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Attitudinal scale measures in Euclidean geometry: What do they measure?

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The purpose of the study was to look at the two forms of validation, i.e. face validity and construct validity, of an attitudinal scale measuring learners' attitude towards Euclidean geometry. The article teases out elements involved in face and construct validation and then engages in a discourse to highlight and investigate those elements in validation that may be untenable in the light of existing practice. With the support of empirical data, the argument presented is that the use of face and construct validity should be a given in studies involving the measurement of attitude.

Introduction

There have been a number of studies investigating learners' attitude towards mathematics or a specific aspect of mathematics (Aiken, 1970; 1976; 1979; Kulm, 1980; Mcleod, 1992; Mogari, 1994; Ruffel *et al.*, 1998; Galbraith & Haines, 1998). These studies present various methods of measuring attitudes of learners towards mathematics, such as, self-report, which entails using questionnaires, attitudinal scales, diaries and essays (Aiken, 1970; Kulm, 1980; Galbraith & Haines, 1998), the observations and interviews (Aiken, 1970; Kulm, 1980). Of all the self-report methods mentioned, attitudinal scale seems to be widely preferred particularly the Likert scale-type one, which measures the extent to which the subjects agree or disagree with the statements by selecting the appropriate column (for example, see Figure 1). For instance, Visser (1986; 1987) used Likert-type attitudinal scales to measure learners' and parents' attitude towards mathematics; Aiken (1979) used two four-component Likert-type attitudinal scales to measure learners' attitude towards mathematics and science; Maqsud (1992) used an attitudinal scale adapted from Aiken's study to measure learners' attitude towards mathematics, etc. The article investigates the extent to which face and construct validity account for the accurate measures of the Likert-type attitudinal scale with reference to learners' attitude towards Euclidean geometry. Attitude in this study refers to one's predisposition towards Euclidean geometry that is a composite variable of enjoyment, motivation, value and belief.

Conceptual framework

What is crucial when measuring pupils' attitudes towards Euclidean geometry is that one should confidently accept the resulting measure produced by the attitudinal scale used. How does one then develop confidence in the measures of an attitudinal scale? Concomitantly, can attitude be accurately measured? Embedded in these questions is an attempt to delve into the extent to which the scale measures learners' attitude towards Euclidean geometry. Accuracy refers to the correctness and exactness with no error of measurement. On the other hand, a measuring scale, for instance an attitudinal scale, is set to be valid if it really measures what it is supposed to measure (Leedy, 1993; Cohen & Manion, 1985; Gay, 1996). In this article, validity refers to the degree with which an attitudinal scale measures learners' attitude towards Euclidean geometry. An attitudinal scale yields authentic results or displays qualities that make the resulting measure acceptable if it is free from any doubts or questions about its accuracy (Leedy, 1993:40).

According to Sakaran (1992) an attitudinal scale is valid when the researcher is reasonably sure that the scale is measuring the construct, behaviour or trait it is set out to measure. Normally one feels confident about the measures of an attitudinal scale if he/she is certain that the validity of the scale has been properly established. As Cascio (1998) indicates 'what a scale measures' and 'how well it measures' are the primary purpose of validation. This suggests that the conclusions drawn about the specific use of an attitudinal scale are the ones validated instead of the scale itself. The notion has also been supported by Lubben *et al.* (2000). They argue that validity is a characteristic of the data and not of the scale itself precisely because validity is contextual. This implies that a scale may be checked or tested and found to produce valid data in a particular context and when used in a different setting it yields data of different validity.

Nevertheless, lack of certainty about the degree with which an attitudinal scale measures what it has been set out to measure, brings doubts about the accuracy of the scale. This is especially true when the attitudinal measures sought may be of great significance to the study being undertaken. Furthermore, one is led to the question: 'Do studies involving measuring attitude really yield genuine results?' The question is based on the principle that a measuring scale with flaws may produce inaccurate measurements.

In order to establish whether or not an attitudinal scale is accurate, the study reviews the processes of face and construct validation. The aim for doing so is to understand what the processes of face and construct validation entail. There is also a need to account for the supposed accuracy with which an attitudinal scale purports to measure pupils' attitude towards Euclidean geometry.

