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Attitudes toward science: measurement and psychometric properties of the Test of Science-Related Attitudes for its use in Spanish-speaking classrooms

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ABSTRACT
Understanding attitudes toward science and measuring them remain two major challenges for science teaching. This article reviews the concept of attitudes toward science and their measurement. It subsequently analyzes the psychometric properties of the *Test of Science-Related Attitudes* (TOSRA), such as its construct validity, its discriminant and concurrent validity, and its reliability. The evidence presented suggests that TOSRA, in its Spanish-adapted version, has adequate construct validity regarding its theoretical referents, as well as good indexes of reliability. In addition, it determines the attitudes toward science of secondary school students in Santiago de Chile ($n = 664$) and analyzes the sex variable as a differentiating factor in such attitudes. The analysis by sex revealed low-relevance gender difference. The results are contrasted with those obtained in English-speaking countries. This TOSRA sample showed good psychometric parameters for measuring and evaluating attitudes toward science, which can be used in classrooms of Spanish-speaking countries or with immigrant populations with limited English proficiency.

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Attitudes toward science; construct validity; Test of Science-Related Attitudes (TOSRA)

Introduction

Nowadays, it is a widely accepted fact that science teaching in schools must be linked with society and students, which highlights the relevance of not only learning concepts but also developing scientific skills and science-related attitudes (Harlen, 2010). It has been observed that attitudes related with school science are fundamental for educating citizens who are responsible for their actions and decisions (Bybee & McCrae, 2011; Jenkins & Pell, 2006; Organisation for Economic Co-operation and Development [OECD], 2008, 2013), achieving better learning standards in scientific disciplines (Saleh & Khine, 2011), and fostering students' interest in conducting scientific activities professionally (Gokhale, Rabe-Hemp, Woeste, & Machina, 2015; OECD, 2008; Tytler & Osborne, 2012). It has been noted that students' attitudes toward a certain disciplinary content, the way in which they are taught, and teacher's characteristics, among other factors, significantly influence

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learning, specifically in the field of science (García & Sánchez, 2006). In fact, one of the main areas of interest of science teachers is to understand how science-related attitudes influence the way in which students learn the subject (Saleh & Khine, 2011). However, apart from being associated with scientific discipline learning, attitudes themselves are a relevant part of learning science and should not be overlooked (OECD, 2013). In this context, attitudes toward science are a focus of growing attention given that, internationally, researchers have noticed a decrease in young people's interest in pursuing a career in science or technology (Blalock et al., 2008; Gokhale et al., 2015; OECD, 2008; Osborne, Simon, & Collins, 2003; Tomas & Ritchie, 2015; Tytler & Osborne, 2012), particularly in the most developed countries (Schreiner & Sjøberg, 2004). This is certainly a concern since the underlying hypothesis is that attitudes influence students' school performance and career choice (Blalock et al., 2008).

Attitudes toward science have been a relevant issue in educational research for at least 40 years (Tytler, 2014; Tytler & Osborne, 2012). Given their linkages with other concepts within the affective domain such as values and interests, it is necessary to first conceptualize and delimitate attitudes.

Several authors have striven to define the concept of attitudes toward science (Fraser, 1981; García & Sánchez, 2006; Gardner, 1975; Osborne et al., 2003; Vázquez & Manassero, 2007). Klopfer (1971) may have advanced the most relevant distinction in science-related attitudes (Tytler & Osborne, 2012) by differentiating scientific attitudes from attitudes toward science. Klopfer (1971) refers to a set of attitudes that characterize scientific work, such as objectivity, rationality, and skepticism. In contrast, attitudes toward science are mostly part of the affective domain. According to Klopfer (1971), attitudes toward science are predispositions toward a number of objects: (1) science and scientists, (2) attitude to inquiry, (3) adoption of scientific attitudes, (4) enjoyment of science learning experiences, (5) interest in science learning experiences, and (6) interest in a career in science.

Researchers agree that the concept of attitudes toward science is complex and multidimensional; for this reason, we should not envision a single 'attitude toward science' construct, but multiple individual constructs (Tytler, 2014; Vázquez & Manassero, 2007). Thus, the attitudinal dimensions considered relevant today are closely aligned with Klopfer's: science and scientists; school science; the enjoyment of scientific learning experiences; interest in science and science-related activities; and the desire to pursue a scientific career or to have a science-related job (Tytler & Osborne, 2012).

Attitudes toward science can be influenced by a number of variables. Some authors state that sex is the strongest differentiating factor in attitudes toward science (Brotman & Moore, 2008; Osborne et al., 2003). In general, girls display less favorable attitudes (Hayes & Tariq, 2000; Tytler, 2014; Von Roten, 2004), especially in the area of physics (Osborne, Simon, & Tytler, 2009); however, they have a more favorable attitude toward health-related subjects (Jerrim & Schoon, 2014; Tytler, 2014). In contrast, other studies reveal either no difference between boys' and girls' attitudes toward science (Akpinar, Yildiz, Tatar, & Ergin, 2009; Jerrim & Schoon, 2014; Manassero, Vázquez, Bennàssar-Roig, & García-Carmona, 2010; OECD, 2008), or differences that are nullified when controlling for socio-demographic variables (Von Roten, 2004) or for the students' scientific knowledge (Hayes & Tariq, 2000). Although the effect of the sex variable is not conclusive, analyzing male and female's attitudes toward science is relevant because those attitudes can have a significant influence on students' higher education path and choice of job (OECD, 2008). For example, 14% of the young women who entered university in 2012 chose a science-related major, while 39% of young men chose to pursue studies in this field (OECD, 2015). This gap may be greater in Latin America, where girls tend to follow gender stereotypes when choosing a profession (Scantlebury & Baker, 2007). This may be connected with parents' expectations. In Chile, for example, 50% of the parents of boys expect them to do a major in science, technology, engineering, or mathematics (STEM), while only 16% of the parents of girls have this expectation (OECD, 2015). Other variables that can influence attitudes toward science are socio-economic and cultural factors such as religion, beliefs, language, income, parents' job and educational level, and parents' expectations for their children (Orbay, Gokdere, Tereci, & Aydin, 2010; Ornek, 2011).

Although there have been many attempts (Osborne et al., 2009) to measure and evaluate them, the measurement of attitudes toward science has many limitations.

