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Parental Attitudes Towards STEM Scale: Development and Psychometric Properties

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ABSTRACT

This study describes the development of the science, technology, engineering, and mathematics (STEM) Scale, intended to assess parental attitudes toward school programs designed to deliver STEM, and evaluates its psychometric properties. The study group included 400 parents of students (138 males and 262 females) enrolled in STEM programs throughout the Kingdom of Saudi Arabia. As a result of the analysis, a 50-item scale comprising four subscales was developed: (a) perceived value, (b) perceived control, (c) affective component, and (d) intention component. Exploratory and confirmatory factor analyses confirmed a four-factor structural model that had a satisfactory fit. Cronbach's alpha of the overall scale demonstrated good internal consistency. Preliminary results suggest that parental attitudes toward the STEM scale have adequate convergent and divergent validity.

Keywords: psychometric properties, reliability, validity, parental attitudes towards STEM, scale

INTRODUCTION

Parental Attitudes Towards STEM Scale: Development and Psychometric Properties

Advances in science have increased the capacity and the need for individuals to come up with innovations in their fields of study (Tindle et al., 2022). In fact, global economies in the 21st century seek those individuals who are competent in their disciplines and have a good understanding of science, technology, engineering, and mathematics (STEM). Despite the increasing need for individuals with knowledge in STEM fields, current educational systems do not provide students with the required knowledge in these areas (Yıldırım and Selvi, 2015). STEM education is essential for future student success (Abo Hamza et al., 2024; Stohlmann et al., 2012). Consequently, many countries have tried and are still seeking to improve the quality of education provided in these disciplines.

With the growing interest in promoting STEM as a career path for both undergraduate and graduate students, it is important to understand the factors that influence student learning in these sciences (Soylu, 2016). Parental attitudes are one of the most important factors influencing student learning. They play an important role in mediating the link between teachers and students, as well as stimulating children's interest in STEM. Thus, it is important to measure the impact parents have on developing STEM programs by assessing their attitudes toward STEM.

Social influences, such as the attitudes of parents (Irawati and Zamroni, 2020), family-related factors (Watts et al., 2024) and teachers attitudes toward a subject (Peterson et al., 2016), likely affects students' educational aspirations and interests. Among these, parental involvement in the learning process has been shown to influence both the teaching and learning process (Wankat, 2007; Yun et al., 2010). Several studies have revealed that parents have a significant impact on students' learning and motivation to study (e.g., George and Kaplan, 1998). Researchers in many diverse areas have focused on parental influences on children's academic achievement (Seyfried and Chung, 2002). These studies suggest that it is essential to urge parents, as well as students, to develop improved conceptual understanding, such as geometry, to encourage their children to encourage children to apply concepts from geometry. Therefore, this study aimed to develop a scale to assess parental attitudes toward STEM programs in the Kingdom of Saudi Arabic (KSA).

STEM Programs

STEM has gained widespread global interest from educational institutions and workforce in recent years (English, 2016). In the 1990s, after the economic downturn and increased competition among advanced economies, STEM programs were introduced in the USA as a reform curriculum aimed to prepare students for the global economy in the 21st century (Abo Hamza et al., 2024; Guyotte et al., 2014; Yakman and Hyonyong, 2012). Since their introduction, STEM programs have become the focus of attention for teachers and researchers (Sousa and Pilecki, 2013; Soylu, 2016).

Social and personal issues related to health, the environment, and even social networks, require an understanding of STEM. In this way, students' learning of STEM at all levels of schooling contributes to their intellectual development, career choices, and the ability to make informed decisions not only in political and civic matters but also in their private lives (National Research Council, 2011). In addition to improving academic achievement, STEM programs provide students with the basic knowledge needed to participate in the future workforce (Quigley and Herro, 2016).

