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Curriculum Independence of Self Assessment: Implications for Mathematics & Statistics Education

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Abstract

This present paper highlights the independence of self assessment from curricular distinctions and its specific implications for Mathematics and Statistics education. Self assessment (SA) was defined as the involvement of students in identifying standards and/or criteria to apply to their work and making judgements about the extent to which they met these criteria and standards. The sample comprised 515 students (15 – 17 year olds) drawn from 10 high schools spanning all levels of academic achievement on a small Caribbean island. Mathematics with Statistics is compulsory for all participants. The research design was a Posttest-Only Control-Group Experimental Design. SA was the experimental variable. The results of an external regional examination was the posttest. Students were trained by their teachers, who were trained, using 12 researcher designed SA modules. Participants responded to a 48-dichotomous item instrument called a self assessment profile 2 (SA2). The methodology utilized a mixed methods (quantitative and qualitative) approach. SA2 was factor analysed (linear and nonlinear) against students' academic achievement in traditional designated curricular areas (business studies, humanities, science and technical studies), at the external regional examination. Results indicated that SA was independent of curricular areas, providing support favoring the holistic nature of SA and its use in the teaching/learning nexus in Mathematics and Statistics. Additional evidence came from the feedback from participants responding to semi-structured interviews, opinionnaires and students' academic records. Implications for Mathematics and Statistics education are discussed and recommendations for future research in this area are proposed.

Keywords: Self assessment, mathematics education, statistics education, business studies, humanities, science, technical studies.

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INTRODUCTION

Using the operational definition of self assessment (SA) as the involvement of students in identifying standards and/or criteria to apply to their work and making judgments about the extent to which they met these criteria and standards (Boud, 1986:5), a number of experts have propounded the virtues of self assessment. McAlpine (2000) insisted that self assessment promotes intrinsic motivation, and critical thinking, and assists in the development of independent learners. Towler and Broadfoot (1992) emphasized the need for a school approach to facilitate the training of students in self assessment skills. Topping (2002) also called for an exploration of the effects of self assessment. Black & Wiliam (1998b:10) posited that pupils can only achieve a learning goal if they understand that goal and can assess what they need to do to reach it. Fontana & Fernandes (1994); Ninness, Ninness, Sherman & Schotta (1998); and Klein (1998) concentrated on the use of self assessment skills in Mathematics, Billingsley (1995) in Writing, and Oskarrson (1984) and Blue (1994) in Foreign Language. A comprehensive study accepted the challenge to design, construct and implement self assessment modules (available upon request) that deliberately sampled a variety of traditional subject areas and offered regular on-site researcher monitoring in order to train high school teachers, who would in turn train their students in self assessment skills, independent of subject area disciplines. Because Mathematics with Statistics was compulsory for all students, Mathematics and Statistics education was impacted by SA training.

PARTICIPANTS

Using predetermined criteria, ten state-owned high schools were selected, representative of the top, middle and bottom achieving schools, stratified according to a triangulation of criteria (1) academic excellence (2) parental endorsements and (3) Ministry of Education ratings. This produced a sample comprising 515 Form 5 students (15 – 17 years old, Grade 11: USA equivalent; Year 10: Australian equivalent) from a small Caribbean island. All students in the same class were taught the same subject by the same teacher at the same time. The sample represented approximately a quarter of the population undertaking study in Form 5 on the island. A group comprising 256 students received formal training in self assessment skills. Another group of 259 students received no formal training in self assessment skills. The control group was drawn from different classes at the same schools and matched with the experimental classes using the criteria listed above. The tossing of an unbiased coin (control = heads) determined the treatment groups. There 233 male participants.

DATA ANALYSIS

A matrix M with 130 variables formed the entire dataset. Five hundred and fifteen rows represented the total number of participants from both treatment groups. In the matrix M, Column 1 contained information about the sex of the participants (male or female); Column 2 contained information about the treatment groups (experimental or control); Columns 3 -50 incl. (1 for each item entry) contained information about the total number of items in the self assessment profile 1 (SA1); Columns 51-58 incl. (2 digits maximum) contained information about the scores on self assessment scales in SA1; Columns 59-60 incl. (2 digits maximum) contained information about the composite or total score on SA1; Columns 61-124 incl. (1 for each item entry) contained information about the total number of items in the self assessment profile 2 (SA2); Columns 125-132 incl. (2 digits maximum) contained information about the scores on self assessment scales in SA2; Columns 133-134 incl. (2 digits maximum) contained information about the composite or total score on SA2; Columns 135-142 incl. (2 digits maximum) contained information about the quantified academic achievement (AA) scores for curricular areas of Business Studies (AAb), Humanities (AAh), Science (AAs) and Technical Studies (AAt); Columns 143-144 incl. (2 digits maximum) contained information about the composite or total academic achievement (AA) score.