Use of instruments whose psychometric properties are unknown

Potvin and Hasni (2014) conducted a systematic review of the literature on instruments that measure science-related attitudes published between 2000 and 2012 and found that among 228 selected articles, 12 were validations of instruments for evaluating attitudes toward science, only 3 of which reported reliability and validity criteria. A broader review, covering between 1935 and 2005 which analyzed 150 articles referencing 66 instruments, revealed that most instruments lacked psychometric tests, thus demonstrating the scarcity of valid and reliable instruments for measuring attitudes toward science (Blalock et al., 2008). Construct validity is crucial in the development of instruments to measure attitudes (Tytler, 2014).

Few instruments measure the attitudes toward science in Spanish-speaking school students

Spanish has the second largest number of native speakers in the world, and Latinos are the fastest growing ethnic group in the U.S.A (Greenberg, 2012; Zuniga, Olson, & Winter, 2005); however, the availability of instruments in this language, if one wishes to use them in Spanish-speaking populations (Spanish-speaking countries or immigrant population), is limited. Even though some instruments have been translated and used at the classroom level, validation studies have not always been conducted, nor have their psychometric properties been reported.

Instruments with an unclear definition of the concept of attitudes toward science

Potvin and Hasni (2014) state that nearly half of the articles do not provide a definition of the concept of attitude toward science that they use. Likewise the contents and dimensions to be evaluated are not always clearly defined (Potvin & Hasni, 2014). For Aydeniz and Kotowski (2014), this negatively impacts the generation of a body of methodological knowledge for their measurement.

Notwithstanding the limitations associated with measuring attitudes toward science, it is important to evaluate them and to have valid and reliable tools available for use in the classroom, especially in Latin American countries or in areas with a large Spanish-speaking immigrant population, where these instruments are scarce and poorly known by teachers.

In the English-speaking world, one of the most extensively used instruments for measuring science-related attitudes is the *Test of Science-Related Attitudes* (TOSRA), developed by Fraser (1978, 1981) using the conceptual framework of Klopfer's classification (1971). When analyzing more recent conceptions of attitudes toward science against the theoretical foundations of TOSRA, it is evident that the TOSRA instrument is still current and applicable (Tytler & Osborne, 2012). TOSRA has internal consistency ranging from 0.64 to 0.93 for its subscales, and adequate test–retest reliability (Unfried, Faber, Stanhope, & Wiebe, 2015).

The goals of this study are to analyze TOSRA's psychometric properties in secondary school students in the Metropolitan Region of Chile; to study the behavior of this scale according to the student's sex; and to provide a reliable and valid instrument for assessing attitudes toward science in Spanish-speaking populations.

Methodology

Participants

The participants in the study were 664 adolescents pursuing mandatory secondary school studies at 11 schools of the Metropolitan Region. The socio-economic status (SES) of the schools was as follows: 3 mid-SES schools (25%), 2 mid-high SES schools (21%), and 6 high SES schools (54%). Of the total number of subjects, 41% were male ($n = 273$) and 59% female ($n = 391$). Their mean age was 15.75 years, (SD = 0.70).

The selection criteria used were (a) schools with scores over 250 points on the 2008 national standardized language test, SIMCE ($M = 250$; SD = 50), in order to control for the possible effects of poorly developed reading comprehension skills; (b) similar ratio of male and female participants; and (c) willingness to participate in the study. Fifteen schools that met these criteria were selected at random, 11 of which agreed to participate.

Instrumentation

Two instruments were used: TOSRA as the object of analysis and the Protocol of Science-Related Attitudes (PAC, in its Spanish acronym) (Vázquez & Manassero, 1997) as a complementary instrument to analyze concurrent and discriminant validity.

TOSRA (Fraser, 1981) comprises 70 items grouped into 7 subscales: (1) *Social implications of science,* which measures the subject's attitude toward the positive or negative effects of science on society; (2) *Normality of scientists,* which evaluates the subject's beliefs about the lifestyle of scientists; (3) *Attitude toward scientific inquiry,* which measures the subject's preference for using scientific research methods; (4) *Adoption of scientific attitudes,* which evaluates the subject's willingness to revise his/her opinions based on experimentation and empirical data; (5) *Enjoyment of science lessons;* (6) *Leisure interest in science;* and (7) *Career interest in science.* Each subscale comprises 10 statements to which students must react using a 5-point Likert-type scale that ranges from *Strongly disagree* (1) to *Strongly agree* (5). Five of these items are worded positively and five negatively to avoid stereotyped responses. The coding of the items according to their positive or negative meaning can be found in Fraser (1981).

TOSRA was initially translated from English into Spanish by the researchers; afterwards, a bilingual native English speaker reviewed the Spanish version. The review criteria included: (a) preservation of the meaning or intent of the statements, (b) use of language suitable for the respondents' context and age, (c) use of standard Spanish to ensure good comprehension by all Spanish-speaking populations, regardless of their country of origin; and (d) respect for the formal aspects of the instrument. The Spanish version of TOSRA has been included at the end of the paper (see Appendix).

In order to estimate the concurrent and discriminant validity (subcategories of construct validity) of the 70 items that comprise the TOSRA, 20 PAC items were included. PAC (Vázquez & Manassero, 1997) was chosen considering the theoretical equivalence between two subscales of the instruments, the type of item (5-point Likert scale), and the use of the Spanish language. According to Cronbach's alpha, the overall reliability is 0.90. For the subscales used in the study, *Social image of Science and Technology* and *Elements of Science and Technology in schools*, reliability was 0.76 and 0.72, respectively (Vázquez & Manassero, 1997). The theoretical correspondence between TOSRA and PAC for the scales used is presented in Table 1.

Data collection was carried out by the researchers in a period of approximately one month. All students in the participating classrooms took the test, which lasted approximately 30 minutes. The objectives of the scale were explained to the participants, who were informed that there were no right or wrong answers and also assured that the results would be confidential. The students participated voluntarily. After the process was completed, a feedback report on the results for the whole group was submitted to each school, without comparing schools or identifying students in order to maintain confidentiality.

Table 1. Equivalence between the TOSRA and PAC subscales used to estimate discriminant and concurrent validity.

PAC	Examples of PAC items used	TOSRA	Examples of TOSRA items
Social image of Science and Technology Refers to attitudes toward sociological aspects of science and technology in interaction with society and vice versa. (12 items).	• We have a better world to live in thanks to science. • Science helps us to save time and effort. • Diseases can be cured thanks to science.	Social implications of science (S)	• Science can help us to make the world a better place in the future. • Science helps us to make life better. • Money spent on science is well worth spending.
Elements of Science and Technology in schools Refers to attitudes toward aspects of science and technology as perceived by students in the school context. (8 items).	• Science is very hard to learn. • Students study science because they are made to. • Studying science is a nightmare.	Enjoyment of science lessons (E)	• I dislike science lessons. • Science lessons are a waste of time. • Science lessons bore me.

