DOCUMENT RESUME

ED 464 088 TM 033 768

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TITLE	Construct Validation and a More Parsimonious Mathematics Beliefs Scales.
PUB DATE	2001-11-00
NOTE	23p.; Paper presented at the Annual Meeting of the Mid-South Educational Research Association (30th, Little Rock, AR, November 14-16, 2001).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150) -- Tests/Questionnaires (160)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Beliefs; *Construct Validity; *Elementary School Teachers; Factor Analysis; Higher Education; Intermediate Grades; Likert Scales; *Mathematics; Mathematics Teachers; Preservice Teachers

ABSTRACT

Teacher beliefs are instrumental in defining teacher pedagogical and content tasks and for processing information relevant to those tasks. In this study, a Likert-type instrument, Mathematics Beliefs Scales (E. Fennema, T. Carpenter, and M. Loef, 1990), was used to measure the mathematical beliefs of teachers. This instrument was designed with four subscales. After the Beliefs Scale was administered to 123 inservice teachers and 54 preservice teachers, a factor analysis was performed to re-examine patterns in the data set to determine what the instrument actually measured. These analyses resulted in a determination of 3 factors and the reduction of the original 48 items to a more user-friendly, modified, 18-item revised scale. Appendixes contain the original scale and the revised version. (Contains 2 tables and 21 references.) (Author/SLD)

Running Head: MATHEMATICS BELIEFS SCALES

Construct Validation and a More Parsimonious Mathematics Beliefs Scales

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Paper presented at the 2001 Annual Meeting of the Mid-South Educational Research Association, Little Rock, AR, November 14-16, 2001.

Abstract

Beliefs are the bedrock and cornerstone at the heart of our actions (Corey, 1937) and best indicators of the decisions individuals make throughout their lives (Dewey, 1933). Beliefs are mental representations of reality that guide thought and behavior (Pajares, 1992). Teacher beliefs are instrumental in defining teacher pedagogical and content tasks and for processing information relevant to those tasks (Nespor, 1987).

In this study, a Likert-type instrument entitled, *Mathematics Beliefs Scales* (Fennema, Carpenter, & Loef 1990) was used to measure the mathematical beliefs of teachers. Originally when created, the researchers designed it to measure four subscales. After administering the *Beliefs* Scales to (n =123) inservice teachers and (n = 54) preservice teachers, a factor analysis was preformed to re-examine patterns in the data set to determine what the instrument actually measured. Results of these analyses led to both a determination of three factors and to reducing the 48 items to a more user-friendly modified 18-item *Revised Scale*.

Construct Validation and a More Parsimonious Mathematics Beliefs Scales

Beliefs have been described and defined by different researchers in different ways. Beliefs are the bedrock and cornerstone at the heart of our actions (Corey, 1937). Beliefs are the best indicators of the decisions individuals make throughout their lives (Dewey, 1933). Beliefs are classified as instrumental and relational approaches to a situation (Carter & Yackel, 1989). Pajares (1992) proposed that beliefs are mental representations of reality that guide thought and behavior and are often initiated early in life and maintained in the face of strong contradictions. These entrenched beliefs serve as a filter through which teachers view the world and interpret information. All teachers possess beliefs about their profession, their students, how learning takes place, and the subject areas they teach. It follows, therefore, that teacher practices should flow from these beliefs. Teacher beliefs are instrumental in defining teacher pedagogical and content tasks and for processing information relevant to those tasks (Nespor, 1987).

In *Principles and Standards for School Mathematics* (2000), the National Council of Teachers of Mathematics state in the 'Teaching Principle' that "Effective teachers realize that the decisions they make shape students' mathematical dispositions and can create a rich setting for learning" (NCTM, 2000, p.18). These decisions are controlled and influenced by their beliefs. Thus beliefs are implicit in teacher discourse, teacher objectives, and teacher practices.

Many researchers have studied teacher beliefs about mathematics. Teachers' beliefs and practices essentially mold classroom teaching, including discourse. "One's conception of what mathematics is affects one's conception of how it should be presented. One's manner of presenting it is an indication of what one believes to be the most essential in it...The issue, then, is not, what is the best way to teach? But, what is mathematics really all about?" (Hersh, 1986, p. 13).

