participant responses as the Trichotomous Outcome Variables. Appendix II data displays that participants primarily and overwhelmingly selected the

Tri–Squared Effect Size	Tri^2_{Eff}
Small	0.10
Medium	0.30
Large	0.50

Table 1. The Tri–Squared Effect Size

Number of Research Participants Placed in Intervals Based off of Tri-Squared Effect Size Magnitude: [Small, Medium, or Large] is Based off of the Tri-Squared Mean = [d.f.] = 4											
Magnitude	Small Unit Intervals: Multiple of 1 = 4[4] = 4.4 = 16 Therefore, Interval has Increments of 16					Medium Unit Intervals: Multiple of 2 = 4[16] = 4[4.4] = 64 Therefore, Interval has Increments of 64			Large Unit Intervals: Multiple of 3 4[4.4.4] = 4[64] = 256		
Number of Participants	1-16	17-33	34-40	41-57	58-74	75-139	140-204	205-269	270-526	527-783	784-1040+
Probability P(x)	0.995	0.975	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.002	0.001

Table 2. The Tri–Squared Probability Distribution

Tri–Squared Distribution Table: Displaying Primary Alpha Levels with Associated Critical Values for Hypothesis Tests											
α Level	0.995	0.975	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.002	0.001
$Tri^2_{[x]}$ = d.f. = 4	0.207	0.484	5.989	7.779	9.488	11.143	11.668	13.277	14.860	16.924	18.467
Tri^2_{Eff} = Effect Size	Small 4[4]	Small 4[4]	Small 4[4]	Small 4[4]	Small 4[4]	Medium 4[16]	Medium 4[16]	Medium 4[16]	Large 4[64]	Large 4[64]	Large 4[64]+
Tri^2_{ssm} = Sample Size [Intervals]	1-16	17-33	34-40	41-57	58-74	75-139	140-204	205-269	270-526	527-783	784-1040+

Table 3. The Tri–Squared Distribution Table: Displaying Alpha Level, Critical Values, and Sample Size

"Yes" Categorical Variable ($a_1b_1 = 43$, $a_2b_1 = 43$, and $a_3b_1 = 43$) rather than the alternative Categorical Variables of either "No" or "Missing" (the "Missing" C. V. indicated unselected or inapplicable responses to an item). The mathematical formula for the Tri–Squared is reported illustrating the final outcome of the research hypothesis test: the null hypothesis (H_0) is rejected at $p > 0.975$ is 0.484 because the Tri–Squared Test Critical Value of 0.484 < 8.131 the Calculated Tri–Squared Test Value. Qualitative Interview Data follows reported in visual format with associated percentages (Osler, 2012).

Summary

The purpose of this paper is to provide support for the design of specific psychometric instruments in educational research (specifically the novel field of "Education Science"). The novel field of "Educational Science" with the associated Tri–Squared Test was provided as the ideal environment that supports and validates the use of "Trichotomous Psychometrics" as a means of producing event–specific trichotomous instrumentation. Further support was provided through a research study that used a trichotomous instrument to determine the impact of Ninth Grade Academies, Freshman Academies or similar models upon ninth grade minority student achievement. The study provided an ideal example of just how effective trichotomous psychometric instruments are and how they can be used as qualitative data gathering instruments in a research study. Ultimately, the example study determined that the research participants for the most part agreed that 9th Grade Academies, Centers, and Center Models were effective in their respective schools. This outcome is supported by the final results of the Tri–Square analysis which yielded the following: A Critical Tri^2 value of 0.484 < 8.131 the Calculated Tri^2 value. Thus, the research null hypothesis was rejected and it can therefore be stated that 9th Grade Academies, Centers, and Center Models do have an effect on the academic success, make a positive difference, and aid in the retention of students.

The implementation of trichotomous psychometrics as Tri–Squared Inventive Investigative Instruments empowers 21st Century educational researchers as "Educational Scientists" who are embarking on novel approaches to answer age old questions about education, pedagogy, and the process of learning. These "Eduscientists" are seeking instruments that satisfy specific investigative needs, address specific research questions, and validate unique research situations. This type of psychometrics also enables instruments to be especially designed to address the specific needs of educational institutions, specialized learning environments, and distinctive pedagogical situations. It illustrates the value of analyzing small groups, sample sizes, and individuals without sacrificing statistical power or the value of research due to the uniqueness of the environment under examination. In this manner psychometrics expands, new and novel research instruments are developed, and the field of Educational Science is validated.