STEM educational programs aim to provide students with competence, knowledge, and a multi-point view of problems (Şahin et al., 2014) by removing barriers imposed by the traditional education system that offered students STEM subjects separately (Vasquez et al., 2013). Rather than delivering educational content separately, STEM programs integrate the relevant disciplines into a single lesson or module that relies on communication between students and real-life problems. This allows students to put their theoretical knowledge into practice for production and innovation (Çorlu, 2013; Kelley and Knowles, 2016).

The STEM approach is taught in countries such as the USA, China, Korea, Japan, Germany, Turkey, and KSA; however, STEM education is an emerging area for the KSA educational system. Objectives related to the promotion of STEM education are being undertaken in the KSA in accordance with strategic plans prepared by the Ministry of Education (2019). In this process, the importance of the arts in teaching and learning the sciences should not be overlooked. However, the emphasis of curriculum developers and universities is on economic support for new projects that bring together researchers, teachers, and parents to achieve the targeted goals in the new area of STEM. This is a new step, but it is a big step necessary for preparing our future scientists.

Recently, some studies have been conducted at the international level, to measure the attitudes, views, and perceptions of teachers, student teachers, and students in STEM (e.g., Aydin et al., 2017; Berlin and White, 2010; Doğan and Benzer, 2019; Ergün, 2019; Faber et al., 2013; Gülhan and Şahin, 2016; Hacıömeroğlu and Bulut, 2016; Oh et al., 2012; Sjaastad, 2012; Tyler-Wood et al., 2010).

A review of the relevant literature reveals that there are few studies addressing parental attitudes toward STEM educational programs at the international and local levels. There is also a lack of valid and reliable survey instruments assessing the same. This is despite the assertion of many researchers that parental involvement is important in the learning process (Fan and Chen, 2001; Jacobs and Harvey, 2005; Seyfried and Chung, 2002). This may indicate that if parents are not familiar with STEM educational programs, they are unlikely to understand its design and encourage their children to engage in this new approach to learning the sciences. Therefore, our study aims to bridge this research gap by developing a scale to capture parental attitudes toward STEM and evaluate its psychometric properties. This scale can be considered a useful assessment tool for researchers and practitioners seeking to measure parental attitudes toward this new approach to teaching STEM, as well as for Arabic educational systems. Moreover, measuring parental attitudes toward STEM could raise awareness about teaching the sciences and thus, help to integrate STEM into teaching and learning processes.

METHOD

Participants

Parents of students (*n* = 400) enrolled in STEM programs in the KSA participated in the study. One parent from each family was encouraged to participate. Demographically, 33% of the study participants were men and 85% had attended a university. Among them, 20% studied science, 15% studied technology, 15% studied mathematics, and 8.5% studied engineering.

Instruments

Parental attitudes toward STEM were assessed using a self-report instrument consisting of 50 items. These 50 items were designed based on a review of several studies (Abedalaziz et al., 2013; Benek and Akcay, 2019; Doğan and Benzer, 2019; Ergün and Balçın, 2017; Popa and Ciascai, 2017; Selwyn, 1997; Tabuk, 2018) that include the technology acceptance model (Davis, 1989). The items assessed the perceived value of the usefulness of STEAM and STEM educational programs in their child's study, specifically,

(a) perceived control, which refers to perceived comfort level or anxiety of studying STEM educational programs,
(b) an affective component that refers to parents' feelings toward STEM educational programs, and
(c) an intention component that refers to behavioral intentions and actions with respect to STEM educational programs.

Participants responded on a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

Analysis

An exploratory factor analysis (EFA) was conducted using data from 200 participants of the study sample, while a confirmatory factor analysis (CFA) was conducted using data from the remaining 200 participants. In the EFA, the collected data were analyzed using principal component analysis. Scree plot, Kaiser criterion, and parallel analysis were used to establish a criterion to estimate the number of factors to be extracted.

The assessment of our parental attitude scale included several features:

(a) p for the χ^2-statistic,
(b) root mean square error of approximation (RMSEA),
(c) goodness-of-fit index (GFI),
(d) comparative fit index (CFI),
(e) standardized root mean square residual (SRMR),
(f) adjusted goodness-of-fit index (AGFI), and
(g) the Tucker-Lewis index (TLI).

