A Simple Mathematics Motivation Scale and Study of Validation in Mexican Adolescents

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Abstract
The goal of the study was to evaluate and adjust the model that associates mathematical motivation and learning strategies as quantitative instruments. The items related to the task value, cost, and self-efficacy were validated with Mexican students of rural areas in south-west region of Mexico between 12 and 16 years old, using 14 items that measure self-reported motivation levels. The construct validity of the mathematics motivation scale was checked using confirmatory factor analysis (CFA), by analyzing first- and second-order CFA models. The factor reliability was investigated by means of Dillon-Goldstein’s rho and Cronbach’s alpha. The model had adequate goodness of fit in the confirmatory analysis. The instrument proved that it is convenient and reliable for application in mathematics motivation in Mexican adolescents. An advantage of the use of this instrument to be applied by teachers of mathematics is its simplicity, ease of application, and interpretation.

Keywords
motivation, mathematics, self-efficacy, validation, CFA models

Academic motivation is related to the perceptions that students have of themselves and their environment which encourages them to choose an activity, to commit to it, and to persevere to see it through to its conclusion. Motivation affects student creativity, learning styles, and academic achievement (Kuyper et al., 2000) and has been shown to be a useful predictor of high dropout rates (Barkoukis et al., 2008) and to have a positive correlation with high academic performance (Gottfried et al., 2007). The teaching of mathematics constitutes a field of great interest for both mathematics teachers and pedagogues. Teachers must plan the lessons with attractive activities in order to get the students’ attention (Cavallo, 2002). Mathematics teachers are responsible for facilitating the development of positive attitudes toward mathematics from the first courses. It is not enough to work toward the student getting good grades. Academic achievement and liking a subject do not always coincide. It is possible for a student who has no affection for mathematics to obtain good grades in this subject because they are responsible and do the work because it is necessary to advance to the next subject, but they might try to use mathematics as little as possible and, unfortunately, forget what they have learned.

In many cases the learning of mathematics implies greater difficulties for students. The psychosocial factors involved in learning mathematics are especially relevant since they include a similar weight (than the cognitive one) regarding emotional and motivational aspects, which are very influential for performance and achievement (Echeverría Castro et al., 2020). The problem of motivation with respect to mathematics is not new. As in other disciplines, motivation has a big effect on mathematics lessons. Motivation is a construct that makes it possible to explain the reasons for the behavior of students in the mathematics classroom and the objectives and goals they have when attending a mathematics class, as well as their reasons for learning mathematics. The definitions of motivation are many and varied since a wide range of theoretical points of view have been studied that try to explain it by focusing on key dimensions of motivation, for example, self-efficacy (Bandura, 1997), attributions (Skinner et al., 1990), achievement goals (Ames, 1992), self-concept (Guay et al., 2003), and expectation and the value of the task (Eccles et al., 1983).

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Expectancy-value theory is one of the most relevant motivational theories because it has been widely used as a conceptual framework to explain motivation in different educational disciplines. The model is based on the analysis of expectations and the perceived value of homework by students and its links with school performance, persistence, and the choice of further studies, among other factors (Eccles & Wigfield, 2002). This model has shown that value beliefs and expectation of success are related to effort in learning mathematics, higher enrollment in this discipline, and performance (Spinath et al., 2006; Wigfield & Eccles, 2000).

There is a great diversity in studies on mathematical motivation. Berger and Karabenick (2011) developed an expectancy-value model with ninth grade students (usually 14–15 years old) in a Midwest urban high school in the U.S.A. Expectancy was represented by self-concept regarding ability and self-efficacy. They proposed to measure the self-efficacy expectation scale, for which the items were selected from the self-efficacy scale of the Motivated Strategy for Learning Questionnaire (MSLQ) questionnaire (Pintrich et al., 1991), and they also evaluated the scale of task value, which was composed of four categories. The components of the task value were defined and evaluated by Eccles and Wigfield (1995), who confirmed the results of Pintrich and De Groot (1990) that motivation predicts learners’ self-regulatory strategies. Additionally, they concluded that the adaptations of the items used to measure high school students’ use of learning strategies represented an improvement over those in previous versions of the MSLQ. The mathematics motivation scale adapted by Berger and Karabenick (2011) was translated into Spanish by Gasco and Villarroel (2017) and applied to secondary education students between 13 and 16 years in the Basque Autonomous Community of Spain. However, the instrument in Spanish, was not studied its validity by construct, content, and criteria.

The MSLQ made it possible to examine associations between motivation and self-regulation with a greater degree of precision. Actually, considerable support for the association between students’ motivational beliefs and use of learning strategies exists. In the Mexican context, little research has been studied motivation from the perspective of expectancy-value theory.

