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Validation of Student Attitudes toward STEM (S-STEM) Survey in Secondary Schools in Tanzania

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Abstract

Tanzania has been taking various initiatives to promote positive attitudes towards, and interest in science, technology, engineering and mathematics (STEM) among students. Such initiatives call for systematic tools to be used to assess students' attitudes towards STEM so as to inform appropriate interventions. This study investigated the extent to which S-STEM is a valid psychometric instrument for measuring secondary school students' attitudes towards STEM in the Tanzanian context. Additionally, the study sought to establish whether S-STEM is a valid measure of students' attitudes towards STEM across gender. Data was gathered from 16 secondary schools. A total of 1,382 Form 2 (Grade 10) students were sampled from four districts in Northern (N = 659) and North-eastern (N = 723) Tanzania. The study adopted four scales from the S-STEM survey that measures students' attitudes toward STEM, and the 21st century skills. Structural equation modelling and measurement invariance techniques were used to assess the validity of the S-STEM survey in the sampled schools. A structural equation model with 31 out of 37 initially validated items in the S-STEM survey attained moderate to good fit, hence it was valid for measuring both girls' and boys' attitudes towards STEM and 21st century skills in Tanzanian secondary schools. Finally, implications for future practices and further research are discussed.

Keywords: *attitudes, developing world, secondary and high school, STEM education*

1. Introduction

Recent educational policies in different countries have focused on promoting positive attitudes towards, and interest in science, technology, engineering and mathematics (STEM) among students to address the acute shortage of personnel in the STEM workforce. Yet, it is reported that students tend to have low attitudes towards, and a lack of interest in, STEM (Falk et al., 2015; Miller et al., 2017). As a consequence, there is a drop in the number of students pursuing STEM in higher education (ibid.). Following such a situation, there has been a growing amount of attention paid to the study of students' attitudes towards, and interest in STEM (Dabney et al., 2012; Hudson et al., 2020; Miller et al., 2017). Conceptually,

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although interest is viewed as a specific form of attitude, sometimes it is used synonymously with the term attitude (Krapp & Prenzel, 2011). Thus, recent efforts to search for a comprehensive measure of inclinations towards STEM have tended to use both attitude and interest as one inclusive construct. The fascinating attention on attitudes towards, and interest in STEM is increasingly acknowledged as an important aspect of scientific literacy (Krapp & Prenzel, 2011). Essentially, attitudes towards, and interest in STEM have a tremendous influence on attention (Dabney et al., 2012), goals, choice and level of training (Chachashvili-Bolotin et al., 2016; Krapp & Prenzel, 2011; Renninger & Hidi, 2011), enhanced cognitive functioning, and persistence (Dabney et al., 2012; Krapp & Prenzel, 2011). As such, scholars such as Grimmon et al. (2020) have argued that students' interest in STEM should be developed and sustained to make them perform better in STEM subjects. Several other scholars have recommended that efforts to promote students' attitudes towards, and interest in STEM careers should begin as early as during adolescence (Falk et al., 2015; Hudson et al., 2020; Kier et al., 2014).

1.1 The Social Cognitive Career Theory: A Theoretical Framework

Attitudes towards, and interest in STEM subjects and careers are key aspects of the social cognitive career theory (SCCT) (Unfried et al., 2015). According to Krapp and Prenzel (2011), while others view interest as a specific form of attitude, it is often used synonymously with the term attitude. In that regard, while students' attitudes towards science are "composed of self-efficacy and expectancy-value beliefs" (Unfried et al., 2015: 623), interest is "… a psychological state and a predisposition to reengage particular disciplinary content over time that develops through one's interaction with their environment" (Renninger & Hidi, 2011: 170). Consistently, the SCCT is widely acknowledged and used as a suitable theoretical tool for studying and understanding attitudes towards, and interest in STEM; as well as the choice of a STEM career (Chachashvili-Bolotin et al, 2016; Kier et al., 2014; Lent et al., 2008; Schoenfeld et al., 2017). According to these scholars, SCCT is based on Bandura's theory, and is concerned with how personal, behavioural and environmental factors interact to influence career choice. In other words, attitudes towards, and interest in a STEM career are a function of an interaction among "self-efficacy beliefs, outcome expectation, and goals" (Schoenfeld et al., 2017: 4). That is to say, the more students possess these variables, the more likely they will be interested to engage in a particular task. For instance, a student who believes s/he can succeed in Mathematics (self-efficacy), and is confident that Mathematics will help him/her pursue a career in engineering (outcome expectation), is more likely to develop positive attitudes towards, and interest in that subject. According to Chachashvili-Bolotinet al. (2016), career interest and choice result from an interaction among self-efficacy, outcome expectations, environmental support and barriers, and interests. It is also important to note that these personal, behavioural and environmental variables interrelate and change with time (Schoenfeld et al., 2017). That is to say, attitudes and interests involve conscious or unconscious calculations informed by one's belief that something is doable and enjoyable, and will result into the achievement of goals despite opportunity costs.

