DEVELOPMENT AND VALIDATION OF AN INSTRUMENT FOR STUDENTS' ASSESSMENT OF MATHEMATICS TEACHERS' EFFECTIVENESS IN COLLEGES OF EDUCATION IN BENUE STATE, NIGERIA

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Abstract
Guided by three objectives which were translated to three research questions, this study developed and validated an instrument for students' evaluation of mathematics teachers' effectiveness in colleges of education in Benue State, Nigeria. It adopted the instrumentation research design in which a sample size of 352 NCE 2 and 3 mathematics students was drawn from a population of 2,930 students in colleges of education in the state. The steps in instrument development were strictly followed and the initial draft of 60 items was subjected to factor analysis which resulted in five factors with forty-two items. Kaiser's rule and eigenvalue ≥1 scree plot and Orthogonal Varimax rotation were adopted to extract five factors as dimensions of effective teaching. The data was also subjected to exploratory factor analysis and Cronbach alpha coefficient to establish the validity and reliability of the instrument. This yielded a reliability coefficient of .74 indicating high internal consistency. Based on the analysis and results, the researchers concluded that, the instrument was significantly valid and reliable. It was therefore recommended for use by colleges of education, other tertiary education institutions, researchers and measurement experts.

Keywords: mathematics teacher, factorial validation, instrument, exploratory factor analysis, teacher effectiveness, valuation.

Introduction

Mathematics is often considered as the language of science and technology. It is pervades all disciplines and competence in mathematics is vital to finding solutions to human problems and challenges. For instance, revolution electronics that transformed the way we think and communicate would not have been possible without mathematics. The invention of calculators, computers, radios, satellites, telephones and televisions would have been a mirage without mathematics. Recent development in mathematics has paved way for improvement to our ability to predict the weather, study the origin of the universe, measure effectively the effects of environmental hazards, predict with some degree of accuracy the outcomes of elections, and account for certain changes which occur in our society. All these are indications that mathematics is useful in every facet of life (Catano, & Harvey, 2011). This makes mathematics indispensable for the proper functioning of our technological society.

In Nigeria, mathematics is a prerequisite for careers in the sciences, medicine, pharmacy, engineering and other courses like accounting, economics, banking and finance. In realization of the significant role of mathematics in nation building, the

National Policy of Education (2014) made the subject compulsory in primary and secondary schools in Nigeria.

A mathematics teacher is a person who understands the class, their learning ability, their interests and their characteristics as it relates to mathematics. The teacher is a major factor in the achievement of students in mathematics as the teacher's personality, qualification, professional status, mastery of the subject and teaching skills impact significantly on students' performance. There is therefore a need to regularly evaluate who the teacher of mathematics is and how effective is the teacher's delivery.

Harbor-Peters in Adikwu, Aduloju and Agi (2016) describe evaluation as a systematic process of determining the extent to which instructional objectives are achieved by learners. Ebel in Momoh (2015) submits that evaluation of teaching effectiveness provides relevant and accurate information that facilitates wise decision making in the education sector. Chen and Hoshower in Goe, Bell and Little (2008) affirm that evaluation of teaching involves collecting evidence from various stakeholders, including students for the purpose of improving effectiveness of the teaching-learning process. Teachers need to be regularly assessed to ensure best performance.

But the question is,' How is effectiveness identified and measured? It is through the use valid and reliable instruments. Such instruments are scarce or non-existent in colleges of education in Benue State since no provision is made for them in the state's education system. Inyiagu (2014) identified various approaches to evaluating mathematics teachers' effectiveness in Nigeria. Institutions of higher learning assess teachers by the quality and quantity of publications and research work produced. Pagge in Inyiagu (2009) observes that mathematics teachers in colleges of education may divert all their energy and resources to the production of "papers" at the expense of giving sound instruction to the students since that forms the basis for their evaluation. This situation has resulted in many NCE holders of mathematics qualification having inadequate skills that will make them enter and prosper in the labour market.