Face and construct validity

Face validity

Face validity is commonly used in educational research, particularly by postgraduate students and other novice researchers, to validate research instruments including attitudinal scale. The general perception is that face validity is convenient, easy to use and less demanding in that one identifies credible experts in the area being studied, who are then expected to studiously apply their knowledge and skills to scrutinise the instrument to determine the degree to which the scale measures what it is meant to measure. In order to do this, they are expected to establish, among others, whether

1. the scale is of the appropriate length, that is, is "the sample being measured adequate to be representative of the behaviour or trait being measured" (Leedy, 1993:41). By sample Leedy refers to a set of statements or items;
2. the statements or items of the attitudinal scale relate to the behaviour or trait being studied;
3. the statements or items are explicit and by no means ambiguous. It is important that the statements or items are interpreted correctly by respondents so as to provide genuine responses.

At the end of the process the experts provide a verbal analysis about their perceptions as to the accuracy or otherwise of the attitudinal scale. Obviously, whatever judgement they come up with regarding the attitudinal scale they were examining remains an opinion and may be different from expert to expert. But consensus among experts is crucial if the face validation has to be acceptable.

On the other hand, as Saunders & Banda (1997) noted, postgraduate students prefer to undertake research projects for their dissertations that are less problematic and hassle-free so that they could finish their degrees quicker. As a result, most of them follow the less and demanding route and get their research instruments face validated by the so-called experts. Since the students have faith and confidence in the experts they never challenge their views about the instruments. They, instead, simply effect the suggested changes and be content that their attitudinal scales have been duly validated.

Judging by the nature of this form of validation, it is evident that face validity is a subjective way of determining the validity of an attitudinal scale and provides face value analysis of an attitudinal scale. As a result it lacks a systematic analysis of the content area being studied. Hence, Gay (1996) insists that face validity should not be equated to content validity.

Construct validity

Construct validity establishes the extent to which a construct, attribute or trait is being measured. Cohen & Manion (1985) consider it as "a way of determining the nature of underlying variables among a large number of measures" (p.346). In particular, the construct validity of an attitudinal scale is determined by establishing whether the statements or items, constituting a component variable (construct, attribute or trait), do load significantly on the factor (component variable) that they are meant to measure. If those statements or items do, then they indeed measure the variable they supposed to measure. Thus, factor analysis may very well be considered a means of determining construct validity.

By virtue of the fact that factor analysis relies solely on the use of statistics it is categorised as a quantitative process of establishing the validity of an attitudinal scale. According to Gay (1996) such a statistical approach is value-free and also has potential to control extraneous variables. Hence, Browne (2000) thinks that mathematically oriented procedures provide methodology for obtaining measurements of constructs of interest particularly where summated rating attitudinal scales are used.

However, Leedy (1993) feels that statistical methods do not detect whether a response was given as a result of misunderstanding statements or words in an attitudinal scale or not. Instead they (statistical methods) only work with the scores of the responses. Sanders & Banda (1997) have also criticised the statistical methods. To them statistical procedures "reduce the data to measurable values, that tend to divert attention from factors which reduce validity" (p.13). For example, when administering a questionnaire that has badly formulated statements, methods that solely involve statistics may not detect such problems. It should be noted that badly constructed statements might lead to wrong responses especially when the attitudinal scale is not in the home language of the subjects.

Given the apparent strengths of the two forms of validation, a study is necessary to describe the extent to which face and construct validity free the attitudinal scale from errors of measurement. A review of the processes of face validation and construct validation will provide insight into the accuracy of the scale.

Developing and validating the attitudinal scale

The article is derived from a main study of the use of ethno-mathematical material, which has been developed from the activity of constructing the chassis of a miniature wire car, in the learning of properties of a rectangle with a view to establish whether it will have any effect on pupils' attitude towards Euclidean geometry. The main study was conceptualised around the fact that learning geometrical aspects in a familiar context can be fun and enjoyable. Hence, an attitudinal scale was developed to determine, using a non-equivalent control group design, the effect of the ethno-mathematical treatment on the pupils' attitude towards Euclidean geometry.

An attitudinal scale was developed and then taken through the process of determining its validity and reliability. In order to ratify the use of the attitudinal scale to measure pupils' attitude towards geometry, the scale was sent to two noted educational psychologists who have published extensively in the area of attitude towards science and mathematics. When the scale came back from face validation, all the suggested changes were made accordingly.