Additionally, the SCCT significantly considers how attitudes and interests are related to some socially and culturally constructed inputs such as socio-economic background, gender, personality and race. In this regard, attitudes towards, and interest in STEM should be thought beyond school variables. For instance, Falk et al. (2015) found that

parents' attitudes toward science were positively associated with students' general interest in STEM; implying that non-school factors are also important in influencing students' attitudes towards, and interest in STEM. On the contrary, students' interest in STEM is not correlated with teacher variables (ibid.). Indeed, not only can scientific knowledge be acquired out of school (Krapp & Prenzel, 2011), but also out-of-school activities are strong predictors of career interest in STEM (Dabney et al, 2012; Price et al., 2018). Despite its wide usage, Lent et al. (2008) have warned that the SCCT framework should be operationalized to suit the needs of the population being studied. In this regard, the framework guided our understanding of attitudes towards STEM, our search of literature, and our consideration of several independent variables, such as gender.

1.2 Gendered Patterns in Attitudes Towards and Interests in STEM

Efforts to improve attitudes towards, and interest in STEM among marginalized groups such as women (Price et al., 2018; Reddy, 2017; Sax et al., 2015; Tzu-Ling, 2019), students with disabilities (Kolne & Lindsay, 2020), and students from poor backgrounds (Grimmon et al., 2020) are very well documented in the literature on STEM. Nonetheless, the gender gap—both in terms of attitudes towards, and interest in STEM, and in terms of participation in STEM—seem to outpower those efforts. With respect to gender differences in the attitudes towards, and interest in STEM, research has produced mixed results, although women have generally tended to lag behind (Chachashvili-Bolotin et al., 2016). Moreover, Price et al. (2018) found that women who participated in an out-of-school programs during their adolescence were more interested in STEM careers as compared to men. In another study involving high school STEM students, Tzu-Ling (2019) found that males received more support from the family as compared to females. Also, while task value predicted STEM career interests for both males and females, self-efficacy of STEM predicted STEM career interests for male students only.

In various studies, gender differences in the way students perceive instructional interventions have been noted. For instance, Zuo et al. (2019) found that, while risk-taking enhanced attitudes towards mathematics among male and female high school students, having a higher level of autonomy in mathematics classes was associated with more positive attitudes toward mathematics among females only. Sax et al. (2015) have generalized that female students tend to have a lack of interest in mathematics compared to their male counterparts. Furthermore, according to Kier et al. (2014), men and women differ with regard to their attitudes towards, and interest in STEM; whereby it was found that women are more inclined towards the biological sciences, while men are more inclined towards the physical sciences. Yet, Reddy's (2017) investigation of seventh graders' attitudes towards science in South Africa found no significant difference between boys and girls. Prompted by these contradictions in previous research, the present study sought to establish whether S-STEM applies equally to male and female students. This was considered important given that no study on this subject has been done in the Tanzanian context, which might be different from the contexts where many of these studies have been conducted.

1.3 STEM Education in Tanzania

In the Tanzanian education system, the formal structure of education is 2: 7: 4: 2: 3+, whereby 2 years is for pre-primary, 7 years for primary, 4 years for Ordinary level (Form 1

to 4) secondary, 2 years Advanced level (Form 5 to 6) secondary, and 3 years and above for tertiary and higher education (MoEVT, 2014). During the primary school years, all students study a compulsory integrated science subject called Science and Technology, which is taught using the Swahili language (MoEST, 2019). Ordinary level secondary education, which is part of basic education, is a level where students are supposed to take all subjects taught at school, including Mathematics, English, Kiswahili, Biology, Civics, Physics, Chemistry, Geography and History during their first two years. While in their third year of secondary education, students are required to select one among the optional bias subjects, which includes Science (Ndalichako & Komba, 2014). This means that all subjects taught in O-level secondary school are compulsory for all students in Form 1 and 2. In opting for the bias subjects such as science, students in their 3rd year of secondary education (Form 3) select subjects of their interests. For instance, students opting for science take Physics, Chemistry, Biology and Mathematics in their 3rd and 4th years of secondary school, in addition to compulsory subjects that include Civics, English and Kiswahili.