A factor analysis of the interrelationships obtained from scores on self assessment variables would not produce factors that could be interpreted as variations in subject curricular areas underlying academic achievement (AA) was the specific hypothesis formulated for testing. In order to examine the factor structures underlying all items in SA2 for each of the four curricular subject areas of Business Studies (AAb), Humanities (AAh), Science (AAs) and Technical Studies (AAt), a total of four factor structures were examined, representing the four curricular areas in AA. The four datasets for this purpose were: SA2AAb (variables in columns 61-124 (incl.), 135, 136, n = 174); SA2AAs (variables in columns 61-124 (incl.), 137, 138, n = 159); SA2AAh (variables in columns 61-124 (incl.), 139, 140, n = 329); SA2AAt (variables in columns 61-124 (incl.), 141, 142, n = 272). The subjects are categorized in curricular area (Table 1).

Table 1. *Categorization of subjects in curricular areas*

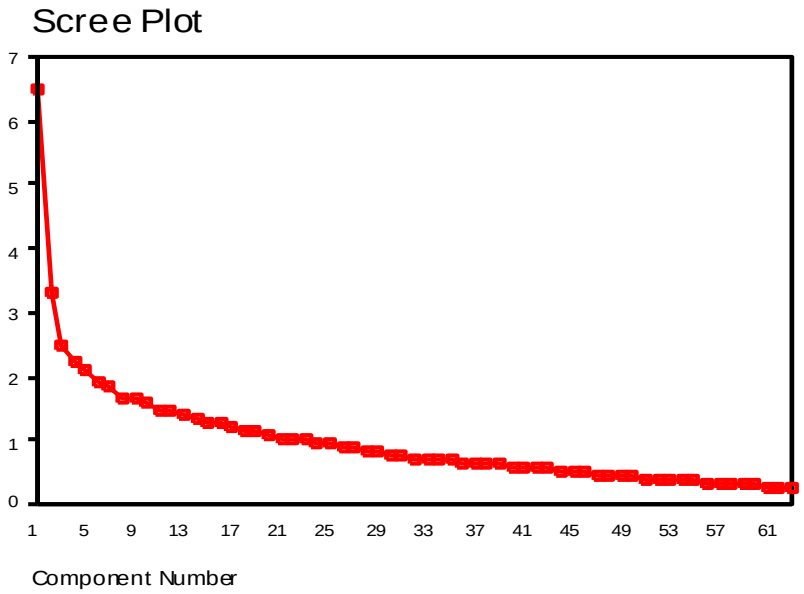
Business Studies AAb	Humanities AAh	Science *AAs*	Technical Studies AAt
Principles of Accounts	Caribbean History	Agricultural Science (DA, Double Award)	Building Technology
Principles of Business	**English B** (English Literature)	Agricultural Science (SA, Single Award)	Woods
Office Procedures	**French**	**Biology**	**Electrical Technology**
Shorthand and Typed Transcription	**Geography**	**Chemistry**	**Food & Nutrition**
Typewriting	**Music**	**Integrated Science**	**Home Economics Management**
Information Technology	Religious Education	**Physics**	**Information Technology**
	Social Studies	**Electricity/Electronics**	Mechanical Engineering Technology
	Spanish	**Geography**	**Metals**
	Visual Arts	**Information Technology**	**Technical Drawing**
			Visual Arts
			Clothing & Textiles

Note. English A (English Language) and Mathematics with Statistics were compulsory for all students and were therefore not included into the curricular areas as defined above. English A (English Language) and English B (English Literature) are two separate subjects. Agriculture Double Award is considered is equivalent to two subjects but Agriculture Single Award is considered one subject.