The next step was to ascertain whether the statements of the attitudinal scale were indeed measuring the component variables they were meant to measure. This was done using factor analysis. In order to this, the attitudinal scale was administered to a convenience sample consisting of 173 Grade 9 mathematics learners taken from three schools around Thohoyandou, Limpopo province, South Africa. The learners were expected to indicate the extent to which they agree or disagree with each statement by making a cross in the box they think it best represents their feelings. No time limit was enforced for the completion of the attitude test. After scoring the learners' responses, it was then determined whether the statements load on the component variables they were meant to measure.

Based on what emerged from the two forms of validation, a decision had to be taken about the accuracy of the attitudinal scale. The complexities and rigour of each of the processes of face validation and construct validation informed the decision. The article will therefore raise an issue with the degree of accuracy the attitudinal scale measures learners' attitude towards Euclidean geometry.

Development of the attitudinal scale

Profile of Aiken's attitudinal scale

The attitudinal scale used in this study was modelled on the one used by Aiken (1979) on the Iranian public middle schools. Aiken used the scale as a basis for determining the attitude of middle school pupils towards mathematics. The scale was a five point Likert-type scale with 24 statements to be answered by indicating whether one strongly agrees, agrees, is neutral, disagrees or strongly disagrees with each statement or not.

The scale had both negative and positive statements that measured learners' enjoyment of mathematics, motivation to study mathematics, the importance of mathematics and the freedom from fear of mathematics. Each of the four sub-variables had three positive and three negative statements. The Alpha Cronbach coefficients of the scale for each of the four variables ranged from 0.5 to 0.86 and those for the overall scale were from 0.81 to 0.91. All the coefficients were computed on the basis of grade-level and gender. The interrelation coefficients among the 24 statements suggested that only three sub-variables, i.e. enjoyment, importance and freedom from fear, were being studied because the motivation sub-variable was too closely related to the other three sub-variables, particularly enjoyment (Aiken, 1979).

Adapting Aiken's attitudinal scale

The Aiken's attitudinal scale was modified as follows:

1. Double-barrel statements in Aiken's attitudinal scale such as "I want to develop my mathematical skills and study this subject more", "mathematics makes me feel uneasy and confused" and "mathematics helps to develop the mind and teaches a person to think" had either the first or second part of the statement deleted, depending whether the statement was repeated in the attitudinal scale. The items were made short because long statements can be boring and do not appeal to the respondents (see Figure 1).
2. The wording of the statements of the attitudinal scale was made explicit and void of any ambiguity. For example,
   a) "I find geometry boring" instead of "I find mathematics dull and boring".
   b) "I need geometry in my daily activities" instead of "Mathematics is not especially important in everyday life".
   c) "I would like to develop my geometry skills more" instead of "I want to develop my mathematical skills and study this subject more".
3. The sub-scale on "freedom from fear of Euclidean geometry" was deleted and dropped by the one on "beliefs about geometry".
4. The scale was confined to geometry by replacing mathematics by geometry in all the statements of Aiken (see Figure 1).
5. The scale was shortened to 20 items, which were divided into

four sets of statements. Statements 1, 5, 9, 13, and 17 measured learners' enjoyment of geometry; 2, 6, 10, 14, and 18 dealt with how pupils valued geometry; 3, 7, 11, 15, and 19 determined on learners' motivation to study geometry and statements 4, 8, 12, 16, and 20 focused on learners' beliefs about geometry. Figure 1 contains the attitudinal scale adapted from Aiken.

Instructions: Please indicate your answer by making a cross in the column you think best represents your feelings about the statement given. SD (strongly disagree), D (disagree), U (undecided), A (agree), SA (strongly agree).