Researchers (Franke, Levi, Jacobs, & Empson, 1996; Knapp & Peterson 1995; Vacc, Bright, & Bowman, 1998) realized that changing beliefs took much time and support. Other researchers also found that substantial improvements occur in classroom achievement when teachers shift their beliefs along with their practices (Fennema, Carpenter, Putnam, Wheaten, Pratt, & Remillard, 1992; Fennema, Franke, Carpenter, & Carey 1993).

Researchers (Carter & Norwood, 1997; Ford, 1994; Lubinski, 1993) have also compared teachers' and students' beliefs about mathematics. In addition to these researcher other studies also revealed a definite relationship between teacher beliefs and actual classroom content, and how students learned in individual classrooms (Grant, Hiebert & Wearne, 1994). Clarke (1997) looked at how the beliefs held by teachers were reflected in the roles of the teachers – what the teachers did. Students in a research classroom studied by Carter and Norwood (1997) believed different factors such as task orientation, ego orientation, and extrinsic motivation scales were also important in mathematics success. Student responses possibly indicated that students were mirroring their teachers' beliefs.

Battista (1994) stated that teachers who are presently teaching mathematics learned from teachers who used traditional curriculum fostering beliefs dissonant from those proposed by the mathematics reform movement. The researcher depicted teachers as educators in a vicious cycle, teaching the same way that they were taught in school. These teachers held a view that was in direct contrast to the reform movement. "Teachers who see mathematics as following set procedures invented by others will have little experience making sense out of mathematics" (p. 467).

The *Preparing Elementary Teachers to Teach Mathematics (PETTM) Project* (1988-1991) was a cooperative university/school effort to improve the teaching of mathematics by elementary teachers with its primary focus on improving the university training of preservice teachers (PSTs) in mathematics. A summary of the project evaluation indicated that the PSTs have formed beliefs that are conducive to teaching mathematics from a problem-solving perspective, that a working relationship with the local school district did take place, and that the PETTM Project did have positive impact on teachers teaching and on students' problem-solving abilities and attitudes. (Kloosterman, Peter; & Others, 1991).

Constructivist teachers are educators whose beliefs and practices allow students to construct their own knowledge through active investigation and meaningful discourse (Vacc, 1995). Beliefs are essential influences on how and whether teachers acquire constructivist knowledge in the first place, and on how and whether teachers would be inclined to implement constructivism in the classroom (Nespor, 1987). When there is an agreement in the constructivist beliefs and practices of teachers, improved teaching should occur. This alignment is referred to as consonance between teacher objectives, plans, and practices. Conversely, when there is dissonance or a discrepancy in beliefs and practices, ineffective teaching results (Pokola, 1984; Thornton, 1985).

Steele (1994) explored how implementing a constructivist approach in a mathematics methods class might change the prospective teachers' conceptions about mathematics and mathematics teaching and learning. The study used qualitative measures for five randomly selected students from the class of 19. In addition, the study administered the Mathematics Beliefs Scales (MBS) at the beginning and end of the course. The course's major components were mathematical inquiry and investigation through problem solving in cooperative groups and whole-class discussions, reading assignments, problem assignments, student assessment interviews, constructivist teaching plans, creating alternate algorithms, final exam, and math logs. Qualitative data results indicated that cooperative groups and use of manipulatives contributed significantly to challenging the preservice teachers' conceptions and beliefs. By the end of the course nearly all students had begun to talk differently about their own learning of mathematics. For the first time they understood the meanings of rules and procedures, were willing to take risks and defend their own solutions to problems, and they had a different image of teaching mathematics. The MBS results supported this finding.