RESULTS

The matrix of intercorrelations (available upon request) was carefully studied to anticipate the links among groups of variables prior to factoring and rotation. The matrix showed that a number of variables appeared to be linked to each other. The results obtained from SPSS using each dataset were graphically illustrated in Figures 1, 2, 3 and 4. Sampling adequacy was confirmed (Kaiser-Meyer-Olkin (KMO) = .86) and the Bartlett's test of sphericity was significant (.02), confirming that the correlation matrix was not an identity matrix. From the SPSS linear factor analysis, the Scree plot for SA2AAb (Figure 1) confirmed a two factor model (eigenvalues: 6.5, 3.4), accounting for 64.59% of the variance.

Figure 1. *Scree Plot for SA2AAb*

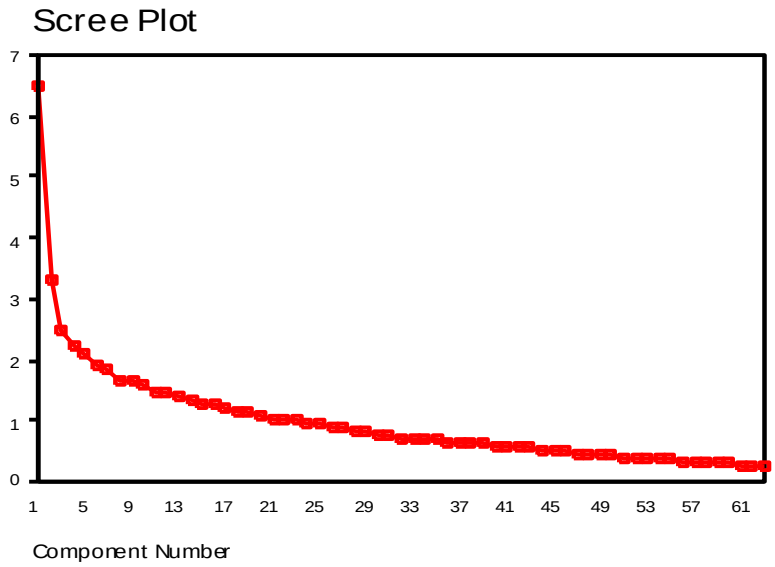


The component transformation matrix showed both factors having a low correlation of 0.19 indicating that the two factors were measuring fairly discrete attributes of the construct self assessment. Other factors emerging with eigenvalues greater than one (2.5, 2.3, 2.1, 1.9, 1.8, 1.6, 1.5, …, 1.0) were bunched together and were contributing minimally to the total overall variance (3.92%, 3.51%, 3.28%, 2.99%, 2.93%, 2.61%, 2.56%, …, 1.57%).

Whilst one may argue that at a glance there appears to be three factors, one must bear in mind that an overall judgment must be taken, noting all the following considerations, Keiser-Guttman rule for eigenvalues greater than 1 and selectively retaining only those factors with eigenvalues greater than 1 or greater than the average eigenvalue in the sample; 'elbow' where there was a rapid decline to a flat slope; intersection between the Scree plot and the plot of eigenvalues from random data (Horn's parallel analysis and Horn's modified parallel analysis); overall fit as each successive factor was added using the chi-square test of residuals; low correlation (.21) between the identified factors; high correlations between scales that loaded on the same factor or latent trait; low correlations between items that loaded on different factors; univocal loadings on the identified factors; conformity of fit indices (□2, CFI, IFI, TLI, RNI, RMSEA, SRMR, NFI, NNFI, GFI, AGFI, PGFI) to acceptable values); results from non linear factor analysis using dual scaling analysis from the DUAL3 computer program; results from non linear factor analysis using IRT from the NOHARM computer program and theoretical definition of the construct from the current literature and contextual interpretation of the same.

In a similar manner, the Scree plot for SA2AAh (Figure 2) also confirmed a two factor model (eigenvalues: 6.5, 3.4), accounting for 64.44% of the variance as confirmed from the table of commonalities.