Generally, there is a very low rate of participation in STEM in Tanzanian schools, which begins to be felt more clearly when students make their choices. In particular, the educational and training policy in Tanzania indicates that only 30–35 out of 100 secondary school students were studying science subjects in Form 3 and 4 (MoEVT, 2014). A dire shortage of science and mathematics teachers, laboratories, and other teaching-and-learning facilities discourages students from opting for STEM subjects (Semali & Mehta 2012; Ndalichako & Komba 2014). Consequently, a great majority of secondary school students prefer social sciences (arts) subjects to natural science subjects owing to the aforementioned challenges and the negative attitudes they hold towards STEM subjects. In addition, students' non-preference of science subjects is partly attributable to a long trend of poor performance in those subjects (MoEST, 2016; 2019). Despite the intensity of this situation, only a few studies have been conducted to investigate the matter; most of which focus on the language of instruction (Mkimbili, 2019), teaching approaches (Kitta & Tilya, 2010), and teacher quality (Komba & Nkumbi, 2008). Other studies have shown that mathematics teachers experience pedagogical challenges in carrying out formative assessments (Kyaruzi et al., 2018): as a result students perceive teacher feedback as less supportive in improving learning (Kyaruzi et al., 2019). However, no study has been conducted to measure and/or validate the existing instruments for measuring students' attitudes towards, and interest in STEM subjects (S-STEM) and careers, which is why this study was deemed necessary.

2. Measurement and Validation of S-STEM Questionnaire Across Gender

Several instruments (Grimmon et al., 2020; Kier et al., 2014; Unfried et al., 2015), mostly based on the SCCT, have been developed and applied in various contexts. In recent years, the STEM Career Interest Survey (STEM-CIS) (Kier et al., 2014) has increasingly been considered as a sound instrument. The STEM-CIS uses 44 items to measure STEM career interest across four sub-scales of science, technology, engineering, and mathematics. Despite its wide recognition, the STEM-CIS has been criticized for not being adequate enough in exploring some of the important input variables. For instance, Grimmon et al. (2020) have criticized it for overlooking the aspect of gender. As a response, Grimmon et al. (2020) developed a new version of STEM-CIS (the STEM-Leiden Interest Test, or STEM-LIT) for measuring STEM career interests among children from low socio-economic

backgrounds in the Dutch context. The final version was tested on primary students (10–12 years of age, N = 212), and yielded a score of 0.91 for the entire scale in terms of Cronbach's alpha. Not only does the STEM-LIT provide evidence to support the STEM-CIS, but it also covers the issue of gender, thus proving to be reliable for both boys and girls. Nonetheless, in recent years there has been more attention paid to career skills (e.g., problem-solving, critical thinking and self-regulation skills) that are needed for citizenship, and the ability to compete in the globalized world. These skills, commonly referred to as '21st century skills' (Unfried et al., 2015: 623), are considered very essential to STEM professionals.

There is an increased attention on the validation of questionnaire tools or models prior to applying them to new cultural contexts because their validity is prone to the effect of contextual factors (Brown et al., 2017; Kyaruzi, 2021). The validation of previously validated questionnaires usually involves developing confirmatory factor analysis models based on previous researches or theories by using analysis techniques, such as the structural equation modelling (SEM) technique. In this study, we specified the structural equation model based on previous studies (Kier et al., 2014: Unfried et al., 2015) on the scales for measuring students' attitudes towards STEM (S-STEM). Unlike Kier et al. (2014) who independently estimated four models for each construct of the S-STEM, we estimated the model by fully inter-correlating all the constructs. Likewise, unlike Unfried et al. (2015) who correlated residual errors, we did not correlate residual errors because it is believed that errors should be freely estimated in a model to avoid improving the model fit without theoretical justifications (Hermida, 2015). Generally, the evaluation of model fit is usually based on a multiple of fit indicators, according to Byrne (2010) and Fan and Sivo (2007), who recommend that: (a) A good model fit is based on a combination of the root mean squared error of approximation (RMSEA), a standardized root mean residual (SRMR) below .05, and a comparative fit index (CFI) and Gamma hat values above 0.95; and (b) a model is said to have an acceptable fit when it attains RMSEA and SRMR below 0.08, and CFI scores above 0.90 (Hu & Bentler, 1999).

There is an increasing body of literature calling for the need to establish evidence for measurement invariances (assessing if the measurement tools applies equally between groups) before making a comparison of different groups (e.g., gender, ethnic groups, research treatment conditions such as experimental and control groups, etc.). It follows that measurement invariance was essential in establishing whether S-STEM applies equally to boys and girls. Such evidence is essential to facilitate meaningful interpretation, or the application of the scale. A model's measurement invariance in groups is usually evaluated by establishing whether fixing model parameters (e.g., factor regression weights, covariances, factor intercepts, or residuals) result in a statistically significant difference in model fit (Vandenberg & Lance 2000). Typically, measurement invariance is achieved when the difference in χ^2, taking into account the difference in *df*, is not statistically significant (i.e., $p > 0.05$); and the difference in CFI (ΔCFI) is ≤ 0.01 (Brown et al., 2015).