Methodology

For the purposes of this study, a Likert-type instrument entitled, *Mathematics Beliefs Scales* (Fennema, Carpenter, & Loef 1990), included in Appendix A, measured the mathematical beliefs of teachers. Teachers were asked to complete the *Mathematics Beliefs Scales* questionnaire (Fennema, Carpenter, & Loef, 1990) which was adapted from Fennema, Carpenter and Peterson (1987). This scale was developed under a grant from the National Science Foundation through the University of Wisconsin, Madison. "The internal consistency of teachers' scores was determined on each subscale using Cronbach's alpha using a sample of 39 teachers. The internal consistency of teacher scores on the total belief scale was .93" (Peterson, Fennema, Carpenter, & Loef, 1989, p. 8). The subscales assess (a) the beliefs of teachers about how children learn mathematics,

(b) about how mathematics should be taught, and (c) about the relationship between learning and concepts and procedures. The scale is a paper-and-pencil Likert-type instrument that contains 48 statements. Responses range from: A =Strongly Agree, B =Agree, C =Undecided, D= Disagree, E= Strongly Disagree. Each A represented = 5, B= 4, C= 3, D= 2, E= 1. An answer sheet was included for facility of answering and scoring. The survey was coded as follows: The positive items were left alone and the negative items were coded in the opposite direction. The following items were coded negatively: 5, 7, 8, 11, 14, 15, 16, 17, 18, 22, 23, 24, 26, 29, 34, 35, 38, 39, 42, 44, 45, 46, 47, and 48. The responses were added to get a total for each teacher, and a mean score was obtained by dividing by 48.

Two separate studies were conducted. The first study was conducted from March 2000 to May 2000. Data collection began with random collection of the beliefs of the teachers from the *Mathematics Beliefs Scales (MBS)*. The surveys were distributed to 4th- and 5th-grade teachers from 18 public schools in five school districts in a southeastern state. The *Mathematics Beliefs Scales* (Fennema, Carpenter, & Loef 1990) included in Appendix A was either sent by mail or hand-delivered to 176 teachers, with 123 returned either in person or by mail.

Table 1 displays the number of beliefs scales returned from each school and district.

INSERT TABLE 1 ABOUT HERE

The second study was conducted at a large southwestern state public university during the spring 2001 semester of senior methods block. Participants could be characterized as traditional teacher education students. They were all female and in the final year of their undergraduate education. Ethnicity was predominately Caucasian (91.7%; Hispanic 8.3%) and their mean age was 21.4 (SD 1.9). On the last day of mathematics methods class, 54 (N=54) senior preservice teachers were given the *MBS*. These preservice teachers had completed 52 full days in elementary classrooms and had developed a weeklong integrated unit and had written and taught a minimum of four constructivist lessons. The students had also been involved in inquiry-type, hands-on, cooperative group activities involving the ten process and content strands of the *Principles and Standards for School Mathematics* (NCTM, 2000) during their mathematics block instruction. In addition, they maintained reflective journal of classroom activities and field experiences.

Information from both of the study surveys was examined and data entered into a computer file. Each of the responses to the 48 items of *MBS* was entered in 48 separate columns. Numerical data were entered from 5 to 1 based on the Likert scale responses of A to E respectively. Negative statements were then recoded. An average scale score on the total scale was obtained and on this score teachers were divided into two categories. Classroom teachers in the first study whose mean score was less than 2.5 were considered low constructivist in their beliefs and those whose mean score was greater than 3.5 were considered constructivist in their beliefs. Seven of these teachers placed in the low constructivist belief category and 25 in the constructivist belief category. In the second study, eleven of the preservice teachers could be considered constructivist in their beliefs, while only one would be categorized as having low constructivist beliefs.

Reliability

The coefficient-alpha reliability of the scores on the 48-item belief scale for the 123 classroom teachers was .68. This reliability is marginally acceptable according to Shavelson (1988). Reliability was lower than the published reliability of .93 obtained by Fennema, Carpenter, and Peterson (1987) using a sample of 39 teachers in a Mid-western state. This difference possibly suggests this researcher used a more homogeneous sample of teachers rather than those used by the previously mentioned researchers. The coefficient-alpha reliability of the scores on the 48-item belief scale for the 54 preservice teachers was .86 suggesting a more heterogeneous group than the classroom teachers. The combined reliability for both studies was .78 which was acceptable (Shavelson, 1988).

Factor Analysis

Factor analysis is a statistical method used to analyze interrelationships among a large number of variables and used to explain those variables in relationship to their common constructs or factors. It was employed in this study to determine a more parsimonious model of the *MBS*. The process involves finding a procedure for condensing the information contained in a number of original variables into a smaller set of factors with a minimum loss of information (Hair, Anderson, Tathem, & Black, 1998). Because of this process, the number of factors will always be less than the number of original variables.