	SD	D	U	A	SA
1. Geometry is an interesting subject					
2. I need geometry in my daily activities					
3. I would like to develop my geometrical skills more					
4. In our class the teacher is the only one who knows geometry					
5. I find geometry boring					
6. Geometry can be used in situations outside classroom					
7. I would always want to learn more about geometry					
8. Methods that are used in our geometry textbooks are the best to solve geometrical problems					
9. I do not like solving geometry problems on my own					
10. I do not find geometry useful to me					
11. I study geometry only when I am going to have a test					
12. I only learn geometry when I have to revise for test					
13. I enjoy my geometry lessons					
14. I find geometry useful to me in my daily life					
15. I feel we should be given more homework in geometry					
16. I only learned my geometry at school					
17. I wish we were only taught geometry at school					
18. I have used my school geometry to solve problems outside school					
19. I intend studying as much geometry as I can in future					
20. For me to do well in geometry I have to memorise theorems and formulas					

Figure 1 The attitudinal scale adapted from that of Aiken (1979)

The internal reliability of the attitudinal scale and the four component variables, namely, enjoyment; motivation; belief; and value of geometry were then determined using the alpha coefficient of Cronbach.

Results

Reliability

The reliability was independently done using a computer software package, Statistical Analysis System (SAS). The Cronbach alpha coefficient values yielded are given in Table 1.

Table 1 Cronbach Alpha Coefficients of reliability for the four dimensions of attitude in the scale and total attitude

Variable	Alpha coefficients
Enjoyment	0.88
Value	0.89
Motivation	0.88
Belief	0.84
Total Attitude	0.85

The Cronbach alpha coefficients of the attitudinal scale compare well with those of the scale used by Aiken (1979) which ranged from 0.50 to 0.86 for the four attitudinal dimensions, namely enjoyment; motivation; value; and fear of geometry. One can claim that the attitudinal scale and its four sub-scales of the component variables consistently measured the learners' attitude towards geometry, enjoyment of geometry, their value of geometry, motivation in studying geometry and beliefs about geometry. Furthermore, it emerges from the results that the alpha coefficients for this study were relatively higher as compared to those of the study by Aiken.

Face validity

The following are points that were raised by the experts when they face validated the attitudinal scale:

1. The experts felt that long sentences like "Geometry can be used in situations outside the classroom because it involves practical problems" should be avoided. Instead, it should only be "Geometry can be used in situations outside the classroom".
2. They were happy with the wording of the statements of the test. They did not find words and statements ambiguous.
3. The level of the complexity of the language was appropriate for the second language middle school pupils.
4. Negative statements were found to be negative indeed.

Overall the attitudinal scale as well as the four component variables, i.e. enjoyment, motivation, value, and beliefs, were appropriate for the purpose they were meant for. Furthermore all the statements of the attitudinal scale were thought to be relevant for the respective component variables.

Construct validity

The factor loading of the statements of the attitudinal scale was determined through principal component (PC) factor analysis and a summary thereof is presented in Table 2. The plot of Eigenvalue shows that the data are best represented by four underlying factors. The level for inclusion of the factors for the sample size of 173 was 0.41 (Hair *et al*., 1998).

Table 2 The PC factor analysis of pupils' attitude towards Euclidean geometry

	Rotated factor pattern			
Statements	Enjoyment	Confidence	Value	Obligation
13	0.74605	0.06740	0.19093	0.13740
14	0.68526	0.09834	0.10011	–0.18809
15	0.62160	0.07141	–0.12811	0.26470
1	0.60091	–0.11558	0.09114	0.14514
19	0.46845	0.11932	0.30272	–0.28768
18	0.43484	–0.02683	0.02177	–0.10855
17	0.43179	–0.37987	0.02016	0.10782
10	0.10294	0.58263	0.15716	–0.10381
12	–0.07104	0.58168	–0.13486	0.07782
4	–0.06344	0.53839	0.00624	0.00386
11	–0.15708	0.44090	0.14644	0.32240
7	0.22941	0.38360	0.27659	0.25738
16	0.09341	0.38152	0.29432	–0.15314
2	0.20256	0.34957	0.29597	–0.02697
6	0.03129	0.02085	0.77185	–0.04660
8	0.08011	0.02760	0.61581	–0.10542
3	0.17895	0.14773	0.52177	0.34072
5	0.03283	0.39618	–0.15010	0.46788
9	0.12327	–0.04418	–0.17875	0.46418
20	0.14895	0.13885	–0.40985	–0.63502

According to Table 2, the statements loading was as follows: Statements number 1, 13, 14, 15, 17, 18, and 19 load on one factor. These were then thought to be measuring the pupils' enjoyment of geometry. The second set consisting of statements 2, 4, 7, 10, 11, 12, and 16 was set to study pupils' confidence to study geometry. Factor analysis also revealed that statements number 3, 6, and 8 load together and were taken to establish how pupils rate the importance of geometry. Lastly statements 5, 9, and 20, which loaded negatively, were thought to measure the obligatory feeling to study geometry. Statement 5 was grouped with statements 9 and 20 and not with statements

2, 4, 7, 10, 11, 12, and 16 since it loaded relatively higher in the factor thought to be obligation.