2.1 Study Rationale and Research Questions

Given the vital influence of attitudes and interest in STEM on the likelihood of an individual to choose a STEM career (Kier et al., 2014; Unfried et al., 2015; Grimmon et al., 2020), there have been intensified efforts to construct and validate instruments for measuring students'

attitudes towards, and interest in pursuing a STEM career mostly in developing countries. So far, in the context of Tanzania, no study has systematically measured the attitudes towards, and interest in STEM career among secondary school students. Thus, we build on recent developments in the measurement of attitudes towards, and interest in STEM to validate the "Upper Elementary School and Middle/High School Student Attitudes towards STEM (S-STEM)" (Unfried et al., 2015: 622) in the context of Tanzania. The S-STEM was chosen because it includes a sub-scale of 21st century skills that are essential in promoting STEM education. Additionally, we establish whether the S-STEM would produce a valid psychometric scale reliable for both male and female students. Deviating from S-STEM, STEM-CIS and STEM-LIT, we extend the sample of our study beyond students from low socio-economic backgrounds (i.e., covering students from all socio-economic backgrounds). Specifically, our study was guided by the following research questions:

1) To what extent is S-STEM a valid psychometric instrument for measuring students' attitudes towards STEM and 21st century skills in the Tanzanian context?
2) Does S-STEM measure male and female secondary school students' attitudes towards STEM equally?

3. Methodology

3.1 Participants

The participating students were studying in sixteen secondary schools sampled from two different regions in Tanzania. Since STEM comprises important subjects in Tanzania's education, two geographical zones—the Coastal zone, and the Lake zone—were randomly sampled from the five geographical zones of the country. In the sampling process, the names of all the five geographical zones were written on pieces of paper (one name on each piece). Then the pieces of paper were rigorously shaken, and two of them were randomly picked thereafter. Subsequently, one region was randomly selected from each of the two zones: namely, Dar es Salaam in the Coastal zone, and Kagera in the Lake zone. In each region, two districts were sampled on the basis of their geographical locations. In this regard, one district located at the headquarters of each sampled region (i.e., urban) was purposively sampled; that is, Ilala in Dar es Salaam, and Bukoba in Kagera. Meanwhile, the remaining districts in each region were written on pieces of paper, which were then rigorously shaken before one of them was picked as a study area. The sampled districts were Ubungo and Muleba, both of which somehow represented the peripheral parts of the sampled regions.

Given that STEM-related subjects are studied in all secondary schools from Form 1 to Form 2 before making specialisations in Form 3, four schools were randomly sampled from each of the sampled districts. In total, sixteen (16) government-owned secondary schools were selected, i.e., eight (8) schools from each region. Form 2 students in each of the sampled secondary schools participated in the study because at this class level, students are about to specialize (when they enter Form 3) in either STEM-related subjects or non-STEM subjects. In each of the sampled schools, one stream of a Form 2 class was randomly picked by the researchers and then all students in that particular stream of the class were requested to participate voluntarily in the study, with informed consent. In total, 1,382 students volunteered to take part in the study. Table 1 summarises the demographic characteristics of the participants sampled from the four districts in Dar es Salaam and Kagera regions.

Table 1: Demographics of Participating Students and Schools Split by Regions

Demographics	Total	Dar es Salaam Region	Kagera Region
Gender			
Female	708 (51.2%)	306 (46.4%)	402 (55.6%)
Male	674 (48.8%)	353(53.6%)	321 (44.4%)
Age			
Female	16.31 (1.04)	14.99 (0.72)	15.60 (0.94)
Male	16.73 (1.16)	15.56 (0.95)	16.11 (1.07)
Location			
Rural	725 (52.5%)	356 (53.9%)	365 (51.2%)
Urban	657 (47.5%)	305 (46.1%)	352 (48.8%)
Parents' highest education			
Primary	400 (29.5%)	125 (19.4%)	275 (38.6%)
Diploma	618 (45.6%)	302 (47.0%)	316 (44.4%)
Bachelor degree	143 (10.6%)	84 (13.1%)	59 (8.3%)
Master degree and above	73 (5.4%)	46 (7.2%)	27 (3.8%)
	121 (8.9%)	86 (6.5%)	35 (4.9%)

Note: Participants (%), Mean (Standard deviation)