The *MBS* contained 48 variables, and each time it was administered the participants in the study complained of its length and its repetitive nature. Therefore, the aim of this study was to reduce the number of variables and thus items on the scale but yet obtain roughly the same information. The original researchers designed the instrument to measure four subscales on the beliefs of teachers (a) about how children learn mathematics, (b) about how mathematics should be taught, (c) about the relationship between learning and concepts and procedures, and (d) about what should provide the basis for sequencing topics in addition and subtraction instruction. Due to the length of the scale and the repetitive nature of some of the statements, it was questioned whether this instrument actually measured four factors that the original authors claimed were measured.

To determine how many factors would emerge for the data in the present study, the techniques of exploratory factor analysis were used. Analysis of correlation matrix involving items from the original *Beliefs Scales* yielded 14 components with eigenvalues greater than one, and the scree plot indicated at least six components. Because it was difficult to interpret this unrotated factor solution, a first-order principal components analysis with an orthogonal rotation method was employed on the 48 original items. Orthogonal rotation was used to obtain a more parsimonious and thus more replicable solution (Kieffer, 1999).

Because the goal was to develop a shorter measure, criteria for omitting or retaining items were invoked. First, the last three of the six components had few items defining these constructs, and the first three components explained more variance and were deemed most noteworthy. Therefore, items primarily saturating the last three of the six components were omitted. Second, items that were "multivocal" (i.e. "spoke through two or more components, as reflected in pattern/structure coefficients on two more components > [.30] were omitted. Third, "univocal" items which most saturated the first three components were retained. In this manner 18 items were selected to constitute a short form of the measure.

These 18 variables explained 46.23% of the observed variance. The communality coefficients (h^2) are the amount of variance in each item that was useful in all of the factors as a set. The arithmetic mean of these 18 values ranged from .192 to .638 with .462 of the variance being explained by the extracted factors. Although a little less than 50% of the variance was explained (3.5% more variance) when a four-factor model was employed, only two of the items correlated appreciably with factor IV. An examination of the results presented for the three-factor solution rotated to the varimax criterion is displayed in Table 2. The rotated component matrix contains 18 variables, six correlating with each of the three components. The cutoff used for saliency was variables with pattern/structure coefficients greater that [.30].

INSERT TABLE 2 ABOUT HERE

The saturation of factors can be determined from the table. All of these items measure teacher beliefs concerning different areas of mathematics education. Factor I is most highly saturated with variables 22, 23, 29, 39, 42, and 47. All of these items deal with how children learn mathematics with a high score defining teachers who believe that children can construct their own knowledge. A low score indicated that students receive most of their knowledge directly from the teacher. This factor can be named "Student Learning". Factor II is most highly saturated with variables 16, 25, 26, 36, 45, and 46. All of these items are measuring the sequence of learning, concentrating on which skills should be taught before what other skills and prerequisites for learning certain skills. A high score indicating that students can solve real-world problems before knowing all their computational skills. A low score designating a teacher who feels that it is necessary for all computational skills to be learned before a student can attempt to solve even simple word problems. This factor can be named "Stages of Learning". Factor III is most highly saturated with variables 2, 5, 9, 30, 32, and 37. All of these items measure teacher beliefs about how teachers should teach. This factor can be called "Teacher Practices". A high score indicating that teachers facilitate student knowledge, while a low score defines a teacher who feels that his/her practices need to be organized to direct student learning.

Conclusions/Results

The results of this study developed a revised Beliefs Scale (displayed in Appendix 2) consisting of 18 items shortened from 48 items. Six items measure each of the three factors. The analytic method produced a modified scale that still measures what the original authors intended for it to measure, namely the beliefs of teachers about how children learn (Factor 1: Student Learning), the role of the teacher in sequencing of teaching both computational and application skills (Factor 2: Stages of Learning), and the relationships between teaching computational skills and problem solving skills (Factor 3: Teacher Practices).

The results presented here are a start to the Revised Version of the *MBS*. The items will need to be reordered so that all of one factor are not all together. The next step will be to change one of the negatively worded questions to make it positively worded. The original scales had an even number of questions negatively and positively worded.