Based on the shortcomings of this approach, there is a need to explore some techniques of evaluating mathematics teachers' effectiveness to supplement the existing ones as they lack the involvement of students. Nakpodia (2011) considers students' evaluation as the best to achieve teacher effectiveness. The evaluation should be based on method of teaching, communication skills, use of instructional materials, mastery of subject matter, students-teacher rapport, classroom management, motivation and reinforcement. Students' evaluation of their mathematics teachers' effectiveness therefore requires a valid and reliable instrument. The question therefore is how valid and reliable are the existing instruments to evaluate mathematics teachers' effectiveness? This calls for the development of a valid and reliable instrument for students to effectively evaluate their mathematics teachers. It is therefore expedient to provide students with an instrument if they are to evaluate their mathematics teachers' effectiveness with some validity. The present study is aimed at developing and validating an instrument that will possess both effectiveness variables and psychometric properties such as validity and reliability to

evaluate the effectiveness of mathematics teachers' in colleges of education in Benue State, Nigeria.

Research Questions

The following research questions guided the study:

What is the factor structure of mathematics teachers' evaluation instrument (MTEI)?

How many major dimensions of effective teaching will emerge from the factor analysis of the items of mathematics teachers' evaluation instrument (MTEI)?

How valid is the mathematics teachers' evaluation instrument (MTEI)?

What is the reliability coefficient of the mathematics teachers' evaluation instrument (MTEI)?

Methodology

An instrumentation research design was adopted for the study. The population consisted of 2,930 mathematics students from six colleges of education in Benue State. A multi-stage sampling procedure was used to select the sample size of 352 mathematics students. The sampling stages involved in this study were sampling of schools and research subjects - mathematics students. Proportionate stratified random sampling and simple random sampling techniques were also employed. At the first stage, the researcher employed proportionate stratified random sampling technique to randomly select the required number of mathematics students in each of the sampled colleges of education. Proportionate stratified random sampling is a probability sampling technique in which different strata in a population are identified and the number of elements drawn from each stratum is proportionate to the relative number of elements in the stratum. The colleges of education in the study area were divided into six strata from which research subjects were proportionately selected. Furthermore, simple random sampling technique was applied by using ballot papers with inscriptions of yes or no; only students who picked "Yes" participated in the study.

A sixty-item Mathematics Teachers' Evaluation Instrument (MTEI) was developed and validated for the study by the researchers. Designed to measure mathematics teachers' effectiveness in colleges of education in Benue State, the instrument had a four-point rating scale of strongly agreed (SA), agreed (A), disagreed (D) and strongly disagreed (SD).The instrument was validated at different stages by specialists in measurement, evaluation and mathematics education to determine the face and content validity. Ten out of the 70 items constructed were eliminated after face and content validity. This reduced the items to 60. The second stage was the establishment of construct validity. The retained items were trial tested on NCE 2 and 3 mathematics students and the data collected were subjected to exploratory factor analysis (EFA) which employed principal component matrix. The researcher employed exploratory factor analysis (EFA) since the researchers did not know how many dimensions would emerge. Orthogonal Varimax was used in rotating the axes because the factors were uncorrelated (Field, 2005). The items that failed to have minimum factor loadings of .400 were eliminated. This is in

accordance with the recommendations of Field (2005) that only factor loadings with an absolute value $\geq .400$ (which explains around 16% of variance) should be interpreted. The items that loaded in more than one interpretable factor were also eliminated. Out of 60 items that were subjected to factor analysis, 42 were retained while 18 were deleted.

Results

The results of the study are presented according to the research questions.

Research Question 1: What is the factor structure of Mathematics Teachers' Evaluation Instrument?

To answer research question one, principal component analysis (PCA) was conducted to confirm the appropriate number of factors to be extracted. The result is presented in Table 1.

Table 1: **Percentage Cumulative Variance of Mathematics Teachers' Evaluation Instrument**

Factors	Eigen-values	% of Variance	Cumulative %
1	10.534	17.556	17.556
2	2.871	4.785	22.341
3	2.232	3.719	26.061
4	2.150	3.584	29.644
5	2.042	3.404	33.048
6	1.660	2.767	35.815
7	1.570	2.617	38.432
8	1.542	2.570	41.002
9	1.513	2.521	43.543
10	1.368	2.280	45.803
11	1.326	2.211	48.014
12	1.299	2.166	50.180
13	1.256	2.093	52.273
14	1.221	2.035	54.308
15	1.191	1.984	56.293
16	1.156	1.927	58.220
17	1.114	1.857	60.077
18	1.030	1.717	61.794
19	1.010	1.683	63.477

Table 1 shows that 19 factors were extracted accounting for 63.48% variance. This means that 19 factors loaded with eigenvalue greater than 1.0 which were responsible for 63.48% of variations in students' evaluation of their teachers' effectiveness. Factor one contributed the highest percentage variance of 17.56% with eigenvalue of 10.53, while factor 19 contributed the least percentage variance of 1.68% with eigenvalue of 1.01.To determine how many factors to be retained, scree plot was used as presented in Figure 1.