3.2 Research Design

This study mainly employed a quantitative research approach in examining the validity of S-STEM Survey in the Tanzanian context. Specifically, a cross-sectional survey research design was used, in which quantitative data were collected from a large sample of participants. The cross-sectional survey research design was used because it is considered to be the most economical and effective when quantitatively describing respondents' behaviours (Cohen et al., 2020). Furthermore, it can be used to measure a variety of issues such as attitudes, opinions, values, or other psychological and sociological constructs (Ary et al., 2010). Besides, the design enables researchers to collect a large amount of data for establishing a robust measurement model by using the structural equation model technique to link constructs (Anderson & Gerbing, 1988). Ideally, the cross-sectional survey combines three designs—descriptive, correlational, and causal-comparative—to answer research questions.

3.3 Instruments

The study adopted the previously validated "Upper Elementary School and Middle/High School Student Attitudes toward STEM (S-STEM)" (Unfried et al., 2015: 622). The S-STEM comprises of four factors that were estimated to measure students' attitudes towards science, mathematics, engineering and technology, and the 21st century skills. The S-STEM was originally administered online to 4,232 rural middle public school students in the south-eastern state of USA to measure their attitudes towards science, mathematics, engineering and technology, and the 21st century skills. Several dimensions measuring self-efficacy, personal goals, outcome expectations, personal inputs, interest in science, mathematics, and technology; as well as contextual support was combined to constitute the S-STEM. The S-STEM questionnaire consisted of 37 items measured on a 5–point Likert-type scale responses, including 'Strongly Disagree' (1), 'Disagree' (2), 'Neutral' (3) 'Agree' (4), and 'Strongly Agree' (5). We deliberately changed from a 5–point scale to a 6–point scale to avoid a middle category due to its ambiguous perceptual meaning (Kulas &

Stachowski, 2009). Although English is used as a medium of instruction in secondary schools, many students still struggle learning science by using English, which is a second language to them (Mkimbili, 2019). Consequently, we translated the S-STEM questionnaire from English into Swahili language by following the translation and back-translation procedures, and using two experts of both languages to edit the questionnaire items independently. The questionnaires were personally administered by the researchers; hence, all issues related to clarity could be cleared as students responded to the questionnaire items. Table 2 presents a summary of scales, a sample item per scale, and the scale internal reliability (Cronbach's α) from the original study. See Table A1 in the Appendix for a detailed description of items used in the questionnaire.

Table 2: Scales, Sample Items, Mean Scores and Estimates of Reliability

Sub-scales	Sample item	Mean (SD)	No. items	Cronbach's α	
				Original Study	*Present Study*
Mathematics interest	I can get a good grade in math.	3.98 (0.92)	8	0.85	0.88
Science interest	I will need science for my future work.	4.62 (0.91)	9	0.83	0.83
Engineering and technology interest	I like to imagine creating new products.	4.98 (0.77)	9	0.84	0.84
21st Century competences	I am confident; I can lead others to accomplish a goal.	5.40 (0.59)	11	0.87	0.88

Note: SD = Standard deviation

3.4 Ethical Issues and Considerations

Ethical issues such as negotiating access through informed consent (Moosa, 2013), anonymity to ensure confidentiality, and giving back and ensuring participants become part of the research process (Moosa, 2013) were strictly observed. For example, prior to their actual participation, respondents were informed of their rights such as voluntary participation, withdrawing from the study any time, and the right to ask for clarification. Likewise, they were assured that confidentiality of the information shared by them with the researchers would be observed accordingly. In that regard, students' participation in the study was preceded by voluntary signing of consent forms. As well, all the data gathered from the participants were kept anonymous during data collection and reporting. Apart from all that, this research was carried out under permission from all the authorities concerned. The researchers obtained research clearance from the University of Dar es Salaam, and were granted the go-ahead approval by the respective regional and district authorities in the study areas.

3.5 Data Inspection

Prior to data analysis, data cleaning was carried out to handle wrongly entered data and missing values. Few cases of data values beyond our measurement scales were taken care of by revisiting the questionnaires and fixing them accordingly. Further, an analysis of missing values was carried out, whereby 48 respondents (approximately 4%) had more than 10% missing data. These were excluded from the sample, leaving a total of 1382 respondents

as the final sample. The missing data from the remaining values were completely at random (MCAR) because Little's MCAR test was not statistically significant ($\chi^2 = 88.56$, $df = 82$, $p = 0.29$) (Peugh & Enders, 2004). It was essential to have a complete data set without missing values to be able to conduct analyses with the structural equation modelling technique. Subsequently, the remaining missing values were imputed using the expectation maximisation, which is regarded as an effective imputation technique for data that are completely missing at random (Musil et al., 2002). The skewness and kurtosis for all the four scales in Table 2 were well below 2 and 4, respectively; suggesting that the data did not violate the normality assumption (Finney & DiStefano, 2013).