As a result of the factor analysis, there are now 10 negatively worded items and 8 positively worded items. After completing those tasks, the next step will be to administer it to the fall 2001 preservice teachers to check the reliability of the scores with a similar sample. This shortened version of the *MBS* should assist in data collection by (a) shortening the time it takes to administer the scale, (b) removing seemingly redundant items, and (c) focusing on specific constructs contained within the instrument.

Discussion

It is important to understand teacher beliefs since ultimately these beliefs lead to student achievement. Researchers have investigated how teacher's knowledge of and beliefs about their students' thinking are closely related to student achievement (Carpenter, Fennema, Peterson, & Carey, 1988). In another study, Fisher, Berlinger, Filby, Marliave, Cahn, & Dishaw (1980) found that teachers who could predict student success in certain areas of standardized tests were significantly correlated with how their students performed on the test. In a related study (Peterson, Fennema, & Loaf, 1989) found a significant correlation between the problem solving of students and teacher beliefs about problem solving. Teachers who had students who performed well in problem solving tended to agree with the more constructivist, cognitively-based items on the *MBS*. These teachers believed that teachers should help students construct their own knowledge and that their instruction should add to students' prior knowledge about a concept. These teachers did not see their role as providers of all knowledge and students as "sponges" waiting to absorb their knowledge.

Long-lasting instructional changes only result from essential modifications in what teachers believe, know, and practice (Putnam, Wheaten, Pratt, & Remillard, 1992).

The National Institute of Education (1975) in their document entitled, *Teaching as Clinical Information Processing* posited a close relationship between beliefs and practices stating "what teachers do is directed in no small measure by what they think" (p.1). Moreover, it is "necessary for any innovations in the context, practices and technology of teaching to be mediated through the minds and motives of teachers" (p. 1).

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Appendix A

MATHEMATICS BELIEFS SCALES

Elizabeth Fennema – Thomas Carpenter – Megan Loef
-1990-

A=Strongly Agree B=Agree C=Undecided D=Disagree E=Strongly Disagree

1. Children should solve word problems before they master computational procedures.
2. Teachers should encourage children to find their own solutions to math problems even if they are inefficient.
3. Children should understand computational procedures before children spend much time practicing computational procedures.
4. Time should be spent solving simple word problems before children spend much time practicing computational procedures.
5. Teachers should teach exact procedures for solving word problems.
6. Children should understand the meaning of an operation (addition, subtraction, multiplication, or division) before they memorize number facts.
7. The teacher should demonstrate how to solve simple word problems before children are allowed to solve word problems.
8. The use of key words is an effective way for children to solve word problems.
9. Mathematics should be presented to children in such a way that they can discover relationships for themselves.
10. Even children who have not learned basic facts can have effective methods for solving problems.
11. It is important for a child to be a good listener in order to learn how to do mathematics.
12. Most young children can figure out a way to solve simple word problems.
13. Children should have many informal experiences solving simple word problems before they are expected to memorize number facts.
14. An effective teacher demonstrates the right way to do a word problem.
15. Children should be told to solve problems the way the teacher has taught them.
16. Most young children have to be shown how to solve simple word problems.
17. Children's written answers to paper-and-pencil mathematical problems indicate their level of understanding.
18. The best way to teach problem solving is to show children how to solve one kind of problem at a time.
19. It is better to provide a variety of word problems for children to solve.
20. Children learn math best by figuring out for themselves the ways to find answers to simple word problems.
21. Children usually can figure out for themselves how to solve simple word problems.
22. Recall of number facts should precede the development of an understanding of the related operation (addition, subtraction, multiplication, or division).
23. Children will not understand an operation (addition, subtraction, multiplication, or division) until they have mastered some of the relevant number facts.
24. Most children cannot figure math out for themselves and must be explicitly taught.
25. Children should understand computational procedures before they master them.
26. Children learn math best by attending to the teacher's explanations.
27. It is important for a child to discover how to solve simple word problems for him/herself.
28. Children should be allowed to invent new ways to solve simple word problems before the teacher demonstrates how to solve them.