Data analysis

Descriptive statistics (mean and standard deviation) were calculated for the items and the subscales. The internal consistency of the scales was calculated using Cronbach's alpha. Construct validity was verified using two methods: (1) exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), both analyses used the principal axis factoring with promax rotation, which assumed correlation between the subscales. For CFA, the adjustment of the model was tested using structural equation modeling. (2) Discriminant and concurrent validity analysis was determined through Campbell and Fiske's multitrait-multimethod matrix (1959). In order to establish statistically significant differences between men and women, a student *t*-test was carried out in independent samples when the normality assumption was met. When the normality assumption was not met, a Mann–Whitney *U*-test was carried out, using a Komogorov–Smirnov test. The variance homogeneity assumption was tested using the Levene test. A statistical significance of 0.05 was assumed. The effect size was estimated using Cohen's *d*. No missing data were detected. The analyses were carried out with SPSS version 23 and R Studio for CFA.

Results

The total mean score was 3.20 points (SD = 0.49), on a scale from 1 to 5, with 1 being the most negative attitude toward science and 5 the most positive. Of the seven subscales that comprise the instrument, the one with the highest mean is *adoption of scientific attitudes* (A) (M = 3.61; SD = 0.59), while the one with the lowest is *leisure interest in science* (L), (M = 2.67; SD = 0.77). The total internal consistency of the TOSRA was 0.94; in the subscales, it ranged from 0.63 to 0.90 (Table 2). Six subscales showed good consistency indexes (>0.7) (Tavakol & Dennick, 2011), while subscale N was below (>0.6) (Table 2).

Construct validity was measured with a factor exploratory analysis, considering the seven theoretical subscales of the TOSRA. The analysis fit the data well (Kaiser-Meyer-Olkin = 0.94); in addition, Bartlett's sphericity test was also significant ($p < .001$). The seven factors explained 45% of the variance.

Table 3 shows the EFA results, which reveal that items weigh mostly on the theoretical subscales. This is true for subscales S, N, I, and A. There are some items that do not present a significant weight (<.3), as is the case in items 2 and 36. On the other hand, there are items that weigh significantly on another subscale, as is the case in items 8 and 44. Items on the subscales E, L, and C come together in one factor. Table 3 also presents the CFA results. It is observed that the majority of items weigh significantly on the

Table 2. Descriptive statistics and internal consistency of the TOSRA attitude scale and its subscales.

		Subscales						
	Total score	S	N	I	A	E	L	C
Valid *N*	664	664	664	664	664	664	664	664
M	3.20	3.46	3.26	3.38	3.61	3.09	2.67	2.91
SD	0.49	0.60	0.46	0.67	0.59	0.86	0.77	0.79
Cronbach's alpha	0.94	0.79	0.63	0.82	0.75	0.90	0.83	0.86

Notes: S = Social implications of science; N = Normality of scientists; I = Attitude toward scientific inquiry; A = Adoption of scientific attitudes; E = Enjoyment of science lessons; L = Leisure interest in science; and C = Career interest in science.

Table 3. EFA and CFA of the TOSRA with promax rotation.

TOSRA subscale		Item (English)	Item (Spanish)	EFA results					CFA results						
				S	N	I	A	E + L + C	S	N	I	A	E	L	C
S	1	Money spent on science is well worth spending	El dinero que se invierte en ciencia es dinero bien invertido	.54					.58						
	8	(–) Science is man's worst enemy	(–) La ciencia es el peor enemigo del hombre				.50		.55						
	15	Public money spent on science in the last 10 years has been used wisely	El dinero público dedicado a la ciencia en los últimos años ha sido utilizado con inteligencia	.31					—						
	22	(–) Scientific discoveries are doing more harm than good	(–) Los descubrimientos científicos están produciendo más daño que beneficio	.37					.49						
	29	The government should spend more money on scientific research	El gobierno debe gastar más dinero en la investigación científica	.64					.69						
	36	(–) Too many laboratories are being built at the expense of the rest of education	(–) Se están construyendo demasiados laboratorios a costa de la disminución de inversión para el resto de la educación	—					—						
	43	Science helps to make life better	La ciencia contribuye a mejorar la calidad de vida	.61					.69						
	50	(–) This country is spending too much money on science	(–) Nuestro país está gastando demasiado dinero en la ciencia	.40					.42						
	57	Science can help to make the world a better place in the future	La ciencia puede ayudar a hacer del mundo un lugar mejor	.65					.72						
	64	(–) Money used on scientific projects is wasted	(–) El dinero utilizado en proyectos científicos es dinero desperdiciado				.54		.67						
N	2	(–) Scientists usually like to go to their laboratories when they have a day off	(–) A los científicos les gusta ir a sus laboratorios cuando tienen un día libre		—					—					
	9	Scientists are about as fit and healthy as other people	Los científicos son tan saludables y tienen la misma condición física que el resto de las personas		—					—					
	16	(–) Scientists do not have enough time to spend with their families	(–) Los científicos no tienen suficiente tiempo para estar con sus familias		.32					.28					
	23	Scientists like sport as much as other people do	Los científicos gustan del deporte tanto como el resto de las personas		.52					.44					
	30	(–) Scientists are less friendly than other people	(–) Los científicos son menos amigables que otras personas		.43					.51					
	37	Scientists can have a normal family life	Los científicos pueden tener una vida familiar normal		.51					.60					
	44	(–) Scientists do not care about their working conditions	(–) Los científicos no están preocupados por sus condiciones de trabajo		—					—					
	51	Scientists are just as interested in art and music as other people are	Los científicos están tan interesados en el arte y la música como el resto de la gente		.41					.43					
	58	(–) Few scientists are happily married	(–) Pocos científicos tienen éxito en su vida matrimonial		.46					.46					
	65	If you met a scientist he would probably look like anyone else you might meet	Si conocieras a un científico, probablemente él se vería como una persona común y corriente				.44			.48					

(*Continued*)

Table 3. Continued.