3.6 Analysis

The data for the present study were analysed by using the SEM and measurement invariance techniques. Particularly, the analyses were performed with the SPSS, version 24, using the analysis of moment structure (AMOS) option. The SEM involved developing confirmatory factor analysis models based previous studies (Kier et al., 2014: Unfried et al., 2015) on the scales for measuring STEM-career interest. Unlike Kier et al. (2014), who independently estimated four models for each construct of the S-STEM, we estimated the model by fully inter-correlating all the constructs. Likewise, unlike Unfried et al. (2015), who correlated residual errors, we did not correlate residual errors because it is believed that errors should be freely estimated in the model. In addition, measurement invariance was essential in establishing whether the S-STEM applies to boys and girls equally. Such evidence was essential to facilitate meaningful interpretation, and/or the application of the scale.

4. Results

4.1 Measuring Students' Attitudes Toward STEM in Secondary Schools in Tanzania

The main purpose of this study was to investigate the extent to which the S-STEM is a valid psychometric instrument for measuring secondary school students' attitudes towards STEM and the 21st century skills in the Tanzanian context. To achieve this, the S-STEM was estimated by the SPSS, version 24, using the AMOS option. In the first iteration, all 37 variables were specified in the AMOS to assess how the model fits with the Tanzanian sample. Fit indices for the full model ranged from poor to moderate (CFI = .885, Gamma hat = .898, SRMR = .0483, RMSEA = .058 [90% CI = .056, .059]). Furthermore, after eliminating four items (M5, S8, T3, and TS10) with less than 0.3 regression weight, the model fit improved to CFI = .906, Gamma hat = .915, SRMR = .0438, RMSEA = .056 (90% CI = .054, .059). The model was further improved by eliminating two items. Item M1 (*Math has been my worst subject)* was eliminated because it had high modification indices with M3 (*Math is hard for me*), hence suggesting that the two items had overlapping contents. Likewise, item T8 (*Knowing how to use math and science together will allow me to invent useful things)* was removed because it was attracted to both math and science scales (see Table A2 for a detailed list of the questionnaire items that were removed). Therefore, the final model fit improved to CFI = .920, Gamma hat = .925, SRMR = .0427, RMSEA = .054 (90% CI = .052, .056). After attaining an acceptable to good model fit based on multiple fit indicators, the 31–variable model was considered to be a valid model for measuring students' attitudes towards STEM in the Tanzanian context as indicated in Figure 1.