The standard criteria ($p > 0.05$; SRMR < 0.08, RMSEA < 0.06, CFI > 0.95, GFI > 0.95, AGFI > 0.95, and TLI > 0.95) were used for good fit (Kline, 2015).

The validity of our parental attitude measurement scale (PAMS) was assessed by examining complementary factors: convergent validity and discriminant validity. Convergent validity is concerned with measuring the degree of a positive relationship between the items of the scale developed, and other scales that measure the same concept/construct. Therefore, the purpose of convergent validity is to confirm that items and questions that are theoretically related, are in fact related. However, discriminate validity indicates that the present scale is not related to other scales that measure theoretically different concepts.

Convergent viability was evaluated by the main criteria: factor loading, composite reliability (CMR), and average variance extracted (AVE). The CMR value shows the degree to which the construct indicators reflect the underlying structure, while the AVE reveals the total amount of variance in the indicators represented by the underlying structure. Hair et al. (2010) recommended that values for factor loading, AVE, and CMR must be greater than 0.5, 0.5, and 0.7, respectively. In addition, for a distinct variable, the correlation between the variables must be lower than the square root of the AVE (Hulland, 1999).

Discriminatory validity is assessed using Fornell and Larcker (1981) criterion, by comparing the square root of the AVE with the relationship between factors (Hair et al., 2016). In addition, for a distinct variable, the correlation between the variables must be less than the square root of the AVE (Hulland, 1999).

Table 1. Factor loadings, communalities (h^2), Eigenvalue (λ), and the variance accounted by each factor

Factor	Item	Factors 1	2	3	4	h^2	λ	% variance
PV	PV6	.80				.64	22.25	55.63
	PV10	.79				.62		
	PV4	.77				.59		
	PV8	.76				.58		
	PV3	.74				.55		
	PV14	.73				.53		
	PV7	.72				.52		
	PV13	.72				.52		
	PV15	.71				.50		
	PV2	.70				.49		
	PV12	.70				.49		
	PV5	.70				.49		
	PV1	.69				.48		
	PV17	.69				.48		
	PV9	.69				.48		
PC	PC31		.79			.62	2.63	6.58
	PC30		.73			.53		
	PC32		.73			.53		
	PC20		.70			.49		
	PC29		.68			.46		
	PC11		.67			.45		
	PC49		.67			.45		
	PC25		.67			.45		
	PC24		.65			.42		
	PC33		.62			.38		
AC	AC37			.75		.56	2.40	6.00
	AC34			.74		.55		
	AC35			.74		.55		
	AC36			.72		.52		
	AC23			.67		.45		
	AC46			.60		.36		
	AC22			.57		.32		
	AC38			.55		.30		
	AC42			.52		.27		
	AC27			.51		.26		
IC	IC44				.82	.67	1.69	4.21
	IC47				.79	.62		
	IC40				.76	.58		
	IC50				.76	.58		
	IC45				.70	.49		

RESULTS

Exploratory Factor Analysis

Principal component analysis yielded eight factors with Eigenvalues greater than one that accounted for 80% of the total variance. As a four-factor solution was supported by the theoretical structure of the scale, four factors were extracted and rotated for interpretation using oblique rotation. The three criteria tests were repeated after removing ten of the 50 items that had factor loadings less than 0.30 (Hair et al., 2010) and loaded in more than one factor (Field, 2011). The remaining 40 items were subjected to principal component analysis, followed by oblique rotation. Factor 1 (perceived value: PV) represented 55.63% of the total variance (Eigenvalue = 22.25), factor 2 (perceived control: PC) represented 6.58% (Eigenvalue = 2.63), factor 3 (affective component: AC) represented 6.00% (Eigenvalue = 2.40), and factor 4 (intention component: IC) represented 4.21% of the total variance (Eigenvalue = 1.69). **Table 1** illustrates factor loadings, communalities, Eigenvalues, and the variance accounted for by each factor.