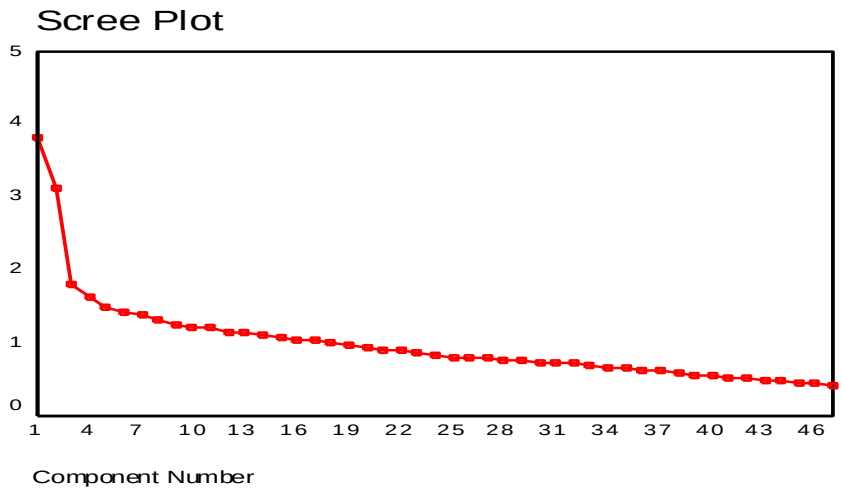
Figure 2. *Scree Plot for SA2AAh*



The component transformation matrix showed both factors having a low correlation of 0.20, indicating that the two factors were measuring fairly discrete attributes of the construct self assessment. Other factors emerging with eigenvalues greater than one (2.5, 2.3, 2.0, 1.9, 1.7, …, 1.0) were bunched together and were contributing minimally to the total overall variance (3.94%, 3.75%, 3.22%, 3.04%, 2.70%, …, 1.57%). Despite conventional criteria, the reasonableness of the solution and the interpretability of the other factors guided the selection process.

From the SPSS linear factor analysis, the Scree plot for SA2AAs (Figure 3) also confirmed a two factor model (eigenvalues: 6.5, 3.4), accounting for 64.57% of the variance.

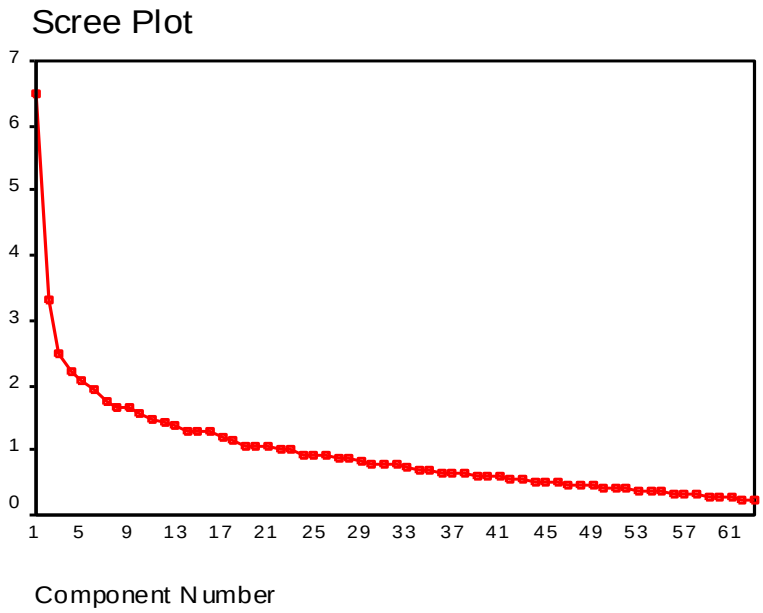
Figure 3. *Scree Plot for SA2AAs*



The component transformation matrix showed that both factors had a low correlation of 0.21, indicating that the two factors were measuring fairly discrete attributes of the construct self assessment. Other factors emerging with eigenvalues greater than one (2.6, 2.3, 2.1, 2.0, …1.1) were bunched together and were contributing minimally to the total overall variance (4.06%, 3.62%, 3.28%, 3.07%,…,1.58% respectively).

In the case of SA2AAt, corresponding eigenvalues for the two acceptable factors were 6.5 and 3.4 (Figure 4), accounting for 62.71% of the variance.

Figure 4. *Scree Plot for SA2AAt*



Other unacceptable factors had eigenvalues of 2.5, 2.2, 2.1, 1.9, 1.8…1.0 with contributing variances of 3.90%, 3.44%, 3.24%, 3.00%, 2.77%,…1.59% respectively. Further, the total variance accounted for appeared similar for each curricular area. In summary, a similar two factor structure was apparent for all four curricular areas (AAb, AAh, AAs, AAt). For comparison these variances are summarized in Table 2.