TOSRA subscale		Item (English)	Item (Spanish)	EFA results					CFA results						
				S	N	I	A	E + L + C	S	N	I	A	E	L	C
I	3	I would prefer to find out why something happens by doing an experiment than by being told	Preferiría averiguar el porqué de un fenómeno haciendo un experimento a que me lo cuenten			.63					.75				
	10	(–) Doing experiments is not as good as finding out information from teachers	(–) Hacer experimentos no es tan bueno como obtener información de un profesor			.43	.42				.48				
	17	I would prefer to do experiments than to read about them	Preferiría hacer experimentos que leer sobre ellos			.58					.68				
	24	(–) I would rather agree with other people than do an experiment to find out for myself	(–) Preferiría concordar con otras personas que hacer un experimento para averiguar por mí mismo			.36					.36				
	31	I would prefer to do my own experiments than to find out information from a teacher	Preferiría hacer mis propios experimentos que recibir la información de un profesor			.65					.72				
	38	(–) I would rather find out about things by asking an expert than by doing an experiment	(–) Preferiría averiguar acerca de las cosas preguntándole a un experto, que hacer un experimento			.55					.57				
	45	I would rather solve a problem by doing an experiment than be told the answer	Preferiría resolver un problema haciendo un experimento a que me digan la respuesta			.75					.81				
	52	(–) It is better to ask the teacher the answer than to find it out by doing experiment	(–) Es mejor preguntar al profesor la respuesta que llegar a ella por medio de experimentos			.61					.64				
	59	It would prefer to do an experiment on a topic than to read about it in science magazines	Preferiría hacer un experimento sobre un tema que leer sobre éste en revistas científicas			.62					.66				
	66	(–) It is better to be told scientific facts than to find them out from experiments	(–) Es mejor que los hechos científicos sean contados a descubrirlos a partir de experimentos			.37					.40				
A	4	I enjoy reading about things which disagree with my previous ideas	Me gusta leer sobre temas que no están de acuerdo con mis ideas				—					—			
	11	I dislike repeating experiments to check that I get the same results	No me gusta repetir los experimentos para comprobar que me dan los mismos resultados				—					.33			
	18	I am curious about the world in which we live	Tengo curiosidad acerca del mundo en que vivimos				.57					.66			
	25	Finding out about new things is unimportant	No es importante investigar sobre cosas nuevas				.70					.73			
	32	I like to listen to people whose opinions are different from mine	Me gusta escuchar a las personas cuyas opiniones son diferentes a las mías				.55					.61			
	39	I find it boring to hear about new ideas	Me parece aburrido oír ideas nuevas				.67					.75			
	46	In science experiments I, like to use new methods which I have not used before	En los experimentos científicos, me gusta usar métodos que no he usado antes				.35					.36			
	53	I am unwilling to change my ideas when evidence shows that the ideas are poor	No estoy dispuesto a cambiar mis ideas aunque la realidad muestre que éstas no tienen suficiente base				.41					.45			
	60	In science experiments I report unexpected results as well as expected ones	En los informes científicos reporto tanto los resultados esperados como los inesperados				.37					.38			
	67	I dislike listening to other people's opinions	No me gusta escuchar las opiniones de otras personas				.64					.67			

E	5	Science lessons are fun	Las clases de ciencia son entretenidas		.77	—	
	12	(–) I dislike science lessons	(–) No me gustan las clases de ciencia		.74	—	
	19	School should have more science lessons each week	La escuela debería tener más horas de ciencia a la semana		.77	.90	
	26	(–) Science lessons bore me	(–) Las clases de ciencia me aburren		.77	—	
	33	Science is one of the most interesting school subjects	Las asignaturas científicas son las más interesantes del colegio		.72	.79	
	40	(–) Science lessons are a waste of time	(–) Las clases de ciencia son una pérdida de tiempo		.49	.57	
	47	I really enjoy going to science lessons	Realmente me gusta asistir a las clases de ciencias		.79	.91	
	54	(–) The material covered in science lessons is uninteresting	(–) Los contenidos de los programas de ciencias no son interesantes	.43	.39	.48	
	61	I look forward to science lessons	Espero con ansias las clases de ciencias		.75	.77	
	68	(–) I would enjoy school more if there were no science lessons	(–) Disfrutaría más el colegio si no hubiera clases de ciencia		.65	.78	
L	6	I would like to belong to a science club.	Me gustaría pertenecer a un club de la ciencia		.67		.80
	13	(–) I get bored when watching science programs on TV at home	(–) Me aburro cuando veo en mi casa programas científicos en la televisión	.44	.40		.57
	20	I would like to be given a science book or a piece of scientific equipment as a present	Me gustaría recibir como regalo un libro de ciencias o un instrumento científico		.60		.90
	27	(–) I dislike reading books about science during my holidays	(–) No me gusta leer libros de ciencia durante mis vacaciones		.47		.80
	34	I would like to do science experiments at home	Me gustaría hacer experimentos científicos en mi casa		.52		.68
	41	(–) Talking to friends about science after school would be boring	(–) Sería aburrido conversar con los amigos sobre ciencia después del colegio		.30		.54
	48	I would enjoy having a job in a science laboratory during my school holidays	Disfrutaría tener un trabajo en un laboratorio de ciencias durante mis vacaciones escolares		.56		.74
	55	(–) Listening to talk about science on the radio would be boring	(–) Sería aburrido escuchar un programa de ciencia en la radio		.40		.65
	62	I would enjoy visiting a science museum at the weekend	Me gustaría visitar un museo de ciencias durante mis fines de semana		.50		.78
	69	(–) I dislike reading newspaper articles about science	(–) No me gusta leer artículos periodísticos sobre ciencia		.44		.53

(*Continued*)

Table 3. Continued.

TOSRA subscale		Item (English)	Item (Spanish)	EFA results S	N	I	A	E + L + C	CFA results S	N	I	A	E	L	C
C	7	(–) I would dislike being a scientist after I leave school	(–) Al finalizar mis estudios, me desagradaría ser un científico o científica					.47							.65
	14	When I leave school, I would like to work with people who make discoveries in science	Cuando termine mis estudios, me gustaría trabajar con personas que hacen descubrimientos científicos					.63							.77
	21	(–) I would dislike a job in a science laboratory after I leave school	(–) No me gustaría trabajar en un laboratorio de ciencias después de terminar mis estudios					.57							.77
	28	Working in a science laboratory would be an interesting way to earn a living	Trabajar en un laboratorio de ciencias podría ser una interesante manera de ganarse la vida					.57							.74
	35	(–) A career in science would be dull and boring	(–) Ejercer una carrera científica sería tedioso y aburrido					.72							.86
	42	I would like to teach science when I leave school	Cuando termine mis estudios me gustaría enseñar ciencias.					.49							.51
	49	(–) A job as a scientist would be boring	(–) En el futuro, tener un trabajo científico sería aburrido					.65							.84
	56	A job as a scientist would be interesting	Sería interesante trabajar como científico					.67							.85
	63	(–) I would dislike becoming a scientist because it needs too much education	(–) No me gustaría ser un científico porque se requieren demasiados estudios					.43							.56
	70	I would like to be a scientist when I leave school	Al terminar mis estudios me gustaría ser un científico					.61							.76

Notes: (–) indicates that the item was reverse-coded during analysis; EFA: exploratory factor analysis; CFA: confirmatory factor analysis; —: factor loadings <.3. S = Social implications of science; N = Normality of scientists; I = Attitude toward scientific inquiry; A = Adoption of scientific attitudes; E = Enjoyment of science lessons; L = Leisure interest in science; and C = Career interest in science.