For further evidence of the construct validity of PAMS, Pearson correlation coefficients between item scores and domain scores were extracted. Results revealed that Pearson correlation coefficients ranged from 0.67–0.93 on PV subscale, 0.65–0.82 on PC subscale, 0.69–0.84 on AC subscale, and 0.64–0.76 on IC subscale. All were

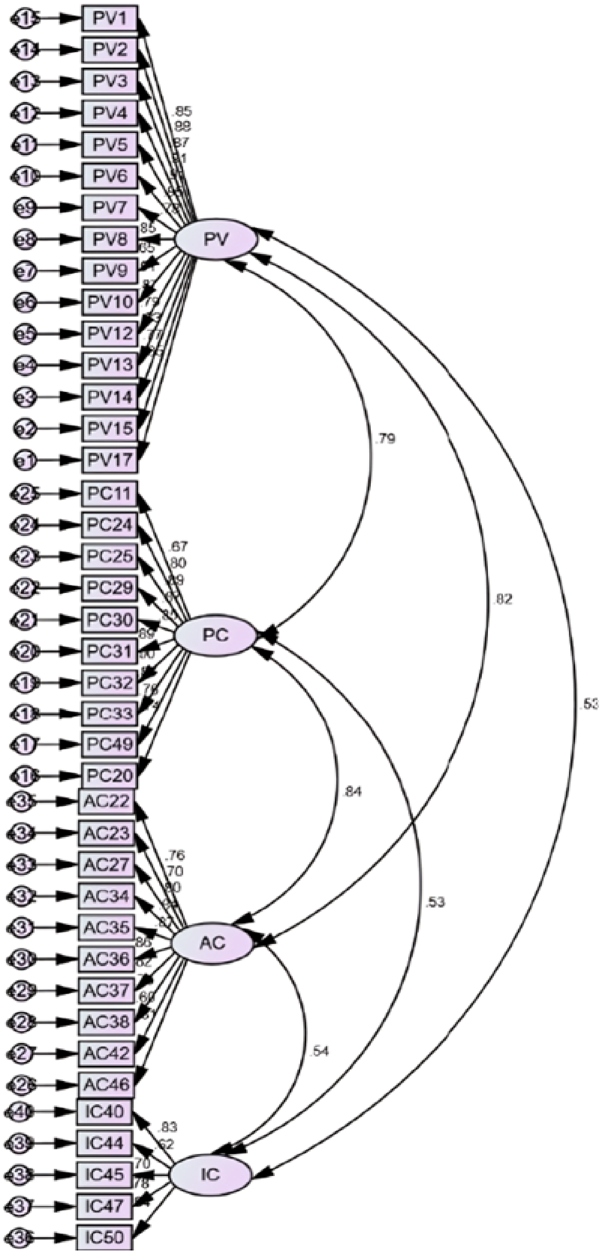

Figure 1. Measurement model for the PAMS

significant ($p < .01$) and higher than the recommended value (0.35; Bryman and Cramer, 1997). Moreover, corrected item-total correlation within the same subscale provides good evidence for content validity because the highest factor loading is central to the dimension assessed by this subscale (Francis et al., 2000). Corrected item-total correlation ranged from 0.65–0.91 on PV subscale, 0.67–0.88 on PC subscale, 0.59–0.84 on AC subscale, 0.61–0.75 on IC subscale, and 0.49–0.75 on the entire scale (PAMS). It is generally agreed that item-total correlation in the range of 0.35–0.65 is useful and statistically significant beyond the 1% level (Brown, 1983; Bryman and Cramer, 1997). These results supported the internal consistency of the scale.

