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A review of Instruments Created to Assess Affect in Mathematics

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In this article, the author provides a discussion of instruments created to help researchers assess affect in mathematics. Published literature was the source of data for the review. The first conclusion is that individuals in educational psychology and mathematics education have helped affect instruments evolve from fairly rudimentary instruments to far more sophisticated instruments used in the assessment of affect in mathematics. As an example, many of the early instruments were used to assess only one component of affect. More recent instruments have been created to allow researchers to investigate multiple facets of affect simultaneously. The second conclusion is that additional needs exist for researchers and educators to accurately assess and fully realize the value of affect in mathematics.

Key words: Affect, assessment, instruments, mathematics.

Educators are in a potentially historic era with respect to pressure on standardized assessments. When excessive efforts are donated to ensuring adequate performance on one test, such as a standardized assessment, other components of education may be sacrificed. Unfortunately, dispositions and motivation are the components of education that are potentially the item most frequently neglected as a result of increased attention to standardized assessments. This is disconcerting because a myriad mathematics educators have pointed to the significance of dispositions and motivation in the mathematics classroom as cited later in the article. The emphasis of this article is on affect and how it has been assessed with students during mathematics.

The term affect has taken on many meanings in the field of psychology. As an example, many individuals use affect as a substitute for terms such as motivation (Holinger, 2008; Jang, Bai, Hu, & Wu, 2009) and disposition (Larsen, 2009), as they have been used interchangeably in literature (Hoffman, 1986). Additional terms associated with affect are feelings (Efklides, Papadaki, Papantoniou, & Kiosseoglou, 1997; Kunzmann, Stange, & Jordan, 2005) and beliefs (Toussaint & Friedman, 2009). When closely analyzed, i.e. through a careful look at its subcomponents, the construct of affect gains clarity. As a result, affect is a more precise term than motivation, disposition, emotions, or disbeliefs. Following an operational definition of affect, the psychological term construct will be defined. Simultaneously, some of the challenges associated with measuring affect will be outlined. A review of selected instruments is provided along with an explication of what the field of mathematics education is doing to meet the needs of the future.

What is Affect and Why measure it?

Consistent with the perception of affect in the field of psychology, scholars in mathematics have referred to affect as motivation (Chouinard & Roy, 2008; Shin, Lee, & Kim, 2009), dispositions (Fennema & Sherman, 1976; Gresalfi, 2009), emotions (Davis, 2007; Else-Quest, Hyde, & Hejmadi, 2008; Frenzel, Pekrun, & Reinhard, 2007), beliefs (Chouinard & Roy, 2008; Grootenboer, 2003), and attitudes (Chouinard & Roy, 2008; Fennema & Sherman, 1976; Grootenboer, 2003) in mathematics education (Hart & Walker, 1993; Hoffman, 1986; McLeod & Adams, 1989). However, Anderson and Bourke (2000) suggest that motivation and affect may be redundant because motivation is implicit throughout all aspects of affect. They define affect as comprised of the sub-components: anxiety, aspiration(s), attitude, interest, locus of control, self-efficacy, self-esteem, and value.

The impetus for measuring affect is precipitated by its importance in the learning process. In 1916, Binet and Simon acknowledged the significance of measuring affect in school learning, though they used different terminology, i.e. non-intellectual characteristics, at the time. In fact, they stated that non-intellectual characteristics were as important as intellectual characteristics in learning. However, they conducted no empirical studies to substantiate or negate this claim. This claim may seem particularly odd coming from the creator of the intelligence quotient (IQ) test. Binet and Simon further promoted the notion that non-intellectual characteristics must be developed prior to intellectual characteristics as they are prerequisite to the successful development of intellectual characteristics. Non-intellectual characteristics later came to be known as non-cognitive variables. A principal component of non-cognitive variables is of course affect, as Messick (1979) described. Hence, going on the premise forwarded by Binet and Simon, neglecting affect completely at the expense of standardized assessments becomes problematic and short-sighted as affect is a large piece of why students perform as they do on standardized assessments. Binet and Simon made this recognition nearly 100 years ago. Incidentally, the significance of affect may be most applicable to students of advanced intellect in middle grades. This is because they run the risk of performing very well on mathematics assessments, due to low ceilings, while concurrently becoming disengaged from genuine learning in the classroom. In the end, low affect and disengagement are the by-products which come as a result of boredom. Hence, a dichotomy in performance and affect may often occur which may be inexplicable to many assessment experts even though a perfectly logical explanation exists for the dichotomy. It is imperative to note however that assessments are a crucial component and connection to learning, teaching, and the interpretation of the curriculum which has practical applications in the mathematics classroom. However, just as assessments should focus on measuring the explicit curriculum, they must also focus on any and all factors that impact its transmittance to students. Affect, as hypothesized by Binet and Simon, is arguably the single greatest factor that impacts the learning process. Very few instances of anomalous data from Trends in International Mathematics and Science Study (Mullis, Martin, Gonzalez, & Chrostowski, 2004) have called this assertion into question. Moreover, the anomalous data was not significant enough to impact the overall correlation between affect and achievement in any of the four, 1995, 1999, 2003, and 2007 TIMSS reports (Martin & Kelly, 1996; Mullis, Martin, & Foy, 2008; Mullis, Martin, Gonzalez, & Chrostowski, 2004; Mullis, Martin, Gonzalez, Gregory, Garden, O'Connor, Chrostowski, & Smith 2000).