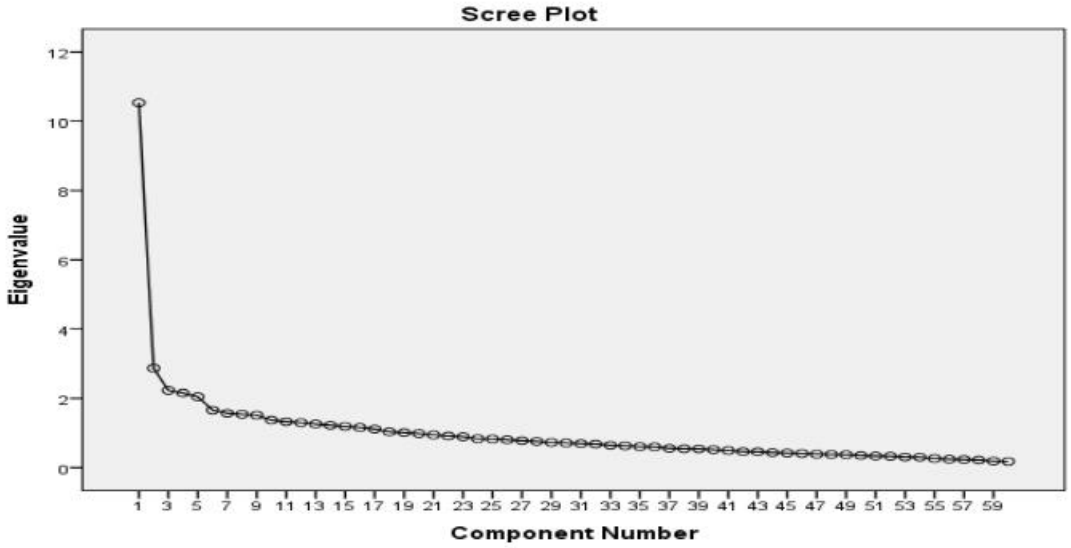

Figure 1: Scree plot for Mathematics Teachers' Evaluation Instrument

The result presented in Figure 1 shows the scree plot for mathematics teachers' evaluation instrument. The point of interest is where the curve starts to flatten, that is the elbowing point. It can be seen that the elbowing point in the scree plot occurred between the 5th and 6th components, with 33.04% of the variance accounted for by the first five components (all with eigenvalues >1).Therefore, only five factors have been retained. The 33.04% of the variance accounted for by the first five components means that the five extracted factors (dimensions) are not the only factors that determine teachers' effectiveness. The researchers decided to choose the fifth factor based on Kaiser (1974) recommendation. Therefore, since the items were uncorrelated, Orthogonal Varimax rotation method was employed.

Research Question 2: How many major dimensions of effective teaching emerged from the factor analysis of the items of mathematics teachers' evaluation instrument (MTEI)?

To assess the major dimensions of effective teaching emerging from the factor analysis of Mathematics Teachers' Evaluation Instrument, the data was subjected to principal component analysis (PCA). The result is presented in Table 2.

Table 2: Rotated Factor Matrix using Principal Component Analysis and their Factor Loadings

ITEM NO	Factor 1	2	3	4	5
ITEM8	**.579**	.115	.066	.106	-.099
ITEM6	**.521**	.009	.012	.071	.039
ITEM1	**.516**	-.011	.099	.175	.223
ITEM12	**.511**	.131	.114	.015	.086
ITEM13	**.499**	.048	-.032	.167	.054
ITEM3	**.498**	.178	.094	.084	.202