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was performed to provide supportive evidence for factor structure. The IBM-SPSS software was used for the same. Prior to CFA, data were examined for outliers, multivariate normality, and multicollinearity. Since the estimation of maximum likelihood assumes multivariate normality of the observed variables, univariate and multivariate normality were evaluated. The results revealed no violation of univariate and multivariate normality. On this basis, the data from our study were considered sufficient for CFA.

The CFA results revealed that the measurement model for the one-factor model of the perceived social support scale had a good fit ($\chi^2 = 8.603$, df = 5, $\chi^2/$ df = 1.72, CFI = 0.99, AGFI = 0.96, TLI = 0.97, RMSEA = 0.05, SRMR = 0.06). **Figure 1** shows the measurement model for the four-factor model of the teacher burnout scale.

Table 2. Factor loading, CMR, and AVE

Factor	Factor loading	AVE	CMR
PV	.847	.71	.92
	.771		
	.832		
	.787		
	.871		
	.915		
	.647		
	.847		
	.779		
	.852		
	.915		
	.906		
	.873		
	.883		
	.846		
PC	.739	.68	.90
	.762		
	.857		
	.902		
	.892		
	.846		
	.867		
	.891		
	.798		
	.672		
AC	.810	.62	.84
	.599		
	.779		
	.825		
	.863		
	.872		
	.839		
	.802		
	.699		
	.758		
IC	.843	.58	.79
	.779		
	.700		
	.625		
	.834		

Table 3. Discriminant validity of the PAMS

Factor	F1	F2	F3	F4
PV	**.84**			
PC	.67**	**.82**		
AC	.51**	.66**	**.79**	
IC	.36**	.41**	.45**	**.76**

Table 2 illustrates the factor loading, composite reliability (CMR), and average variance extracted (AVE) of the four factors. As shown in **Table 2**, the factor loadings for the four factors ranged from 0.647–0.915, 0.672–0.902, 0.699–0.863, and 0.625–0.843, for PV, PC, AC, and IC, respectively. All values were above the threshold value (0.50). Further, all AVE values are greater than the threshold value (0.50). All CMR values were also above the threshold value (0.70). In conclusion, the values of factor loading, AVE, and CMR indicate convergence of the four constructs (factors).

Table 3 shows the correlation matrix of the four factors and square roots of the AVE. The square root of each factor's AVE value was higher than its correlation with other factors, and each item loading was higher on its associated construct (Fornell and Larcker, 1981). As such, PAMS showed satisfactory discriminant reliability. This means that each factor shares more contrast with its elements than it does with the other factors. Accordingly,