In literature there are some instrument proposals to measure motivation in mathematics in secondary schools such as the Mathematics Motivation Scale of 24 items (Zakariya and Massimiliano, 2021) or Mathematics Motivation Questionnaire of 19-items (Fiorella et al., 2021), but the scale adapted by Berger and Karabenick (2011) is the simplest with 14 items. For this reason, our goal is to validate the mathematical motivation scale of Berger and Karabenick (2011) for Mexican secondary school students to know the effects, correlations, and internal consistency of the construct or factors used to get convenient and reliable instrument for mathematics motivation scale.

This work is organized as follows: in the following section, we detail the inclusion criteria of the sample, describe the structure of instrument as well as the items that compose it, and the statistical analysis that was performed. In Section 3, the results are presented, such as the validity and reliability of the instrument, as well as the correlations of the motivation constructs or factor. Finally, in Section 4, we conclude with some comments.

Materials and Methods

Participants

The participants are boys and girls between 12 and 16 years of secondary schools (technical, general, and television) of the first, second, and third grade. Secondary schools are public and rural areas in south-west region of Mexico. Subjects who did not accept participate are excluded from the study.

Mathematics Motivation Scale

The instrument is a self-report measure composed of 14 items that measure self-reported levels of motivation. The instrument comprised five subscales: interest (items 1, 2, and 3), importance (items 4, 5, and 6), utility (items 7, 8, and 9), cost (items 10 and 11), and for the expectancy value, constructs were assessed by three items from self-efficacy (items 12, 13, and 14). All students’ responses were rated on a 5-point scale ranging from 1 (Not at all true of me) to 5 (Very true of me).

CFA Models

The first-order CFA model comprised five latent factors: interest, importance, utility, cost, and self-efficacy, and the second order CFA model called task value is measured by the following three first order factors: interest, importance, and utility. Both the first and second order CFA models were proposed by Berger and Karabenick (2011).

Procedure

First, the main researcher contacted the secondary school directors and explained the goal of the research. Second, once the secondary school directors gave their approval, consent was obtained from teachers and parents, and we informed them about the objective of the study (parents were asked to authorize their children’s participation, and assent was also obtained from child participants). Then, the students were informed of the objective of the study and of the confidentiality of the data obtained. Finally, they answered the instrument and one of the researchers was present in case there were any questions or doubt. A total time of between 8 and 14 minutes was required to complete the instrument.

Statistical Analyses

All of the analyses described below were carried out using R Statistical Software version 3.2.4 with the R package psych
Results

Description of the Sample

A total of 495 participants, who were students in the first (166), second (178), and third (151) grades in secondary school, participated in the study voluntarily. About 213 (43.03%) of the students were boys between 12 and 16 years old ($M=13.19, SD=0.98$), and the girls were between 12 and 16 years old ($M=13.26, SD=0.97$). The average self-reported score of the students in the previous mathematics course was 7.73 ($SD=1.30$) and 8.30 ($SD=1.14$) in boys and girls, respectively. Demographic characteristics of the participants grouped by sex were homogeneous (Table 1) with respect to age, secondary school type, and grade.

First and Second Order CFA Models

Table 2 presents a factor structure made up of five constructs or factors for the first order CFA model and the second order factor called task value with your three correlated first order factors: interest, importance, and utility. The items were ordered in the factors of the original scale version. To check the adequacy of the expected factor structure, CFAs were conducted using the items as factor indicators.

Goodness of Fit

The first- and second-order CFA models used RML as the estimation method. The goodness-of-fit statistics and information criteria of the models estimated are presented in Table 3. In both models, the $\chi^2$ test was significant, and the following robust adjustment indicators were analyzed: RMSEA, SRMR, CFI, and TLI showed an adequate goodness of fit in the first-order model and obtained adequate values in RMSEA, SRMR, CFI, and TLI in the second-order model.
Table 2. First- and Second-Order CFA Models.