Table 2. *Results of linear factor analysis on SA2 using curricular areas of AA*

Code	Curriculum area	Accepted eigenvalues	% variance explained by two factors
AAb	Business Studies	6.48, 3.40	64.59
AAh	Humanities	6.49, 3.41	64.44
AAs	Science	6.47, 3.39	64.57
AAt	Technical Studies	6.47, 3.39	62.71

During and after the formal training in self assessment skills, students were invited to comment on any aspect of the program they desired. From a total of 256 students in the experimental group, 85 % of students responded. The researcher reviewed and grouped together the comments under classifications like, nature of the formal training program in self assessment skills; teachers and teaching methods; career guidance; compartmentalization of subjects; examination schedules and support mechanisms. Of interest in this specific paper are the comments regarding compartmentalization of subjects. Eighty-seven percent of the respondents to the survey reported a new revelation of understanding how the curricular areas were neatly integrated into the entire learning process. Here are some direct quotes from selected students:

> '*…because of the nature of the formal training in self assessment skills I am better able to see how all subject discipline, especially Mathematics and Statistics, are integrated into the whole process of learning'…*(Mia, School B)

> *'…for me not being bound by a syllabus was rather refreshing'* (Joe, School A)

> *'…formal training in self assessment skills took us through examples from a variety of different subject disciplines, especially Mathematics and Statistics, thereby allowing us to see the that knowledge is really a whole,… but it is deliberately divided into parts (subjects) for teaching purposes'* (Sue, School E).

Names and schools are given pseudonyms for preservation of anonymity confidentiality.

In summary, there was evidence to indicate that a factor analysis of the interrelationships obtained from scores on SA variables did not produce factors that could be interpreted as variations in curricular areas underlying academic achievement, as measured by the external regional examinations. SA appears to permeate all curricular areas, (Mathematics/Statistics included), a finding that appears to be in keeping with the very nature of self assessment as expounded by theoreticians in the literature.

DISCUSSION AND CONCLUSIONS

This present paper is an outgrowth of a more comprehensive study that was undertaken in a small country with a population of just over a quarter million, which by virtue of its size may be considered to facilitate change spreading more rapidly than in larger countries. In that broader comprehensive study high school students were trained in self assessment skills and their performance in external examinations was compared to students who were not similarly trained (control group). Results showed that those who were trained significantly

outperformed their counterparts in all curriculum areas, with special reference to Mathematics with Statistics, which is compulsory for all students. Among other factors (not applicable for discussion in this present paper), it may be possible that there may well have been some Hawthorne or Halo Effect in the schools that adopted self assessment training with the enthusiasm of the teacher, the visits of the researcher and the excitement of the students about something 'different' facilitating a more positive learning environment than existed in the control classes.

The nature of the current education system on the island may be considered to promote subject area specialization with its possible inherent tendency to promote compartmentalization and discipline superiority in the minds of its clients. Students doing well in Mathematics with Statistics are normally considered to be 'brighter' than their peers taking art, business and technical subjects. Accordingly, any educational innovation, however different from what existed before, may tend to be viewed in the model of subject or curriculum disciplines. Self assessment training introduced into the high schools was deliberately organized to infiltrate all traditional subjects or curricular disciplines in a manner that attempted to lay the foundation for the kinds of skills students would need as lifelong learners after leaving high school. Boud (2000) observed that while learning tasks in work and life are not formulated as examination questions, the kinds of approaches to identifying criteria for successful performance are the kinds of activities that provide the basis for sustainable assessment for lifelong learning. The twelve researcher-designed self assessment training modules focused on a variety of subject areas (English, Mathematics with Statistics, Information Technology, Spanish, French, Biology, Physics, Chemistry, History and Geography), and provided students with the varied scope for identifying standards and/or criteria to apply to their work and making judgments about the extent to which they met these criteria and standards (Boud, 1986:5). The question that inevitably arose was, 'Can self assessment operate across curricular areas including Mathematics and Statistics?' The signature mark of this present paper is that it seeks to provide empirical evidence that self assessment is curricular independent and the methods used in training may be used in Mathematics and Statistics education. Evidence provided earlier clearly indicates that self assessment operates independently of curricular areas. Could it be that it is the curricular independence of self assessment that allows well known writers on formative assessment like Black, Wiliam and Izard to elaborate on the many pitfalls of assessment usage that are evident in academia today?