ITEM31	**.470**	-.036	.424	.201	-.094
ITEM23	**.450**	.141	-.032	.205	.240
ITEM17	**.446**	.105	.230	.121	.007
ITEM19	**.442**	.056	.056	-.019	.278
ITEM32	**.436**	-.090	.329	.263	-.156
ITEM55	**.433**	.093	.190	.397	-.114
ITEM14	**.430**	.102	.129	.109	.112
ITEM35	.367	-.090	.112	.094	.008
ITEM20	.358	.283	.126	.036	-.077
ITEM22	.350	.349	.129	.132	.234
ITEM9	.323	.238	.127	-.153	.215
ITEM15	.318	.234	.069	.226	.057
ITEM5	.288	.197	.132	.124	-.040
ITEM30	.219	.204	.164	.167	-.171
ITEM27	-.039	**.695**	.061	.207	-.070
ITEM26	.040	**.619**	.136	.129	.093
ITEM28	.005	**.600**	.014	.285	.092
ITEM25	.154	**.599**	.105	.261	-.013
ITEM7	.243	**.549**	.203	.058	.133
ITEM29	.147	**.541**	.069	.082	.127
ITEM21	.279	**.449**	.098	.037	.016
ITEM10	.041	.368	.230	-.188	.328
ITEM38	.093	.346	.137	.089	.276
ITEM36	-.014	.025	.324	.056	.040
ITEM44	.232	.203	**.496**	.058	.192
ITEM33	.109	.158	**.495**	.287	-.004
ITEM18	.162	.065	**.445**	-.146	-.076
ITEM42	.254	.271	**.443**	.185	.044
ITEM43	.108	.115	**.432**	.208	.293
ITEM45	.233	-.037	**.421**	.221	.143
ITEM11	.281	.143	**.419**	-.214	.191
ITEM37	.156	.137	**.419**	.120	-.113
ITEM52	.037	.145	.386	.220	.057
ITEM39	-.151	.320	.381	.085	.204
ITEM16	-.228	.332	.378	-.077	.193
ITEM34	.160	.114	.352	.328	.158
ITEM24	.123	.280	.349	.119	.043
ITEM46	.157	-.032	.269	.191	.233
ITEM58	.241	.133	.260	.217	.063
ITEM47	.062	.022	.054	**.660**	.116
ITEM48	.042	.203	.108	**.541**	.131
ITEM57	.170	.209	.263	**.517**	.010

ITEM54	.369	.275	.040	**.490**	-.102
ITEM50	.066	.062	.013	**.485**	.066
ITEM60	.210	.138	.017	**.472**	.152
ITEM56	.230	.165	.161	**.471**	.159
ITEM53	.179	.042	.153	**.469**	.066
ITEM49	.157	.169	.112	**.406**	.026
ITEM40	-.031	.115	.013	.190	**.671**
ITEM2	-.001	.205	-.111	.059	**.663**
ITEM4	.240	.026	.107	-.017	**.564**
ITEM51	.128	.031	.040	.118	**.522**
ITEM41	-.080	.062	.308	.361	**.480**
ITEM59	.142	-.041	.294	.198	**.379**

Table 2 shows the major factors that emerged with their factor loadings. From the results of the factor analysis based on the criteria that a factor loading less than .400 and items being loaded on more than one interpretable component are to be eliminated, five major factors emerged with 42 isolated items. The extracts of the various factors and items substantially loaded on them show that the 5 factors emerged with 13, 7, 8, 9 and 5 items for factor 1, 2, 3, 4 and 5 respectively. The items that loaded on a factor were carefully studied and labelled appropriately based on the underlying tune of the items. The result is presented in Table 3.

Table 3: Five Dimensions (factors) of Mathematics Teachers' Evaluation Instrument (MTEI)

S/no	Factor	No. of items	Items
1	Teachers' knowledge of subject matter	13	1, 3, 6, 8, 12, 13, 14, 17, 19, 23, 31, 32, 55
2	Teacher-student rapport	7	7, 21, 25, 26, 27, 28, 29
3	Classroom management and method of teaching	8	11, 18, 33, 37, 42, 43, 44, 45
4	Instructional materials and Classroom management	9	47, 48, 49, 50, 53, 54, 56, 57, 60
5	Evaluation procedure	5	2, 4, 40, 41, 51
Total		**42**	**42**