Table 4. CFA goodness-of-fit indices.

	χ^2	df	χ^2/df	χ^2 *p* value	GFI	RMSEA	SRMR
Theoretical model	8363.68	2345	3.57	<0.0001	0.644	0.058	0.185

Note: GFI = goodness of fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

corresponding theoretical scale, with some exceptions that coincide on their most part with what was observed in the EFA results, for instance items 2 and 36.

Table 4 shows the goodness-of-fit parameters of the seven-factor theoretical model. The fit of the model was assessed using root mean square error of approximation (RMSEA). A good fit is indicated by an RMSEA less than 0.06 (Unfried et al., 2015), and hence the model is a good fit.

Discriminant and concurrent validity results are presented in Table 5. It shows the correlations between two of the TOSRA subscales of attitudes toward science (S and E) with two PAC subscales.

The 'monotrait-heteromethod' correlations or concurrent validities (correlations between the subscales of different methods or instruments which are equivalent from a theoretical point of view) are significantly higher than zero between subscales S and E of the TOSRA with their PAC equivalents (*Social* and *School*), ($r = 0.68$; $p < .01$ and $r = 0.66$; $p < .01$, respectively). Likewise, the coefficients of concurrent validity are higher than the corresponding correlations for discriminant validity.

Analysis by student sex

At the whole-scale level, no significant differences are observed between males and females (t (662) = 0.05, $p > .05$). No differences by sex at the subscale level were found either ($p > .05$), which was tested using the Mann–Whitney *U*-test. These results are presented in Figure 1.

The analysis of the differences by item according to student sex shows that, of the 70 items that comprise the TOSRA, only 7 display statistically significant differences between the sexes ($p < .05$), 4 of which (11, 24, 62, 66) are favorable to women and 3 (23, 15, 51) are favorable to men; nevertheless, effect sizes are small. Subscales C and E do not show statistically significant differences in any of its items (Table 6).

Discussion and conclusions

The results of the present study suggest that TOSRA is a solid and consistent instrument for evaluating attitudes toward science in secondary school students. In addition, it is an easy-to-use tool for teachers to gain a better understanding of their students' interests and beliefs in connection with science and thus better evaluate and monitor their activities. Due to its ease of use, it has been widely adopted in English-speaking countries (Fraser, Aldridge, & Adolphe, 2010). TOSRA has demonstrated flexibility when used in studies with a selection of less than 7 of its scales (Adamski, Fraser, & Peiro, 2013; Liu & Fraser, 2013; Ogbuehi & Fraser, 2007; Walker, 2006), and when translated into various languages, such as Turkish (Orbay et al., 2010), Urdu (Ali, Mohsin, & Iqbal, 2013),

Table 5. Multitrait-multimethod matrix.

		TOSRA (Method 1)		PAC (Method 2)	
		S	E	Social (S)	School (E)
TOSRA	S	1	0.49**	**0.68****	0.48**
	E		1	0.41**	**0.66****
PAC	Social (S)			1	0.40**
	School (E)				1

Notes: ■: monotrait-monomethod; ■: heterotrait-monomethod; ■: monotrait-heteromethod (concurrent validity; ■: hetero-trait-heteromethod (discriminant validity).
**$p < .01$.

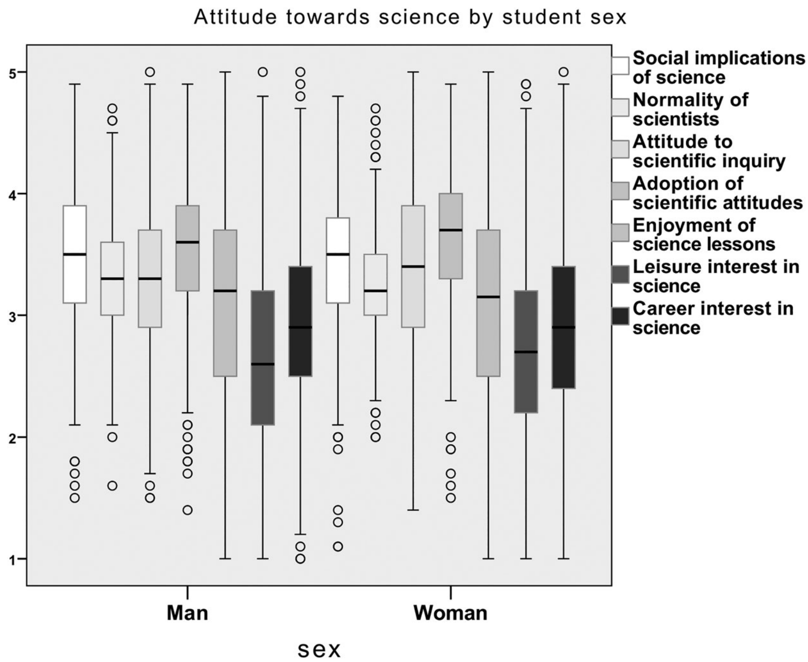


Figure 1. Mean attitude toward science by student sex.

Thai (Santiboon, 2013), and Mandarin (Webb, 2014). Interestingly, TOSRA has also adapted successfully to assess attitudes in non-science classes such as mathematics (Ogbuehi & Fraser, 2007), geography (Walker, 2006), English (Liu & Fraser, 2013), and Spanish classes (Adamski et al., 2013). The evidence presented suggests that its validity and internal consistency are preserved in its Spanish-adapted version, which makes it possible to use it in countries whose official language is Spanish or in countries with a growing immigrant Latino population, such as the U.S.A. Although another instrument (PAC) for this same purpose exits, the scales that are part of TOSRA are considered to be very relevant today (Tytler, 2014; Tytler & Osborne, 2012).