The self assessment training provided was intended to engage students as active participants in their own learning (constructivism) and foster learner reflection on their own learning processes, styles and outcomes; an essential ingredient in Mathematics and Statistics education. Generally, high school students felt that self assessment training permitted them to be reflective, introspective, analytical, critical, autonomous and empowered, which are well known attributes of Mathematics and Statistics education. The students reported that they were better prepared to make informed choices and decisions

about their general lives. For them, the non-compartmentalization of information into discrete subject areas allowed them to appreciate real life problems and find suitable solutions; a skill that is easily transferable to Mathematics and Statistics education. The participants claimed that they were able to see how all subject disciplines were integrated into the whole process of learning. They reported that 'not being bound by a syllabus was rather refreshing'. Self assessment was perceived as assisting in the transference of material from one subject to another because of the methodology utilized in formal self assessment training. High school students felt empowered because of their prior knowledge of their level of preparedness for any impending task. Further, the longitudinal process activated and integrated the learner's prior knowledge and revealed developmental pathways in learning, impacting in the longer term, self-management of learning, facilitating continuous adaptation, modification and tuning of learning by the learner, rather than waiting for others to intervene (Topping, 2002).

Additionally, the broader, more comprehensive study facilitated the shift from traditionalism or authoritarianism to individualism in education since the focus is now on constructivism. Student-centered learning and problem-based learning, in contrast to teacher-centered learning augur well for the advancement of personal goals. Self assessment training appears to have a broad based support from those with a 'progressive' educational philosophy; those who are desirous of having students rigorously engaged in a given subject area and those who would like to permit students' flexibility in learning (Boud, 2002; Topping, 2002). This multi-purpose nature of self assessment underscores further the importance of the comprehensive study.

An individual's Curriculum Vitae (CV) or Résumé is, in a sense, a self assessment of that individual because it represents that individual's phenomenological view of his or her own academic and other personal achievements. A student who has developed self assessment skills may enhance his or her Curriculum Vitae (CV) or Résumé by using those skills to assess and record his or her own accomplishments. Whilst formulating one's Curriculum Vitae (CV) or Résumé, one realizes that curricular disciplines are merely formulated for ease of instruction and for facilitating use of expertise from subject specialists in a variety of curricular disciplines. Such realization intuitively provides a hunch that self assessment should be independent of curricular areas. Incidentally, prospective employers may have important information about potential characteristics of employees at entry points into organizations from résumés.

Empirical support for curricular independence from self assessment may also have implications for Mathematics and Statistics education. The extent to which an individual takes responsibility for his or her actions through self assessment may determine the extent to which he/she can rationally decide whether or not to participate in public demonstrations, civil rights activities or social unrests. Usually in real life situations, participation in such activities is not subject specific. Self assessment, with its non-curricular attribute, may assist individuals in nonviolent conflict resolution given their enhanced ability

to calculate and reason. Participants who are taught to empower themselves through self assessment skills may tend to make worthwhile contributions for meaningful change. That learned ability, to make judgments, independent of subject disciplines, based on informed choices, that is developed and reinforced through formal training in self assessment skills, may create a powerful human being capable of sound judgment and having the ability to make behavioral modifications to every area of academic, social, spiritual, physical, economic and emotional life.

One distinctive feature of the non-curricular nature of self assessment that is worth mentioning here is its inherent benefits for special students studying Mathematics and Statistics, with a wide range of diverse needs. As a result of self assessment practices the issue of unfair competition with more enabled peers may be minimized, since each student may be adjudged in the light of his or her own abilities and unique personality, across subject areas. Thus, expectations for special students may be different from their gifted peers so that unnecessary stress to perform impossible tasks may be minimized.

Excellent Mathematics and Statistics education demand that current innovative research be used to inform practice on an ongoing basis. A better understanding of the factors that influence teaching and learning coupled with appropriate action would undoubtedly lead to improved student achievement. Recognition of the role of self assessment in honing a variety of important life skills augurs well for better Mathematics and Statistics education. In particular, the process of identifying standards and/or criteria to apply to work and making judgements about the extent to which they meet these criteria and standards facilitates the kind of reasoning that is necessary for Mathematics and Statistics. More importantly, is the transference of such skills to all other areas of endeavor that redound to a well rounded individual.

This present paper confirmed that a factor analysis of the interrelationships obtained from scores on self assessment variables produced factors that could be interpreted as interindividual variations on certain variables underlying self assessment, with resulting powerful consequences for Mathematics and Statistics education and the holistic development of the individual.

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