| Items | Factor and items | First-order factor model | Second-order factor model |
|-------|------------------|--------------------------|---------------------------|
|       |                  | SFL  | 95% CI   | AVE  | SFL  | 95% CI   | AVE  |
| 1     | Me gustan las matemáticas. (I like math.) | 0.805 | 0.750–0.859 | 0.648 | 0.810 | 0.757–0.863 | 0.656 |
| 2     | Disfruto con las matemáticas. (I enjoy doing math.) | 0.877 | 0.833–0.921 | 0.769 | 0.871 | 0.823–0.918 | 0.758 |
| 3     | Las matemáticas son emocionantes. (Math is exciting to me.) | 0.757 | 0.699–0.816 | 0.574 | 0.758 | 0.699–0.818 | 0.575 |
|       | **Factor 2: Importance** | | | | | | |
| 4     | Es importante para mi ser alguien que sea bueno en matemáticas. (It is important to me to be the kind of person who is good at math.) | 0.720 | 0.658–0.783 | 0.519 | 0.715 | 0.651–0.779 | 0.511 |
| 5     | Creo que ser bueno en matemáticas es parte importante de mi personalidad. (I believe that being good at math is an important part of who I am.) | 0.765 | 0.706–0.823 | 0.585 | 0.765 | 0.706–0.823 | 0.585 |
| 6     | Es importante para mi ser alguien que puede razonar utilizando fórmulas y operaciones matemáticas. (It is important to me to be a person who can reason using math formulas and operations.) | 0.709 | 0.642–0.775 | 0.502 | 0.714 | 0.649–0.780 | 0.510 |
|       | **Factor 3: Utility** | | | | | | |
| 7     | Creo que las matemáticas pueden ser útiles en el futuro porque me pueden ayudar. (I believe that math will be useful for me later in life.) | 0.819 | 0.764–0.874 | 0.671 | 0.828 | 0.775–0.881 | 0.685 |
| 8     | Creo que ser bueno en matemáticas puede ser útil en el futuro. (I believe that math is valuable because it will help me in the future.) | 0.800 | 0.748–0.852 | 0.640 | 0.801 | 0.750–0.852 | 0.641 |
| 9     | Creo que ser bueno en matemáticas puede ser útil para encontrar trabajo o para ir a la universidad. (I believe that being good at math will be useful when I get a job or go to college.) | 0.772 | 0.714–0.829 | 0.596 | 0.762 | 0.701–0.823 | 0.581 |
|       | **Factor 4: Cost** | | | | | | |
| 10    | Tengo que dejar de hacer muchas cosas para aprender bien matemáticas. (I have to give up a lot to do well in math.) | 0.787 | 0.624–0.950 | 0.619 | 0.762 | 0.601–0.923 | 0.581 |
| 11    | Creo que el éxito en matemáticas requiere dejar otras actividades que me gustan. (I believe that success in math requires that I give up other activities that I enjoy.) | 0.687 | 0.543–0.832 | 0.472 | 0.710 | 0.557–0.863 | 0.504 |
|       | **Factor 5: Self-efficacy** | | | | | | |
| 12    | Creo que tendré una excelente nota en matemáticas. (I believe I will receive an excellent grade in math.) | 0.652 | 0.573–0.731 | 0.425 | 0.627 | 0.545–0.709 | 0.393 |
| 13    | Estoy seguro de que puedo entender los contenidos más difíciles en matemáticas. (I’m certain I can understand the most difficult material presented in math.) | 0.689 | 0.623–0.756 | 0.475 | 0.667 | 0.591–0.744 | 0.445 |
| 14    | Tengo confianza en que puedo aprender los conceptos básicos enseñados en matemáticas. (I’m confident I can learn the basic concepts taught in math.) | 0.706 | 0.641–0.771 | 0.498 | 0.745 | 0.683–0.808 | 0.556 |

Second-order factor: Task value

| Interest | NA | NA | NA | 0.618 | 0.511–0.726 | 0.382 |
| Importance | NA | NA | NA | 0.961 | 0.885–1.000 | 0.923 |
| Utility | NA | NA | NA | 0.790 | 0.715–0.866 | 0.625 |

Note. INT = interest; IMP = importance; UTL = utility; CT = cost; SELF = self-efficacy; VAL = task value; SFL = standardized factor loading; 95% CI = 95% confidence interval; AVE = average value explained; NA = not applicable.
Table 3. Goodness-of-Fit Statistics of the Models Estimated.

| Model          | $\chi^2$ | df  | p-Value | RMSEA | SRMR  | CFI   | TLI   |
|----------------|----------|-----|---------|-------|-------|-------|-------|
| First order    | 114.808  | 67  | <.001   | 0.044 | 0.038 | 0.977 | 0.969 |
| Second order   | 190.447  | 71  | <.001   | 0.068 | 0.064 | 0.943 | 0.927 |

Note: $\chi^2$ = Chi-square test; df = degrees of freedom; RMSEA = root mean square error of approximation; SRMR = standardized root mean residual; CFI = comparative fit index; TLI = Tucker-Lewis index.

**Internal Consistency**

Table 4 shows the mean and standard deviation of scores obtained by the constructs that comprise the questionnaire. Also, this table shows the internal consistency; the questionnaire presented a Dillon-Goldstein’s rho of .892 and Cronbach’s alpha of .872, which indicates that it is reliable for the Mexican population, while the values obtained by constructs were greater than .80. The constructs’ correlations for the CFA models were calculated.