29. Time should be spent practicing computational procedures before children are expected to understand the procedures.
30. The goals of instruction in mathematics are best achieved when students find their own methods for solving problems.
31. Allowing children to discuss their thinking helps them to make sense of mathematics.
32. Teachers should allow children who are having difficulty solving a word problem to continue to try to find a solution.
33. Children can figure out ways to solve many math problems without formal instruction.
34. Teachers should tell children who are having difficulty solving a word problem how to solve the problem.
35. Frequent drills on the basic facts are essential in order for children to learn them.
36. Most young children can figure out a way to solve many mathematics problems without any adult help.
37. Teachers should allow children to figure out their own ways to solve simple word problems.
38. It is better to teach children how to solve one kind of word problem at a time.
39. Children should not solve simple word problems until they have mastered some number facts.
40. Children's explanations of their solutions to problems are good indicators of their mathematics learning.
41. Given appropriate materials, children can create meaningful procedures for computation.
42. Time should be spent practicing computational procedures before children spend much time solving problems.
43. Teachers should facilitate children's inventions of ways to solve simple word problems.
44. It is important for a child to know how to follow directions to be a good problem solver.
45. To be successful in mathematics, a child must be a good listener.
46. Children need explicit instruction on how to solve word problems.
47. Children should master computational procedures before they are expected to understand how those procedures work.
48. Children learn mathematics best from teachers' demonstrations and explanations.

Appendix B
Revised Shortened Version of the Mathematics Beliefs Scales

Factor 1

- Recall of number facts should precede the development of an understanding of the related operation (addition, subtraction, multiplication, or division).
- Children will not understand an operation (addition, subtraction, multiplication, or division) until they have mastered some of the relevant number facts.
- Time should be spent practicing computational procedures before children are expected to understand the procedures.
- Children should not solve simple word problems until they have mastered some number facts.
- Time should be spent practicing computational procedures before children spend much time solving problems.
- Children should master computational procedures before they are expected to understand how those procedures work.

Factor 2

- Most young children have to be shown how to solve simple word problems.
- Children should understand computational procedures before they master them.
- Children learn math best by attending to the teacher's explanations.
- Most young children can figure out a way to solve many mathematics problems without any adult help.
- To be successful in mathematics, a child must be a good listener.
- Children need explicit instruction on how to solve word problems.

Factor 3

- Teachers should encourage children to find their own solutions to math problems even if they are inefficient.
- Teachers should teach exact procedures for solving word problems.
- Mathematics should be presented to children in such a way that they can discover relationships for themselves.
- The goals of instruction in mathematics are best achieved when students find their own methods for solving problems.
- Teachers should allow children who are having difficulty solving a word problem to continue to try to find a solution.
- Teachers should allow children to figure out their own ways to solve simple word problems.

Table 1

Beliefs Scales Returned																					
District 1						District 2					District 3			District 4					District 5		
A	B	C	D	E		A	B	C	D	E		A		A	B	C	D	E		A	
6	6	6	6	6		2	4	5	1	8		18		6	6	6	7	4		22	

n =123 surveys

Table 2
Factor Pattern/Structure Matrix Rotated to the Varimax Criterion

Variable	I	II	III	h^2
VAR22	<u>.706</u>	-.004	-.256	.563
VAR23	<u>.698</u>	.155	-.218	.558
VAR29	<u>.653</u>	-.068	.087	.439
VAR39	<u>.532</u>	.417	.054	.460
VAR42	<u>.485</u>	.470	-.074	.461
VAR47	<u>.769</u>	-.008	-.441	.593
VAR16	-.003	<u>.680</u>	-.029	.463
VAR25	-.222	<u>.553</u>	.020	.355
VAR26	.256	<u>.556</u>	-.024	.375
VAR36	.169	<u>-.607</u>	.210	.441
VAR45	.331	<u>.600</u>	.009	.470
VAR46	.258	<u>.748</u>	-.111	.638
VAR02	-.031	-.269	<u>.632</u>	.473
VAR05	.231	.161	<u>-.578</u>	.413
VAR09	.285	.122	<u>.309</u>	.192
VAR30	-.042	-.040	<u>.782</u>	.615
VAR32	.128	.285	<u>.614</u>	.475
VAR37	-.102	.066	<u>.566</u>	.335
Trace	3.0	2.99	2.67	8.66
<u>% of Variance</u>	16.7	16.6	12.9	46.2

Note: coefficients greater than [.30] are <u>underlined</u>

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

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