Factor 1 has 13 items (1,3,6,8,12,13,14,17,19,23,31,32 and 51) loaded on it which are related to teachers' knowledge of subject matter, motivation and reinforcement of the students. Thus, this factor was named "Teachers' knowledge of subject matter,

motivation and reinforcement". Factor 2 contains seven items (7,21,25,26,27,28 and 29) which showed the relationship between the teacher and students. Thus, the factor was labelled "Teacher-students rapport". Eight items were (11,18,33,37,42,43,44 and 45)loaded on Factor 3. A cursory look at them showed that the items were on classroom management and method of teaching. Therefore, it was named "Classroom management and method of teaching". Factor 4 has nine items (47,48,49,50,53,54,56,57 and 60). The nine items that loaded on Factor 4 reported the effectiveness of the use of instructional materials and the teacher's communication ability in the classroom. The factor was termed "Instructional materials and classroom communication". Five items (2,4,40,41 and 51) were loaded on factor 5. The items were related to teachers' evaluation procedure. Thus, the factor was labelled evaluation procedure. Furthermore, the table shows that the 42 items (1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 17, 18, 19, 21, 23, 25, 26, 27, 28, 29, 31, 32, 33, 37, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 53, 54, 55, 56, 57 and 60) had minimum loadings (loading ≥.400). This means that out of the 60 items on the original instrument only 42 items emerged.

Research Question 3: How factorially valid is the Mathematics Teachers' Evaluation Instrument (MTEI)?

To answer research question 3, the instrument was subjected to exploratory factor analysis using statistical package for social sciences (SPSS). The results are presented in Table 4.

Table 4: Summary of Factor Analysis of the Items of MTEI and the Factor Loadings

Factors	**No of Items Selected**	**Item Loading**	**Impure Items**	**Complex Items**	**Total No of Items not Selected**	**Total No of Items**
Teachers'	1	.516				
Knowledge	2	.663				
of Subject	3	.498				
Matter	4	.564	5			
	6	.521				
	7	.549				
	8	.579		9		
	11	.419		10	13	5
	12	.511				
	13	.499				
	14	.430		15		
	17	.446		16		
	18	.445				
Teacher-	19	.442	20			

Students’	21	.449		22		
Rapport	23 3	.450			24	7
	25	.599				
	26	.619				
	27	.695				
	28	.600				
Classroom	29	.541	30			
Management	31	.470				
and Method	32	.436				
of Teaching	33	.495		34		
	37	.419		35		
 6	40	.671		36	8	
	41	.480		38		
	42	.443		39		
Instructional	43	.432				
Material and	44	.496				
Classroom	45	.421	46			
Management	47	.660				
	48	.541				
 2	49	.406			9	
	50	.485				
	51	.522		52		
	53	.469				
Evaluation	54	.490				
Procedure	55	.433				
	56	.471				
	57 2	.517	58	__		5
	60	.472	59			
Total **18**	**42**		**6**	**12**	**42**	

Results in Table 4 show how the factorial validity of the instrument was ascertained from the pattern and size of the factor loadings obtained from the factor analysis. Field’s (2005) benchmark of .400 and above was used in selecting the items. The results show that items without factor loading up to .400 were considered factorially impure and not selected, while items with factor loading of .400 or more on more than one factor were

considered factorially complex and thus not selected too. Based on this criterion, 42 items were selected from the 60 that were subjected to factor analysis while 18were rejected on the basis of being either factorially impure or factorially complex. This implies that 42 items are considered factorially valid.

Research Question 4: What is the reliability coefficient of the refined mathematics teachers' evaluation instrument (RMTEI)?

The reliability coefficient of the refined mathematics teachers' evaluation instrument was determined using Cronbach coefficient Alpha and estimates presented in Table5.

Table 5: Reliability Estimates of the Refined Mathematics Teachers' Evaluation Instrument (RMTEI)

Factors	Domain	No of Items	Cronbach Alpha Coefficient
1	Knowledge of subject matter, Motivation and Reinforcement	13	.80
2	Teacher-Students Rapport	7	.78
3	Classroom Management and Method of Teaching	8	.70
4	Use of Instructional Materials and Classroom Communication	9	.76
5	Evaluation Procedure	5	.78
Overall		42	.76

The results of the item analysis in Table 3 are internally consistent as evidenced by the values of alpha coefficients obtained from the five factors. The results show that factors 1, 2, 3, 4 and 5 have Cronbach's alpha estimates of .80, .78, .70, .76 and .78 respectively with a high overall reliability of .76. The results further show that the minimum reliability of the refined mathematics evaluation instrument (RMTEI) is .70.This is the minimum reliability estimate for a non-cognitive instrument according to Fraenkel and Wallen (1993). The instrument was highly reliable.