**Correlation Between Constructs**

Table 4 shows the correlations between all the factors were positive, and all confidence intervals of the correlation coefficients were statistically significant except between cost and interest factors of the first-order model. The correlation between the importance and utility constructs was excellent. Also, the correlation between the task value (second order factor) and cost with self-efficacy was excellent. Finally, the correlation between the cost with interest, importance, and utility was poor.

**Discussion and Conclusion**

This study was conducted to provide a convenient and reliable instrument for a mathematics motivation scale. The original version of the mathematics motivation scale was first developed and validated in English by Berger and Karabenick (2011), followed by the Spanish version by Gasco and Villarroel (2017) but without validation. While the motivation of mathematics learning can be measured from numerous perspectives, and our validated instrument of 14-items is only one of these, one of its advantages is that it is one of the simplest in comparison of other instruments as the Mathematics Motivation Scale of 24 items (Zakariya and Massimiliano, 2021) or Mathematics Motivation Questionnaire of 19-items (Fiorella et al., 2021).

Our study provides validation of the mathematics motivation scale in secondary school students of rural areas in south-west region of Mexico. The Spanish version of the questionnaire showed scale consistency with the original and had high internal consistency (Dillon-Goldstein’s rho of .892 and Cronbach’s alpha of .872). Moreover, the subscales showed satisfactory internal consistency. The results obtained in this work confirmed that the first- and second-order CFA models showed desirable properties in terms of construct validity. The second-order CFA models is also proposed by Berger and Karabenick (2011), in this study indicated that specific construct can be formed for cognitive and resource management strategies, respectively, whereas the three types of metacognitive strategies, as interest, importance, and utility, were explained by a single second-order factor called task value. A practical importance of the second-order CFA model is that the task value score was associated with the subscales of cost and self-efficacy, or with other variables or constructs.

In addition, the mathematics motivation scale underwent a validation process, in which it demonstrated appropriate properties for research applications. An advantage of the use of this instrument is its simplicity, ease of application, and interpretation so that it can be applied by teachers of mathematics in rural areas since 60% of teachers of secondary schools in Mexico are in rural areas (INEA, 2014).

The objectives of this paper were limited to the validation of the scale in a group of Mexican students, with the intention of applying the scale to understand academic motivation in future research. In the same way new research can be proposed that allows observing motivation in different contexts within the Mexican educational system. In this research, the data was obtained from rural areas of a state with unfavorable economic conditions. It will be interesting to observe the relationships of these conditions with the academic motivation of the respondents.

If we want to know the personal characteristics that make a male or female student face learning activities with greater or lesser interest or effort, either for the purpose of knowing what aids to provide them with or for the purpose of predicting what their future performance will be, what information should we seek? The MSLQ provides us with useful information for teachers. Expectancy-value theory, through its components (interest, usefulness, and importance and cost of the task), provides clear information on the motivation of students, the value they assign to tasks, and the expectations they have of themselves.

Our study has some limitations. The instrument was validated in secondary school students in rural areas in south-west of Mexico. Some additional opportunities are to validate the instrument in urban schools or private schools.
### Table 4. Descriptive Statistics, Internal Consistency, and Correlations Between Constructs.

| Model        | Construct | Descriptive statistics | Internal consistency | Correlations |
|--------------|-----------|------------------------|----------------------|--------------|
|              |           | M          | SD     | Dillon-Goldstein’s rho | Cronbach’s alpha | INT | IMP | UTL | CT | SELF | VAL |
| First order  | Interest  | 0.00       | 1.063  | 0.919                    | 0.868            | 0.637 | 0.428 | 0.183 | 0.829 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |
| First order  | Importance| 0.00       | 1.051  | 0.875                    | 0.787            | 0.582–0.687 | 0.488 | 0.229 | 0.680 | 0.703 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |
| First order  | Utility   | 0.00       | 0.904  | 0.914                    | 0.860            | 0.353–0.497 | 0.873–0.909 | 0.363 | 0.738 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |
| First order  | Cost      | 0.00       | 0.902  | 0.914                    | 0.860            | 0.353–0.497 | 0.873–0.909 | 0.363 | 0.738 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |
| First order  | Self-efficacy | 0.00     | 0.903  | 0.914                   | 0.860            | 0.353–0.497 | 0.873–0.909 | 0.363 | 0.738 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |
| First order  | Task value | 0.00       | 0.915  | 0.914                    | 0.860            | 0.353–0.497 | 0.873–0.909 | 0.363 | 0.738 | NA   |
| Second order |           |            |        |                          |                 |       |      |      |     |      |     |

Note. SD = standard deviation; INT = interest; IMP = importance; UTL = utility; CT = cost; SELF = self-efficacy; VAL = task value. Pearson’s correlation (upper triangular matrix), 95% confidence Interval (lower triangular matrix); NA = not applicable.
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Ethical Approval
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