Concerning TOSRA's construct validity (estimated using principal axis factoring), it was observed that three of the seven theoretical scales (subscale E: *Enjoyment of science lessons* and subscales L: *Leisure interest in science*, and C: *Career interest in science*) are grouped into one, which points to the strong correlation between them and suggests

Table 6. Items with differences in mean by sex.

Subscale – item			Man *M*	Man SD	Woman *M*	Woman SD	*U*	Sig	*d*
S	15	Public money spent on science in the last ten years has been used wisely	3.21	1.01	3.03	0.90	48391.50	0.02*	0.19
N	23	Scientists like sport as much as other people do.	3.24	1.09	3.09	0.88	48385.00	0.03*	0.15
N	51	Scientists are just as interested in art and music as other people are	3.31	1.06	3.05	1.01	45986.00	0.00**	0.25
I	24	I would rather agree with other people than do an experiment to find out for myself	3.10	1.05	3.37	1.03	45754.00	0.00**	0.26
I	66	It is better to be told scientific facts than to find them out from experiments	3.16	1.06	3.33	1.09	48286.00	0.03*	0.16
A	11	I dislike repeating experiments to check that I get the same results	2.84	1.20	3.07	1.19	47609.50	0.01*	0.19
L	62	I would enjoy visiting a science museum at the weekend	2.63	1.17	2.96	1.23	45310.50	0.00**	0.27

Note: S = Social implications of science; N = Normality of scientists; I = Attitude toward scientific inquiry; A = Adoption of scientific attitudes; and L = Leisure interest in science. *U* = Mann–Whitney *U*-test and *d* = Cohen's *d*.
**$p < .01$.
*$p < .05$.

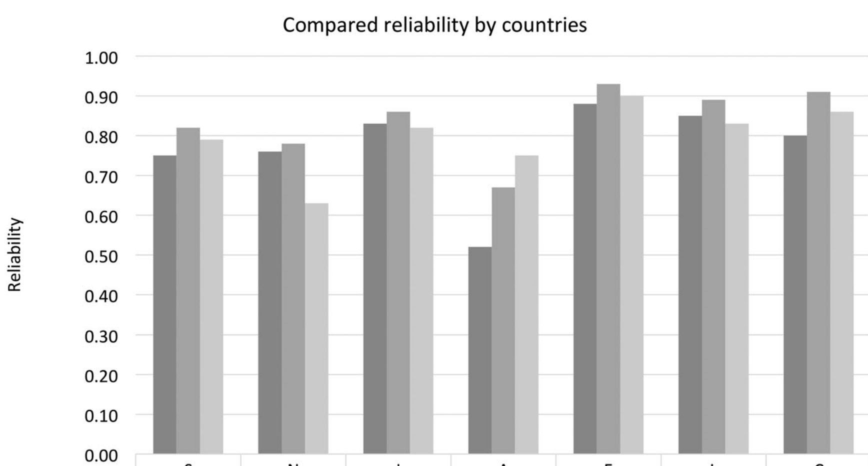
that, if students appreciate and enjoy science lessons, they are very likely to plan to pursue a scientific career or have a science-related job. The other four subscales remain as such. These findings are consistent with the results of other studies carried out in the U.S.A (Khalili, 1987; Smist, 1994). In Indonesia, researchers validated an abbreviated version of the TOSRA with three subscales (*Normality of scientists, Attitude toward scientific inquiry,* and *Career interest in science*), and their results were comparable to those of previous studies (Fraser et al., 2010). Likewise, the test was validated in Pakistan using five subscales (*Social Implications of Science, Attitude toward scientific inquiry, Enjoyment of science lessons, Leisure interest in science,* and *Career interest in science*), and the results show that the subscales *Enjoyment of science lessons* and *Leisure interest in science* are grouped into one dimension (Ali et al., 2013); therefore, in the context where the instrument was applied, this means that students who enjoy science lessons will probably express an interest in this discipline beyond school. As a matter of fact, some studies have found that an interest in careers linked with STEM predicts the probability of achieving STEM-related degrees (Maltese & Tai, 2011; Sadler, Sonnert, Hazari, & Tai, 2012), hence the importance of including attitudes toward science as a learning content in school. There is a growing number of STEM professionals who will continue to grow for years to come (Unfried et al., 2015). The interest toward scientific careers is independent of population origin. However, ethnic minorities and immigrants may face additional barriers (Fouad & Byars-Winston, 2005; Zuniga et al., 2005). For this reason it becomes crucial to increase the availability of instruments that can assess attitude toward science in the immigrant Hispanic population and thus offer equal opportunities where language is not an obstacle.

With respect to discriminant and concurrent validity, the evidence suggests good concurrent validity indexes. This result is not consistent with Khalili's finding (1987); thus, it is recommended that this kind of analysis should be continued since the present study only looked into two subscales. As we found no other studies which involved an analysis of TOSRA's discriminant and concurrent validity using a multitrait-multimethod matrix, the results of the present study are a novel contribution.

Regarding the influence of sex on TOSRA results, no significant differences were found, either at the general scale or at the subscale level. These results are consistent with other studies (Akpinar et al., 2009; Lay & Khoo, 2012; Manassero et al., 2010; OECD, 2008). However, other authors (Osborne et al., 2009) indicate that men have more favorable attitudes toward science. Yet others (Smist, 1994) report differences that are more favorable for women. These apparent contradictions highlight the need to explore more deeply the attitudes toward science in Latin American students since gender stereotypes are more pervasive in the culture of this region (Scantlebury & Baker, 2007). School has a major role to play by fostering equal inclusion for women in science and reducing gaps in this regard.

Our analysis of the internal consistency of the full TOSRA and of its subscales found it to be a reliable instrument. A Cronbach's alpha of 0.94 was observed for the full scale, while the internal consistency values for the subscales ranged from 0.63 to 0.91. Contrasting these data with those obtained during the instrument's validation in Australia (Fraser, 1981) ($n = 1337$) and New Zealand (Lowe, 2004) ($n = 312$) shows that similar values were observed for all subscales. This concordance is graphically portrayed in Figure 2. It should be pointed out that Fraser measured students' attitudes at several educational levels; therefore, for the reliability values to be comparable with those of the Chilean sample, we used the reliability estimated for 10th grade in Australia ($n = 324$); Lowe's study, on the other hand, only considered 10th grade participants.