What Challenges are Associated with Measuring Affect?

Psychology is at the cornerstone of learning mathematics. One of the biggest barriers in accurately measuring affect is that affect is a construct. Not only is affect a construct, but it is an exceptionally complex construct to measure because it has a large number of sub-components. The complexity of psychological constructs is that they are ostensibly non-measurable attributes. For instance, the constructs of anxiety and interest are far more difficult to measure than measurable attributes such as height or weight. This is because society has agreed upon what constitutes an inch, meter and pound, but it has not agreed upon what constitutes psychological constructs such as anxiety or interest. As such, quantifying them is maximally problematic, but not impossible. Recently, some psychologists have started to define some of these constructs in an attempt to measure or assess them in schools. Moreover, increasingly sophisticated statistical procedures have enabled educational psychologists the opportunity to quantify psychological constructs such as those in mathematics teaching and learning.

Another factor that makes measuring affect challenging in mathematics is that there are three characteristics to each component of affect: target, intensity, and direction. The target refers to the object, activity, or idea towards which the feeling is directed. The intensity refers to the degree or strength of the feelings. The direction refers to the positive or negative orientation of feelings. Table 1 illustrates affect and the factors involved in measuring it.

Table 1
Illustration of Factors Involved in Measurement

	Anxiety	Aspiration	Attitude	Interest	Locus of Control	Self-efficacy	Self-esteem	Value
Target								
Intensity								
Direction								

In essence, these components and factors are the sum-total of non-cognitive variables in mathematics education. Therefore, measuring affect in mathematics is at the intersection of mathematics, psychology, and education. Although, mathematics educators have perhaps done more to investigate affect than have experts in any other (school) discipline, a great deal remains misunderstood as a result of a lack of empirical research (MacLeod & Adams, 1989). Sadly, the aforementioned thought from MacLeod and Adams has not changed in the past 20 years.

What is the evolution of instruments, and studies, to measure affect?

Historically, affect gained the attention of social psychologist researchers at the start of the 20th century (Thompson, 1992), although at the time they had no formal instruments to investigate or quantify affect. Subsequently, with the onslaught of attention donated to only observable behavior, given the immense emphasis on behaviorism in the 1920s and 1930s, affect which was at the time considered a non-observable behavior, was of little concern to researchers. Interest in affect re-emerged near the late 1960s and early 1970s. In the next section, the evolution of instruments designed to measure affect is outlined.

For at least 40 years, mathematics educators have been creating instruments to assess affect (DeBellis, 1996; DeBellis & Goldin, 1997; DeBellis & Goldin, 1993; Goldin, 2000; McLeod, 1989, 1992, 1994). Given a myriad of instruments, an exhaustive list of all instruments created to assess affect in mathematics is beyond the scope of this article. Hence, three criteria were used to identify instruments for discussion: statistical data, innovation, and amount of use (from the field of mathematics education). Each instrument discussed has some component of statistical data, innovation, and/or attention.