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Appendix I

A Sample Inventive Investigative Instrument

The Waden 9th Grade Academies, Centers, and Center Models Assessment Instrument ©

A. Has the 9th Grade Academy, Center, or Center Model been:

	Yes	No	Missing
1. Successful?	☐	☐	☐
2. Made a Difference?	☐	☐	☐
3. Aided in Retention?	☐	☐	☐

How as the Academy/Center been successful, made a difference, or aided in retention, if at all?_____

_____

_____

_____

_____

B. Did the 9th Grade Academy, Center, or Center Model Result in the following:

	Yes	No	Missing
4. Positive Impact?	☐	☐	☐
5. Active Participation?	☐	☐	☐
6. Decline in Dropout Rate?	☐	☐	☐

How as the Academy/Center been positive, aided in participation, or decreased the dropout rate, if at all?_____

_____

_____

_____

_____

C. How did the 9th Grade Academy, Center, or Center Model have an impact on the following:

	Yes	No	Missing
7. Positively Effect Standardized Testing?	☐	☐	☐
8. Increase Graduation Rate?	☐	☐	☐
9. Increase Attendance?	☐	☐	☐

How as the Academy/Center positively affected testing, graduation rates, and attendance,if at all?_____

_____

_____

_____

How long has the model/program (freshman/Ninth Grade Academy been operation in your school?_____

_____

How long has the interviewee (yourself) been (working) there and what is the level of his or her involvement in the program such as Assistant Principal, Principal, teacher or other staff member?_____

_____What is the role of those interviewed during the interviews, and their knowledge of the program, whether their knowledge was medium knowledge low level of knowledge etc._____

_____

Appendix II

Example Psychometric Qualitative Outcomes of the Tri–Squared Test

Data Analyzed Using the Trichotomous–Squared Three by Three Table designed to analyze the research questions from an Inventive Investigative Instrument with the following Trichotomous Categorical Variables: a_1 = Successful via: Impact, and Positive Testing [the summation of the outcomes of the assessment instrument item 1]; a_2 = Made a Difference via: Participation, and Graduation Rate [the summation of the outcomes of the assessment instrument item 2]; and a_3 = Aided in Retention via: Drop Out Rate, and Attendance [the summation of the outcomes of the assessment instrument item 3]. The 3 × 3 Table has the following Trichotomous Outcome Variables: b_1 = Yes; b_2 = No; and b_3 = Missing. The Inputted Qualitative Outcomes are reported as follows:

$n_{Tri} = 17$

$\alpha = 0.975$

Trichotomous Outcome Variables	Trichotomous Categorical Variables a_1	a_2	a_3
b_1	48	43	38
b_2	2	4	5
b_3	1	4	8

$$Tri^2 \text{ d.f.} = [C-1][R-1] = [3-1][3-1] = 4 = Tri^2_{[\alpha]}$$

The Tri–Square Test Formula for the Transformation of Trichotomous Qualitative Outcomes into Trichotomous Quantitative Outcomes to Determine the Validity of the Research Hypothesis:

$$Tri^2 = T_{Sum}\left[\left(Tri_x - Tri_y\right)^2 : Tri_y\right]$$

Tri^2 Critical Value Table = 8.131 (with d.f. = 4 at $\alpha = 0.975$). For d.f. = 4, the Critical Value for $p > 0.975$ is 0.484. The

calculated Tri–Square value is 8.131, thus, the null hypothesis (H_0) is rejected by virtue of the hypothesis test which yields the following: Tri–Squared Critical Value of 0.484 < 8.131 the Calculated Tri–Squared Value.

ABOUT THE AUTHOR

A native of North Carolina, James Osler was born and raised in the City of Medicine. An accomplished artist, Osler enjoys using art as a tool to empower others. He completed his B.A. at NCCU with a concentration in Studio. Osler adores teaching. He has always been interested in how information is delivered and continues to explore the many different methods, models, and modes of instruction. After completing a M.A. in Educational Technology he completed a doctorate in Technology Education at North Carolina State University (NCSU). He has authored a series of books and e-books on the creation of empowering entrepreneurial educational experiences. His research focuses on Fundamental Christian Education from the holistic perspective of Qualitative and Quantitative Instructional Design (Osler, 2010). He has authored the Online Graduate Program in Online Instructional Design that is currently a part of the Online Educational Technology Program in the NCCU School of Education. His interests include: a life filled with a love of Almighty GOD and ministry to his fellow man through: teaching, the research, and service. He has been awarded two of the highest honors at NCCU as an employee and as faculty: The Employee Recognition Award for Outstanding Service in 2001 and The University Award for Teaching Excellence in 2008.