The results of the application of TOSRA can be interpreted according to the criterion established by Vázquez and Manassero (1997), that is, that scores under 3 can be regarded as relatively negative attitudes toward science, while scores over 3 indicate a positive attitude. For example, the results of the following subscales can be grouped into a subset of



	S	N	I	A	E	L	C
New Zealand	0.75	0.76	0.83	0.52	0.88	0.85	0.80
Australia	0.82	0.78	0.86	0.67	0.93	0.89	0.91
Chile	0.79	0.63	0.82	0.75	0.90	0.83	0.86

Subescale attitude towards science

Figure 2. Compared reliability of the subscales between applications of TOSRA.

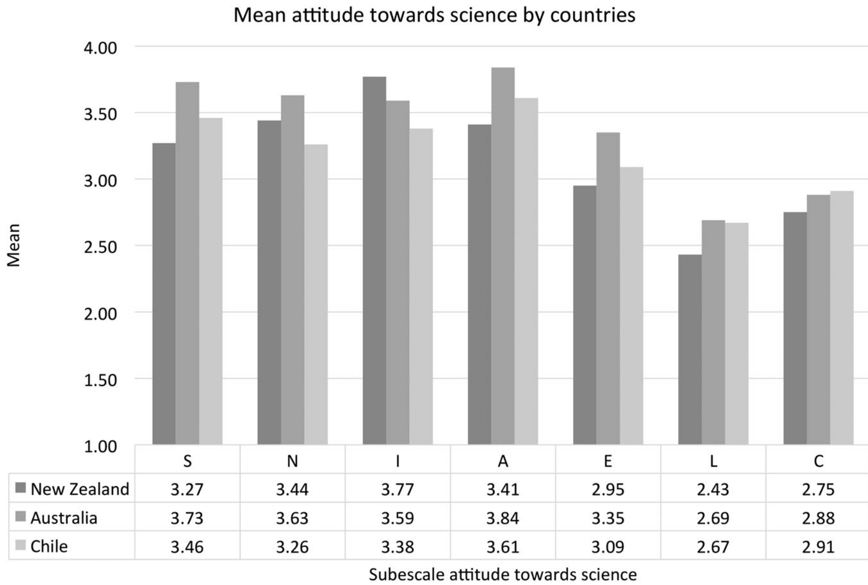


Figure 3. Means of the TOSRA subscales compared by country.

favorable attitudes toward science: S (*Social implications of science*), N (*Normality of scientists*), I (*Attitude toward scientific inquiry*), and A (*Adoption of scientific attitudes*). In contrast, subscales L (*Leisure interest in science*) and C (*Career interest in science*) can be placed within a set of less positive attitudes. On the other hand, subscale E (*Enjoyment of science lessons*) does not clearly belong to any of these two subsets. These findings are fully consistent with the results published by Fraser (1981) and Lowe (2004) (Figure 3). As in the comparison of reliability between countries (Figure 2), we used the estimated means of 10th grade students in Australia.

A very important aspect is that TOSRA takes into account the multidimensionality of the concept of *attitude toward science* by including seven dimensions or individual constructs of attitude currently regarded as relevant (Tytler & Osborne, 2012). This allows teachers to go beyond the notion of attitude as mere interest in learning science in school, and thus embrace other dimensions of attitude toward science, which must be tackled and evaluated in the classroom. This is particularly relevant if teachers wish to teach science in a way that prepares students to participate in decision-making as responsible citizens and to democratically involve themselves in scientific and technological matters.

Practical implications

Even though TOSRA is a scale to evaluate attitudes toward science, it is not the only instrument. Nonetheless, it can be inferred that an instrument of this kind can be easily applied in the classroom and which teachers can interpret with little difficulty. This is possible because TOSRA is a pen-and-paper scale and it only requires 30 minutes for its application.

It is relevant to note that attitudes toward science are part of the science curricula of Latin American countries, and must therefore be evaluated. In addition, it is necessary to assess these attitudes among the rapidly growing immigrant Latino population in the U.S.A, where it is estimated that by 2030 the number of children aged 5–13 will double (Greenberg, 2012). In this context, it is crucial to have a Spanish-language evaluation instrument that allows teachers to assess and monitor the progress of their students in the various dimensions of attitudes toward science. Even though TOSRA is not the final solution after multiple past attempts to measure attitudes toward science, this study shows that it constitutes a very good alternative to evaluate and monitor the attitudes of Spanish-speaking secondary school students, due to its consistent psychometric properties, its ease of use, and its conceptual solidity, which takes into account the multidimensionality of the concept.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix[1]

TOSRA

Test de Actitudes Relacionadas con la Ciencia

Barry J. Fraser

INSTRUCCIONES

1 Este test contiene una serie de afirmaciones sobre la ciencia. Se pide que pienses en estas afirmaciones. No hay respuestas correctas ni incorrectas. Lo que interesa es conocer tu opinión.

2 Por favor, no escribas sobre este cuadernillo. Traspasa tus respuestas a la hoja de respuestas.

3 Para cada afirmación encierra en un círculo:

MA si estás MUY DE ACUERDO con la afirmación;
A si estás de ACUERDO con la afirmación;
N si NO ESTÁS SEGURO;
D si estás en DESACUERDO con la afirmación;
MD si estás MUY EN DESACUERDO con la afirmación.

Ejemplo:

0 Sería interesante aprender sobre barcos.

Supón que estás de ACUERDO con esta afirmación, entonces debes encerrar A en tu hoja de respuestas, de esta forma:

0 MA A N D MD

4 Si cambias de opinión acerca de una respuesta, táchala con una cruz y encierra tu nueva respuesta, de esta forma:

0 MA ~~A~~ N D MD

5 A pesar de que algunas afirmaciones en este test son bastante similares entre sí, <u>debes manifestar su opinión frente a cada afirmación</u>.

6 No olvides escribir tu nombre, curso y colegio en la hoja de respuestas.

[1]TOSRA was developed by Fraser (1981) and has been translated and included in this article with the author's permission.