The first criterion used for identification was statistical data. Specifically, instruments with established validity and reliability coefficients, .80+, are discussed. As an example, Richardson and Suinn’s (1972) Mathematics Anxiety Rating Scale has an internal consistency of .97 and several studies point to high construct validity. Coefficients in this range are typically considered to be sound instruments (Nunnaly, 1978) by members of the mathematics education community. The second criterion used for identification was innovation which means that the instrument provided data on a new facet of affect. All instruments discussed have some degree of innovation in this respect. The third criterion, which is somewhat nebulous in nature, was amount of use in the field of mathematics education. In using the term amount of use, instruments that have ultimately generated multiple follow-up studies or literature reviews are cited. The Fennema-Sherman (1976) Mathematics Attitude Scale is the best example of a high amount of use in the field of mathematics education. The number of actual studies that have used this instrument cannot accurately be counted as a myriad of published as well as unpublished studies have used it. Moreover, most novices in the field of mathematics education are cognizant of the Fennema-Sherman Mathematics Attitude Scale. With each instrument, discussion and commentary are provided. It is important to note that many scales have the word attitude in the title. Historically, the word attitude was used generically to reflect constructs such as enjoyment, value, interest, etc. In more recent times, the term attitude has gained clarification as a construct which is a specific use of attitude rather than a generic one. Hence, when new studies are cited, it may not appear as though a new construct was clarified through the study because the title does not appear to change. In reality, these studies have been cited because they do bring a new perspective to the field of mathematics education.

National Longitudinal Study of Mathematical Abilities

The first study of affect in mathematics was innovative and had high reliability (ranging from .59 to .85), though it did not result in the creation of an instrument that was widely used. This study was conducted on a curriculum that was developed by the School Mathematics Study Group (Higgins, 1970). For this study, researchers focused on student attitudes with the use of 18 scales developed by the National Longitudinal Study of Mathematical Abilities (NLSMA). Their focus was on trying to identify an attitude shift from before instruction to after instruction. Hence, a pre and post-assessment paradigm was used. Results indicated that attitude shifts existed, but that they were rather nominal. Moreover, the attitude shifts, which in many cases were downward shifts, from this study had no significant impact on achievement. McLeod (1994) stated that the reliability of the instrument was questioned at the time and validity was not as much of a concern of the study as was reliability. Some researchers further questioned the data and implied that the data indicative of significance from pre to post-assessments might have been a result of such a large number of participants (>850). That is to say, the greater the number of participants, the easier it is to reach significance. In the end, the overall concept of the study may have been more important to the field of mathematics education than the results of the study were. Specifically, a nationally organized study designed to invest a great deal of time and effort into the investigation of attitude had a very significant impact on the direction of affective assessment in mathematics. Moreover, the study brought attention to the relationship between affect and mathematics achievement.

Mathematics Anxiety Rating Scale

The second study was one conducted by Richardson and Suinn (1972). They developed the Mathematics Anxiety Rating Scale (MARS). It was widely used to assess student anxiety and it was one of the seminal instruments in the field in the early 1970s. This instrument had impressive reliability with ranges from .78 to .96 (Capraro, Capraro, & Henson, 2001) and high validity to substantiate its effectiveness at measuring student anxiety in mathematics. It is a 98-item scale which was comprised of concise descriptions of mathematical situations in which college students rated their anxiety. Richardson and Suinn (1972) indicate that the assessment may be used in therapy or research. One limitation of the instrument was that it did not have applications for use in elementary or secondary public schools as it was validated with tertiary students. Even an unsystematic search of the literature would indicate the ease with which one may find follow-up studies using the MARS. As such, the instrument was high in use in subsequent studies.

Mathematics Attitude Scale

The third study that had a major impact was one conducted by Aiken (1974). He realized that one of the faults of the NLSMA study was that it viewed attitude as a uni-dimensional concept. Similar to the NLSMA investigation, Aiken's research may not have had a significant impact on attitude research per se, inasmuch as it helped him suggest that perhaps the concept of emotions and dispositions may be comprised of more facets than merely attitude. This opened up discussion on what constitutes affect in mathematics. As an ancillary by-product, Aiken claimed that attitude may be multi-dimensional rather than uni-dimensional. Aiken's components of attitude were enjoyment and value of mathematics.