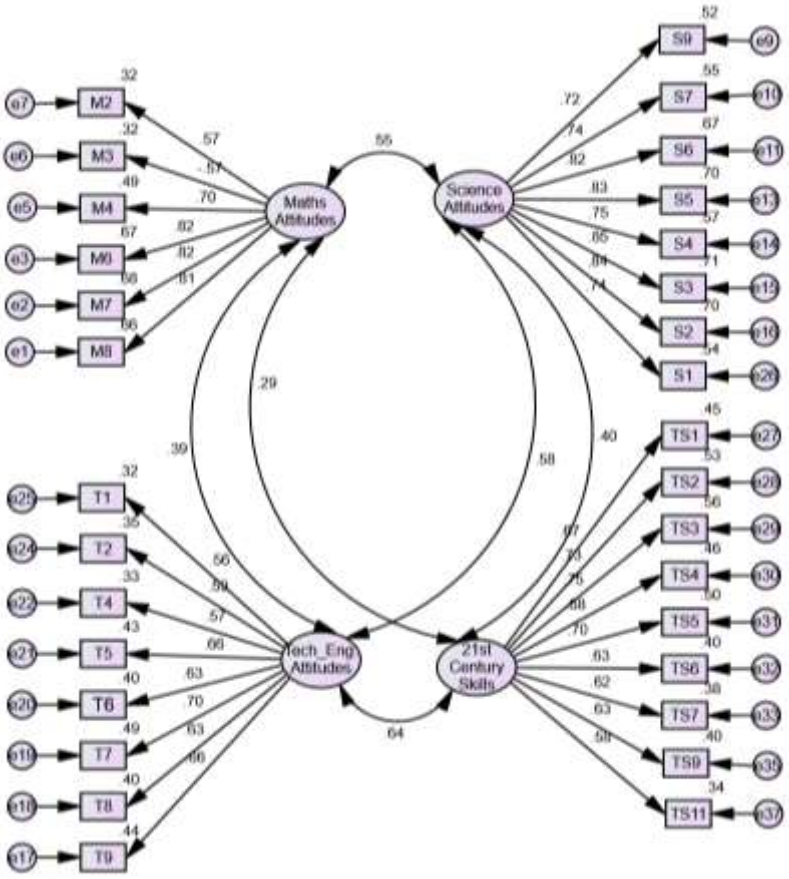


Figure 1: ***Model Illustrating Students' Attitude Towards STEM in Tanzania***

Figure 1 further summarises the squared multiple correlations (R^2) and regression weights for each item in the S-STEM items among students in Tanzanian secondary schools. The regression weights ranged from 0.56–0.72, indicating that the S-STEM variables adequately measured the envisaged constructs. Likewise, the squared multiple correlations (R^2) ranged from 0.32–0.72, which is far above the threshold acceptable (R^2) of 0.30. Further, in the reliability analyses (see Table 2), the S-STEM survey attained good Cronbach's alpha values of 0.88, 0.83, 0.84, and 0.88 for attitudes towards mathematics, attitudes, engineering or technology and the 21st century skills, respectively. Generally, it can be argued that the S-STEM survey is a valid psychometric tool for measuring secondary school students' attitudes towards science, technology or engineering, mathematics, and 21st century skills in Tanzania.

4.2 Measurement Invariances of the S-STEM Across Male and Female Students

The analysis of measurement invariance was conducted in AMOS to ascertain whether the S-STEM instrument applies equally to male and female secondary school students in

Tanzania. As described earlier, measurement invariance is achieved when the difference in χ^2, taking into account the difference in *df*, is not statistically significant (i.e., $p > 0.05$); and the difference in CFI (ΔCFI) is ≤ 0.01 (Brown et al., 2015). Table 3 summarises the results for the measurement invariances of the S-STEM across gender.

Table 3: Measurement Invariance of S-STEM Survey across Gender

Models	$X^2(df)$	CFI	SRMR	RMSEA (90 CI%)	Comp.	ΔX^2(ΔDf)	p-value	ΔCFI	Decision
1a.Unconstrained (configural)	2865.11 (856)	.907	.478	.041 (.040, .043)	-	-	-	-	
1b. Measurement weights (metric)	2911.49 (883)	.906	.050	.041 (.039, .042)	1b vs.1a	46.38 (27)	0.01	<.001	Accept
1c.Measurement intercepts (scalar)	2999.01 (914)	.903	.050	.041 (.039, .042)	1c vs.1b	87.52 (31)	0.00	<.001	Accept
1d. Measurement residuals (error)	3207.66 (955)	.896	.054	.041 (.040, .043)	1d vs.1c	208.65 (41)	0.00	<.001	Accept

Note: Comp = Comparison; SRMR = Standardized Root Mean Residual; RMSEA= Root Mean Squared Error of Approximation; CFI = Comparative Fit Index.

With reference to Table 3, it is noted that measurement invariance was achieved with reference to the CFI fit indicator, whereby the difference in CFI ≤ 0.01 for unconstrained (configural) measurement weight (metric), measurement intercept (scalar), and even the measurement residuals' (error) models. With the exception of the unconstrained model, all models did not attain measurement invariances based on a Chi-square (χ^2) model fit. Nevertheless, since χ^2 is regarded to be a biased fit indicator in large samples (>250) (Fan & Sivo, 2007), our interpretation of the measurement invariances relied solely on the CFI fit indicators. Thus, the S-STEM survey demonstrated full configural, metric, and scalar invariances.

5. Discussion

In this study, we investigated the extent to which the S-STEM is a valid psychometric instrument for measuring secondary school students' attitudes towards STEM and the 21st century skills in Tanzania. Additionally, we established whether the S-STEM instrument applies equally in measuring male and female students' attitude towards STEM and 21st skills.

5.1 Measuring Student Attitude Towards STEM Using S-STEM in the Tanzanian Context

Generally, we found that the S-STEM is a valid, reliable and fair instrument for measuring attitudes towards STEM career and 21st century skills in Tanzania. However, in what appears to be a deviation from Unfried et al. (2015), we dropped 6 items for statistical reasons so as to improve our model fit. Nevertheless, contrary to Unfried et al. (2015), we did not correlate errors, making our analysis a bit stricter. Correlation of errors is criticised for improving a model fit without theoretical justifications (Hermida, 2015): this could explain why some items are dropped. Comparatively, we also observed strong correlations (not beyond the acceptable threshold of 0.70) among the sub-scales. For instance, the attitudes towards mathematics and science are highly correlated at 0.55, nearly in the same way as the attitudes towards technology or engineering to the attitudes towards the 21st century skills are highly correlated at 0.64 as indicated in Figure

1. In the original study (Unfried et al., 2015), the correlations for the same sub-scales were close to a moderate 0.27 and 0.29, respectively. In practice, even though our study does not establish causation, these findings imply that having positive attitudes in science is most likely to promote students' attitudes towards mathematics as well. In this case, given a very poor trend in mathematics achievement among secondary school students in Tanzania (MoEST, 2019), raising students' attitudes towards science could help improve the performance of mathematics.