Discussion

The attitudinal scale used in the study seems to show high internal consistency coefficients. But, it appears that there are contrasting results emerging from the two forms of validation being studied. Firstly, it is evident from the results of face validity that statements for each component variable are deemed appropriate for measuring the variables they are set to measure. However, the PC factor analysis in Table 2 shows that items (= statements) loaded on four different factors (= component variables). This implies that statements that were considered, through face validation, to be genuinely measuring a particular component variable were in fact not measuring it. What seems to be emerging from the results is that the actual composition of component variables is questionable. That is, some of the statements that were thought to be measuring a specific component variable, say enjoyment, are in actual fact measuring a completely different construct. For example, 'I find geometry boring' was accepted by experts during face validation as constituting the enjoyment sub-scale when in fact, as far as factor analysis was concerned, loads with statements measuring what was thought to be learners' obligation to study geometry as well as confidence.

Secondly, the rotated factor pattern in Table 2 shows that enjoyment and confidence have seven statements, respectively, and each of usefulness and obligation has three items. This was contrary to what emerged from face validation in that there were no changes suggested in terms of the number of statements each of the four original component variables (i.e. enjoyment; motivation; value; and beliefs) have. What the experts considered as an accurate attitudinal scale during face validation turned out not to be really the case as far as construct validation was concerned. Hence, Lubben *et al.* (2000) point out that even though face validity has been thought to purport to guarantee content validity, it is insufficient if it is not supported by a systematic content of the construct being explored. For an attitudinal scale to be accurate it has to measure correctly and precisely all its component variables particularly where attitude is a multidimensional construct. Otherwise the scale does not really measure what it is meant to measure.

Thirdly, statements such as "I find geometry boring" were accepted as a negative item during the face validation process. However, in terms of factor analysis the items loaded positively, with a loading value of 0.46788. This contradicts the fact that the statement is a negative one since, according to factor analysis, positive statements load positively while negative statements load negatively.

Lastly, it emerged that face validity ensured that the wording and language of the attitudinal scale was appropriate for the group it was meant for and the statements of the scale were not ambiguous and confusing. While the factor analysis utilised the scores of the learners' responses to determine the interrelationships among the statements of the attitudinal scale. Moreover, during some of the interviews which were conducted with a sample of learners to determine what transpired during the ethno-mathematics lessons, the learners could not understand some of the English words used. As a result the interviews were done in the subjects' mother tongue with the help of an interpreter. It may therefore be that some of the learners' responses in the attitudinal scale were not genuine because of their English deficiency. However factor analysis disregards the issue of language because it only uses the scores of the responses. In other words factor analysis assumes that learners have understood the statements of an attitudinal scale. The issue of language also emerged in the study by Sanders and Banda (1997) where queries were raised about Zuckerman's affect adjective checklist used to measure the attitude of English second-language learners. The concern was about the meanings of some the words in the checklist that were thought to pose problems for learners. Certainly, if there is a problem of understanding a word or statement in an attitudinal scale, the response will not be genuine.

Conclusion

The purpose of this study was to investigate the extent to which face validity and construct validity, through factor analysis, determine the accuracy of an attitudinal scale. Reviewing the process of face validation and construct validation was perceived crucial in this regard. It, however, emerged from the study that there was no consistency between face and construct validity. What was perceived correct and precise by experts during face validation turned out not to be the case with construct validation.

However, it is evident in the study that face validity and construct validity have advantages as well as disadvantages. Therefore, one could not confidently claim that the attitudinal scale was accurate if it had only been either face or construct validated. As way of ensuring that the attitudinal scale accurately measured what it was meant to measure as far as possible, the strengths of the two forms of validation were used precisely because the two tend to compliment each other. Moreover, Fraser (1998) noted that the combined use of qualitative and quantitative approaches has made important accomplishment in educational research.

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