Fennema-Sherman Mathematics Attitude Scale

The fourth study was one conducted by Fennema and Sherman (1976). In the 1980's, this scale was used widely and surprisingly it is even used to this day, nearly 35 years after its creation. The current use of it may be problematic though as word meanings may change over a period of nearly three and a half decades. Some individuals using the instrument have relied on a revised scale that has been validated more recently (Hackett & Betz, 1989). Even still, this revised instrument is now nearly 15 years old. As Huck (2003) states, validity and reliability coefficients are merely estimates so a one-time validation of an instrument should not serve as a compelling rationale to use an instrument with a population that is dramatically distinct from the initial population. Simply because validity and reliability estimates were once obtained with a group for an assessment does not indicate that it will hold for another group especially some 20 to 30 years after the estimates were ascertained. Thus, reliability and validity estimates may become less stable over excessively long periods of time (e.g. several decades).

The Fennema-Sherman Mathematics Attitude Scale was composed of nine separate but intricately intertwined scales. Technically, four scales measured student affect and the other five scales concentrated on issues such as gender, student perception of mother interest in math, student perception of father interest in math, student perception of teacher attitudes towards math, and the usefulness of mathematics as a domain. This instrument accomplished two objectives simultaneously. First, it was the first instrument to assess as many as four components of affect and second it helped the area of gender issues emerge in the field of mathematics. The four affective scales in the Fennema-Sherman Mathematics Attitude Scale are: (student) attitude, self-efficacy, anxiety, and value of mathematics. This instrument may be the most widely used instrument in the assessment of affect in any field.

Attitude towards Mathematics Inventory

The fifth study that has had impact on the field of mathematics education is one conducted by Tapia and Marsh (2004). They developed the Attitude towards Mathematics Inventory (AtMI). This instrument may not be cited or used in follow-up studies as regularly as the aforementioned scales, but it is innovative in that it incorporates confidence (or self-efficacy), anxiety, and value, as well as enjoyment, motivation, and parent/teacher expectations. The 49-item instrument reported an alpha (reliability) of .96. When altered to a 40 item-instrument, this reliability figure rose to .97. It appears to be the case that the mathematics education community has not engaged this instrument to the extent that it has other similar instruments and its long lasting effect may yet be realized. Table 2 provides a summary of the instruments reviewed in the chapter.

Table 2

Summary of the Instruments

Name of Assessment	**Grade Level**	**Area(s) of Affect**	**Person(s)who conducted study**
NLSMA	Secondary: Grade 8	Attitude	School Math Study Group
Math Anxiety Rating Scale	Tertiary: Freshman-	Anxiety	Richardson & Suinn

	Seniors in college		
Mathematics Attitude Inventory	Tertiary: Freshman in college	Value and Enjoyment	Aiken
Fennema-Sherman Mathematics Attitude Scale	Secondary: High school	Attitude, self-efficacy, motivation, and anxiety	Fennema & Sherman
Attitude Towards Mathematics Inventory	Secondary: High School	Self-efficacy, value, anxiety, motivation*	Tapia & Marsh

One caveat with this diagram is that some individuals consider motivation a component of affect and others suggest that the subcomponents of affect make up motivation.

The dynamics of affect, cognition, and social environment

A fifth study worthy of mention is a dissertation completed by Malmivuori (2001). It is important to note that an affective instrument was not created during this study. Instead, Malmivuori elaborates the findings of a meta-analysis completed on affect and mathematics. Perhaps the most salient point in the dissertation is promotion of the idea that affect is an integral component of cognition; not an altogether separate or unrelated aspect of the thinking process as some may suggest. Given the ostensible over-emphasis on cognition from the 1990s to current, the introduction of the idea that affect is part of cognition was significant in that it lent credence to affect as a significant factor in the learning process. Nearly 85 years after Binet and Simon claimed that non-intellectual characteristics were a requisite antecedent to learning, Malmivuori had re-asserted this claim. The difference in her claim, as opposed to Binet and Simon’s claim is that she had statistical evidence as a basis to substantiate her claim. In addition, the reference list of articles is a virtual history of research on affect and mathematics. This dissertation appears to be the most comprehensive review of literature, to date, on affect and mathematics.