Página 2

1 El dinero que se invierte en ciencia es dinero bien invertido.
2 A los científicos les gusta ir a sus laboratorios cuando tienen un día libre.
3 Preferiría averiguar el por qué de un fenómeno haciendo un experimento a que me lo cuenten.
4 Me gusta leer sobre temas que no están de acuerdo con mis ideas.
5 Las clases de ciencia son entretenidas.
6 Me gustaría pertenecer a un club de la ciencia.
7 Al finalizar mis estudios, me desagradaría ser un científico o científica.
8 La ciencia es el peor enemigo del hombre.
9 Los científicos son tan saludables y tienen la misma condición física que el resto de las personas.
10 Hacer experimentos no es tan bueno como obtener información de un profesor.
11 No me gusta repetir los experimentos para comprobar que me dan los mismos resultados.
12 No me gustan las clases de ciencia.
13 Me aburro cuando veo programas científicos en la televisión.
14 Cuando termine mis estudios, me gustaría trabajar con personas que hacen descubrimientos científicos.
15 El dinero público dedicado a la ciencia en los últimos años ha sido utilizado con inteligencia.
16 Los científicos no tienen suficiente tiempo para estar con sus familias.
17 Preferiría hacer experimentos que leer sobre ellos.
18 Tengo curiosidad acerca del mundo en que vivimos.
19 La escuela debería tener más horas de ciencia a la semana.
20 Me gustaría recibir como regalo un libro de ciencias o un instrumento científico.
21 No me gustaría trabajar en un laboratorio de ciencias después de terminar mis estudios.
22 Los descubrimientos científicos están produciendo más daño que beneficio.
23 Los científicos gustan del deporte tanto como el resto de las personas.
24 Preferiría concordar con otras personas que hacer un experimento para averiguar por mí mismo.
25 No es importante investigar sobre cosas nuevas.
26 Las clases de ciencia me aburren.
27 No me gusta leer libros de ciencia durante mis vacaciones.
28 Trabajar en un laboratorio de ciencias podría ser una interesante manera de ganarse la vida.

Página 3

29 El gobierno debe gastar más dinero en la investigación científica.
30 Los científicos son menos amigables que otras personas.
31 Preferiría hacer mis propios experimentos que recibir la información de un profesor.
32 Me gusta escuchar a las personas cuyas opiniones son diferentes a las mías.
33 Las asignaturas científicas son las más interesantes del colegio.
34 Me gustaría hacer experimentos científicos en mi casa.
35 Ejercer una carrera científica sería tedioso y aburrido.
36 Se están construyendo demasiados laboratorios a costa de la disminución de inversión para el resto de la educación.
37 Los científicos pueden tener una vida familiar normal.
38 Preferiría averiguar acerca de las cosas preguntándole a un experto, que hacer un experimento.
39 Me parece aburrido oír ideas nuevas.
40 Las clases de ciencia son una pérdida de tiempo.
41 Sería aburrido conversar con los amigos sobre ciencia después del colegio.
42 Cuando termine mis estudios me gustaría enseñar ciencias.
43 La ciencia contribuye a mejorar la calidad de vida.
44 Los científicos no están preocupados por sus condiciones de trabajo.
45 Preferiría resolver un problema haciendo un experimento a que me digan la respuesta.
46 En los experimentos científicos, me gusta usar métodos que no he usado antes.
47 Realmente me gusta asistir a las clases de ciencias.
48 Disfrutaría tener un trabajo en un laboratorio de ciencias durante mis vacaciones escolares.
49 En el futuro, tener un trabajo científico sería aburrido.

Página 4

50 Nuestro país está gastando demasiado dinero en la ciencia.
51 Los científicos están tan interesados en el arte y la música como el resto de la gente.
52 Es mejor preguntar al profesor la respuesta que llegar a ella por medio de experimentos.
53 No estoy dispuesto a cambiar mis ideas aunque la realidad muestre que éstas no tienen suficiente base.
54 Los contenidos de los programas de ciencias no son interesantes.
55 Sería aburrido escuchar un programa de ciencia en la radio.
56 Sería interesante trabajar como científico.
57 La ciencia puede ayudar a hacer del mundo un lugar mejor.
58 Pocos científicos tiene éxito en su vida matrimonial.
59 Preferiría hacer un experimento sobre un tema que leer sobre este en revistas científicas.
60 En los informes científicos reporto tanto los resultados esperados como los inesperados.
61 Espero con ansias las clases de ciencias.
62 Me gustaría visitar un museo de ciencias durante mis fines de semana.
63 No me gustaría ser un científico porque se requieren demasiados estudios.
64 El dinero utilizado en proyectos científicos es dinero desperdiciado.
65 Si conocieras a un científico, probablemente él se vería como una persona común y corriente.
66 Es mejor que los hechos científicos sean contados a descubrirlos a partir de experimentos.
67 No me gusta escuchar las opiniones de otras personas.
68 Disfrutaría más el colegio si no hubieran clases de ciencia.
69 No me gusta leer artículos periodísticos sobre ciencia.
70 Al terminar mis estudios me gustaría ser un científico.

TOSRA

Nombre ____

Colegio ______________________________ Curso __________

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	MUY DE **A**CUERDO	DE **A**CUERDO	**N**O ESTOY SEGURO(A)	EN **D**ESACUERDO	**M**UY EN **D**ESACUERDO		MUY DE **A**CUERDO	DE **A**CUERDO	**N**O ESTOY SEGURO(A)	EN **D**ESACUERDO	**M**UY EN **D**ESACUERDO		MUY DE **A**CUERDO	DE **A**CUERDO	**N**O ESTOY SEGURO(A)	EN **D**ESACUERDO	**M**UY EN **D**ESACUERDO
1	MA	A	N	D	MD	29	MA	A	N	D	MD	50	MA	A	N	D	MD
2	MA	A	N	D	MD	30	MA	A	N	D	MD	51	MA	A	N	D	MD
3	MA	A	N	D	MD	31	MA	A	N	D	MD	52	MA	A	N	D	MD
4	MA	A	N	D	MD	32	MA	A	N	D	MD	53	MA	A	N	D	MD
5	MA	A	N	D	MD	33	MA	A	N	D	MD	54	MA	A	N	D	MD
6	MA	A	N	D	MD	34	MA	A	N	D	MD	55	MA	A	N	D	MD
7	MA	A	N	D	MD	35	MA	A	N	D	MD	56	MA	A	N	D	MD
8	MA	A	N	D	MD	36	MA	A	N	D	MD	57	MA	A	N	D	MD
9	MA	A	N	D	MD	37	MA	A	N	D	MD	58	MA	A	N	D	MD
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11	MA	A	N	D	MD	39	MA	A	N	D	MD	60	MA	A	N	D	MD
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13	MA	A	N	D	MD	41	MA	A	N	D	MD	62	MA	A	N	D	MD
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26	MA	A	N	D	MD												
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Para uso interno solamente

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