Table 4. Parental attitude scale towards STEM or STEAM

No	Item	Subscale
1	I believe STEM and STEAM play a role in improving our quality of life.	Perceived usefulness
2	I believe those who work in STEM and STEAM make our life more convenient.	Perceived usefulness
3	STEM and STEAM are worth studying.	Perceived usefulness
4	STEM and STEAM improve our society.	Perceived usefulness
5	I believe working in STEM and STEAM help people.	Perceived usefulness
6	I believe those who work in STEM and STEAM fields make my child/(ren)'s lives easier.	Perceived usefulness
7	I would like my child/(ren) to pursue a career in STEM or STEAM.	Behavioral intention
8	My child/(ren) would enjoy studying STEM and STEAM in college.	Perceived control
9	I believe that learning STEM and STEAM ideas and skills would be good for my child/(ren).	Perceived usefulness
10	I believe that teaching STEM and STEAM ideas and skills would be good for my child/(ren).	Perceived usefulness
11	STEM and STEAM skills would be useful for my child/(ren)'s career.	Perceived usefulness
12	My child/(ren)'s school should teach STEM and STEAM concepts and skills.	Behavioral intention
13	My child/(ren) would enjoy learning STEM and STEAM in class 12.	Perceived control
14	Learning STEM and STEAM in class 12 will allow my child/(ren) to better understand other subjects, such as science, arts, mathematics, and technology.	Perceived usefulness
15	I believe my child/(ren) would have an improved quality of life if they learn STEM and STEAM in class 12.	Perceived usefulness
16	I want my child/(ren) to learn STEM and STEAM skills and concepts.	Behavioral intention
17	I want my child/(ren) to understand what those in STEM and STEAM fields do.	Behavioral intention
18	It is more important for girls to learn STEM than it is for boys to learn STEM.	Behavioral intention
19	It is more important for boys to learn STEM than it is for girls to learn engineering.	Behavioral intention
20	It is equally important for girls and boys to learn STEM.	Behavioral intention
21	I am interested in attending workshops about STEM and STEAM at my children's school.	Behavioral intention
22	I think it is necessary to learn about STEM and STEAM fields as early as possible.	Behavioral intention
23	I would like my child to learn STEM and STEAM, but the school day is already too full for my child's school to include engineering.	Behavioral intention
24	I could probably teach myself most of the things I need to know about STEM and STEAM.	Perceived control
25	STEM help my child to improve his future work better.	Perceived usefulness
26	STEM make it possible to work more productively.	Perceived usefulness
27	STEM can allow child to do more interesting and imaginative work in the future.	Perceived usefulness
28	If my child/(ren) learn engineering, then can improve things people use every day.	Perceived usefulness
29	Knowing how to use math and science together will allow my child to invent useful things.	Perceived usefulness
30	Science, mathematics, engineering, and technology are interrelated.	Perceived control
31	Science, mathematics, engineering, and technology skills should be used together when inventing something.	Behavioral intention
32	Science, mathematics, engineering, and technology fields complement each other.	Perceived control
33	If my child/(ren) attend a course that combines Science, mathematics, engineering, and technology skills, they may learn about their skills that they do not aware of.	Perceived usefulness
34	I believe those who work in STEM and STEAM are creative people.	Perceived control
35	I believe those who work in STEM and STEAM are supposed to be good problem solvers.	Perceived control
36	I believe those who work in STEM and STEAM use several different ways to express their opinions.	Perceived control
37	I believe those who work in STEM and STEAM explore new information.	Perceived control
38	I believe those who work in STEM and STEAM design new stuff.	Perceived control
39	I believe those who work in STEM and STEAM earn a lot of money.	Perceived usefulness
40	STEM and STEAM course, workshop, and meeting make me feel uncomfortable.	Perceived usefulness
41	Attending STEAM will not scare my child/(ren).	Affective
42	My child/(ren) hesitate to engage in STEAM program in case he/they look stupid.	Perceived control
43	My child can learn STEAM course independently, without the assistance of others.	Perceived control
44	I hesitate to engage in STEAM and STEM course, workshop, and meeting in case I look stupid.	Perceived control
45	I need an experienced person nearby when I attend STEAM and STEM course or workshop.	Perceived control
46	If I get problems in STEA and STEM, I can usually solve them one way or the other.	Perceived control
47	When I attend STEAM and STEM course or meeting, I am not quite confident about what I am doing.	Affective
48	I do not like people to think I am smart in STEAM and STEM.	Affective
49	I feel confident when I help my child with STEAM and STEM.	Affective
50	The compounds of STEAM and STEM, especially mathematics, are boring.	Affective

discriminant validity appears to be acceptable at the construct level. At the item level, discriminant validity is apparent when one item is related more to the items in the same factor than to items from other factors (Hair et al., 2010). Given that there was no cross-loading among the items in different factors, a satisfactory level of discriminant validity was achieved at the element level.

Cronbach's alpha coefficients for PV, PC, AC, and IC subscales were 0.97, 0.95, 0.94, and 0.87, respectively. The results revealed that the alpha coefficients for the four subscales were significantly high, suggesting that the internal consistency indices of the four aspects were adequate (Leech et al., 2011).

The final form of the questionnaire, as shown in **Table 4**, indicates that 39 statement items were retained and 11 statements were deleted after conducting all the previous validity and reliability operations. These 50 items were divided into four subscales according to their psychometric properties. Table 4 explains the items and how they are all categorized into four subscales:

(a) perceived value,
(b) perceived control,
(c) affective component, and
(d) intention component.