Ma and Kishor's (1997) meta-analysis on attitude towards mathematics (ATM) and its relationship to achievement in mathematics (AIM) is also worthy of note and obviously the emphasis is on the interplay between attitude (not affect as a whole) and achievement. Though they did not have an instrument per se, they did use statistical procedures with data from 113 studies. The combined studies included 82,941 students in 12 grade levels with mixed genders in most of the studies. After collapsing data from the studies, it was found that the effect size between ATM and AIM overall was relatively modest with an effect size of .12.This has relatively little impact on education as it implies that the relationship between the two constructs is, practically speaking, quite weak. Data did suggest that the effect in males (26%) is slightly greater than it is in females (23%). Moreover, data suggests that the relationship between ATM and AIM is virtually non-existent with elementary students, but more pronounced with secondary students. Regarding ethnicities, the relationship between ATM and AIM appears to be significant only for Asian students, but not for any other ethnicity analyzed. Regarding sample sizes, the strength of the relationship appeared to be stronger for sample sizes under 300 and for samples over 300 the sample size was not as robust. Similarly samples were broken down into a timeline that represented five eras (1966-1970, 1971-1975, 1976-1980, 1981-1985, and 1986-1993). Prior to 1975, the effect size held no practical importance for educators, but thereafter the effect size was practically important with the greatest effect occurring in the 1976-1980 era. The researchers postulate that this difference in effect size may be attributable to more sophisticated instrumentation regarding the assessment of attitude.

The greatest implication to come from this study was the outcry for more sophisticated instruments to assess attitudes in mathematics. At the time, Leder (1987) referred to attempts to assess ATM as primitive and suggested that specific components of mathematics in relation to attitude, e.g. problem solving, should be assessed.

Future needs of affective instruments

For approximately 40 years, mathematics educators and educational psychologists have been creating instruments to assess affect. Throughout the creation of these instruments, which have laid the groundwork for future instruments, three needs have gone unmet. First, many of the early instruments were created to assess only one component of affect such as the Mathematics

Anxiety Rating Scale-Revised (Plake & Parker, 1982), the Mathematics Attitude Scale (Aiken, 1972), or the Math Self-Scale (Opachich & Kadijevich, 1997). Of course, two exceptions to this generalization are the Fennema-Sherman Attitude Scale (Fennema & Sherman, 1976) which is comprised of nine scales, four of which assess affect, and the Attitude towards Mathematics Inventory created recently by Tapia and Marsh (2004). A problematic component of the Fennema-Sherman instrument however, is that the initial instrument has not had validity and/or reliability coefficients established in over 30 years even though a shortened version was completed in 1998 (Mulhern & Rae, 1998). Moreover, the Attitudes towards Mathematics Inventory (Tapia & Marsh, 2004) have eight scales, but only four assess affect (anxiety, self-confidence, motivation, and value). Second, instruments are rarely created for direct teacher use in the classroom. They often require a highly trained school psychologist or a psychometrics to administer them, interpret the results, or both. Third, practically all of the current instruments assess students' affect regarding the discipline of mathematics in general as opposed to assessing students' affect during or after the process of mathematical problem solving as Ma and Kosher (1997) suggest. Consequently, with increased emphasis on mathematical problem solving (National Council of Supervisors of Mathematics, 1978; National Council of Teachers of Mathematics, 2000, National Council of Teachers of Mathematics, 1989; National Council of Teachers of Mathematics, 1980), it is astonishing that instruments have not been created previously for direct use during mathematical problem solving. Other than the aforementioned formalized instruments, i.e. instruments with established reliability and validity coefficients, various informal instruments exist to assess affect during or after mathematical problem solving.

Two conclusions may be drawn from this review of affective instruments in mathematics. The first conclusion is that the fields of educational psychology and mathematics education have been prolific in producing affective instruments. The evolution of instruments can be paralleled to other inventions in that subsequent instruments have been produced as needs arise. As an example, the first instruments created to assess affect often only assessed one area of affect. Researchers quickly realized that multiple areas of affect should/could be researched simultaneously with the use of one instrument rather than the use of multiple instruments.

The second conclusion is that the field of mathematics (education) appears to be a leader in content areas related to affect. However, the full value of affect may yet be realized. This is likely the result of two factors. First, affective instruments need to be created so they can be easily implemented and second the intense pressure on standardized assessments may create a barrier for assessing affect in that schools are already investing serious resources in assessing academic achievement. Perhaps the most ironic point however, is the cyclical nature of assessment in this case. Being able to help students monitor and subsequently control affect may ultimately provide significant learning increases in academic achievement yet data about affect is absent as a direct result of increased pressure on standardized assessments.

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