Discussion of Findings

The discussion of the findings of this study is based on the four research questions raised for the study. The finding from research question one as presented in Table 1 reveals that 19 factors of students' evaluation of their mathematics teachers' effectiveness were extracted. However, the factors (dimensions) that were found to best approximate simple structure in terms of achieving easy interpretation were five and they accounted for 33.04% of the total variance in the students' perceptions of their mathematics teachers' effectiveness factors. This implies that the identified factors are not the only factors that determine mathematics teachers' effectiveness in colleges of education. The resulting factor structure of mathematics teachers' evaluation instrument (MTEI) agrees with the findings of Obokuhwo and Joshua (2013), except for some dimensions not represented

in this instrument. The slight difference between the dimensions of the instrument in the present study and those of Obokuhwo and Josua (2013) may be attributed to the naming of the factors (dimensions) of effective teaching.

The result of research question two shown in Table 3 indicates that five major factors emerged with 42 items and that 13 items loaded on factor one and were labelled teachers' knowledge of subject matter, motivation and reinforcement. Seven items loaded on factor two under teacher-students' rapport; eight items loaded on factor three and which was termed classroom management and method of teaching; nine items loaded on factor four labelled instructional materials and classroom communication while five items loaded on factor five which was labelled evaluation procedure. In all, 42 items loaded on five factors after factor analysis. The five dimensions of effective teaching are teachers' knowledge of subject matter, motivation and reinforcement, teacher-students' rapport, classroom management and method of teaching, instructional materials and classroom communication, and evaluation procedure. This implies that out of 60 items on the original drafted instrument, only five factors with 42 items are valid measures of mathematics teachers' effectiveness. The findings of this study are in line with those of Garcia and Garcia (2014) who reported five major factors (dimensions) of effective teaching from the result of the factor analysis. The items that loaded on a factor were carefully studied and labelled appropriately based on the underlying tune of the items. This signifies that the mathematics teachers' effectiveness factors are important in improving mathematics teachers' effectiveness in colleges of education in Benue State. In the same vein, the finding is in agreement with that of Ugodulunwa and Adeyemo (2016) who arrived at five factors from the result of exploratory factor analysis and also labelled them appropriately.

Table 4 shows that all the items of the instrument under the five extracted factors have factor loading of .400 and above and therefore have construct validity. This implies that mathematics teachers' evaluation instrument (MTEI) and its factors (dimensions) are factorially valid and could be used to evaluate mathematics teachers' effectiveness. This finding is corroborated by Field (2005) who recommended a minimum factor loading of .400 and above for accepting any item as valid. Again, the finding of this study agrees with that of Ezeudu, Chiaha and Eze (2013) who reported that teaching practice evaluation form (TPEF) is a valid instrument for measuring teaching practice skills of student teachers in University of Nigeria, Nsukka.

Research question four's findings reveal the internal consistency of the instrument. The results,presented in Table 3, show that refined mathematics Tteachers' evaluation instrument (RMTEI) with its five factors (dimensions)is highly reliable going by Fraenkel and Wallen's (1993) criteria. This is evidenced by the values of alpha reliability coefficient obtained from the factors which ranged between .70 and .80 with an overall reliability of .76. The estimates further show that items of the instrument are

homogeneous. This implies that the instrument is highly reliable and can be used to evaluate mathematics teachers' effectiveness. The findings are in agreement with the work of Inyiagu (2014) because the result of the factor analysis is internally consistent. This was seen from the values of alpha reliability coefficient obtained from the factors which ranged between .77 and .91. The findings are also in line with that of Ugodulunwa and Adeyemo (2016) who reported that the academic environments scale (AES) and its subscales were reliable measuring instruments.

Conclusion

Based on the findings of the study, the researchers concluded that refined mathematics teachers' evaluation instrument (RMTEI), with its five factors (dimensions) of teaching effectiveness, is valid and reliable. It can be used by students to evaluate their teachers' effectiveness.

Recommendations

The instrument is recommended for use by colleges of education and other tiers of education, measurement experts, scale developers and researchers. The study should be conducted in fields of study other than mathematics.

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