DISCUSSION

PAMS was developed to be used as an indicator of parental attitudes toward STEM programs. In summary, the statistical results of the Eigenvalue (greater than 1) coincided with the test of Cattel's slope curve (scree plot test) and explained variance criteria. The results of the confirmatory factor analysis showed that the statistical fit indices indicated a good fit of the four-factor model, as the Chi-square was not statistically significant. As such, the null hypothesis that there is no difference between the assumed model and the real model, with data derived from the sample, cannot be rejected. In other words, there is a match between the assumed and realistic models. The root mean square error of approximation (RMSEA) was a good and distinct fit, and the values of the adjusted fit indexes (adjusted goodness-of-fit index [AGFI]) and comparative fit index (CFI) all exceeded 0.95, indicating a reasonable fit for the current model.

In sum, when comparing the values of the extracted fit indexes, as shown by the results of the CFA, with the values of the criteria to judge the optimal extent of good fit, it becomes clear that the fit indexes indicated that the measurement model emerging from the EFA of parental attitudes toward STEM has a good overall fit. Since the CFA model was built according to the results of the EFA, the structure of parental attitudes toward STEM that emerged from CFA is identical to the model resulting from the EFA. In other words, the realistic model (sample data) is identical to the assumed model. With respect to convergent validity, the extracted values of factor loading, composite reliability, internal consistency, and average variance were statistically significant and were higher than the recommended value for each. This indicates the convergent validity of the PAMS scale. That is, the pool of items for each factor was valid and applicable for measuring their constructs. Moreover, to assess discriminant validity, the Fornell and Larcker (1981) approach was used, which requires that the covariance between the latent variable and the indices assigned to it be greater than any other latent variables.

The results showed that the square root of the average variance extracted for each latent construct was higher than the correlations of any other underlying constructs, indicating the discriminatory validity of the scale. The results indicated that item loading was higher than the recommended value (0.50). This indicates a significant contribution of the item in measuring its factor. In addition, the 4-factor model showed high-quality and fitness indicators. These results provide evidence supporting the construct validity of the PAMS. To determine the similarities between the results of the EFA and CFA in terms of item loadings, the results showed that the item loading on its factor in the CFA (maximum probability method) was close to the EFA (the basic components method). This supports the construct validity of the PAMS. To collect further evidence for the construct validity of the PAMS, Pearson correlation coefficients between item scores and domain scores were extracted. The results revealed that the Pearson correlation coefficients were significant ($p < .01$) and higher than the recommended value (0.35). Moreover, corrected item-total correlation coefficients were statistically significant beyond the 1% level (Brown, 1983; Bryman and Cramer, 1997). These results support the internal consistency of the scale. Cronbach's alpha coefficients for PV, PC, AC, and IC subscales were higher than the recommended value (0.70), which indicates that the scale is reliable and applicable for measuring attitudes toward STEM.

CONCLUSION

The present study aimed to develop and assess the psychometric properties of the PAMS. EFA and CFA were performed to verify the validity of the factor structure of the PAMS. The results showed that the scale items measured four factors. The validity of the factor structure was also verified by assessing the convergent and discriminatory validity of the scale items, and the results showed that all items met the requirements for convergent and discriminant validity of the PAMS. Further evidence for the scale's construct validity was gained using Pearson correlation coefficients between the item score and its corresponding domain score. The corrected item-total correlation coefficients were in the acceptable range, as were Cronbach's alpha coefficients. The results indicate that the PAMS has an acceptable degree of internal consistency.

This study had some limitations. First, the instrument developed in the current study needs to be tested in other cultures to generalize its use in other countries with different educational systems. Second, although data on parent education were collected, the results might differ based on parents' educational level.

Future studies might examine the difference between parents who work in STEM fields and those who work in fields not related to STEM. Different findings might be found based on the parents' majors.

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