Moreover, the correlation between the S-STEM sub-scales implies that one sub-scale can be improved by improving the other. For instance, with the assumption that positive attitudes towards mathematics enhance mathematics achievement (Chachashvili-Bolotin et al., 2016), it is now time to emphasize on the 21st century skills among students since they are strongly associated with attitudes towards technology or engineering.

Further, our findings support the SCCT theoretical framework. Firstly, each sub-scale was composed of items measuring self-efficacy beliefs, outcome expectations, and goals. The observed correlation within the sub-scales is an indication that students' attitudes and interest in STEM are a function of an interaction among self-efficacy beliefs, outcome expectations, and goals, as the SCCT assumes (Schoenfeld et al., 2017). Secondly, outcome expectations (e.g., to become an engineer) goes beyond having attitudes towards, and interest in a single subject. Thus, the observed correlation between the sub-scales might imply students' awareness of what it takes to attain a certain career. In other words, to become an engineer, for instance, one must find value in a combination of science subjects, including the 21st century skills. Therefore, there is a need for teachers to make values inherent in STEM subjects known to students. This can be done by emphasizing on instruction that focuses on the application of knowledge in real-life situations. Finally, according to the SCCT, attitudes and interests are a function of socially and culturally constructed inputs such as socio-economic background, gender, personality, and race.

5.2 Applicability of S-STEM Across Gender in Tanzanian Secondary Schools

In support of earlier studies (e.g., Reddy, 2017), we have found that the S-STEM can be applied to measure the attitudes of both boys and girls towards STEM. Nonetheless, these findings do not imply that the gender gap in STEM has closed in Tanzanian secondary schools. Indeed, research has shown that men and women tend to differ in their attitudes towards STEM careers (Kier et al., 2014; Sax et al., 2015; Zuo et al., 2019). Likewise, girls tend to avoid choosing STEM subjects in Tanzania (MoEST, 2019). Research has also shown that although the gender gap in STEM performance is declining, females are still underrepresented, especially in the hard sciences (Francis et al., 2017; Legewie & DiPrete, 2014; Wang & Degol, 2013). For instance, while the gender gap in STEM performance is closing in developed nations (Contini et al., 2017; Dasgupta & Stout, 2014), other studies (e.g., Dickerson et al., 2015) have concluded that gender gaps in STEM performance still persist in Africa. In Tanzania, Kabote et al. (2014) shows that there is a gender gap in mathematics performance.

According to the SCCT—as detailed in our theoretical framework—attitudes and interests are a function of socially and culturally constructed inputs such as socio-

economic background, gender, personality, and race. Thus, there is a need for further studies to investigate how students' attitudes towards, and interest in STEM are shaped by these inputs. This is because our findings are limited in that regard. Moreover, our findings indicate that the improved S-STEM survey can be used in Tanzania as a valid instrument for measuring attitudes towards STEM and the 21st century skills among girls and boys. Nonetheless, several issues will have to be scrutinised. First, the teaching of science in Tanzanian secondary school follows a subject-based curriculum, with three science subjects (physics, chemistry and biology) taught separately. Given that the teaching of these subjects tends to be highly departmentalized and isolated, there is a need to refine further the S-STEM instrument when measuring subject-specific attitudes independently. For instance, as compared to chemistry and biology, students tend to perform poorly in physics (MoEST, 2019), which implies that students might have differing levels of attitudes across the subjects. Second (but related to the first), technology and/or engineering is not formally registered as a subject in Tanzania. Instead, secondary school students acquire technological and engineering skills as they study other science and ICT subjects. Therefore, our findings should be interpreted with this in mind.

5.3 Limitations and Implications

Although our study validated the S-STEM in a context where no such study has been done, it has few limitations worth noting. Firstly, our study made use of a sample from public schools only. One minor concern would be that most private schools tend to enrol students who have good socio-economic backgrounds. In this case, including private schools would have increased the confidence of our findings. Nevertheless, since the performance of public school students in STEM is relatively similar to that of private school students in Tanzania (MoEST, 2019), we believe that the sample was representative such that including private school students could not bring any major difference in the key findings. Secondly, although English is used as a medium of instruction in secondary schools, many students still struggle learning science by using English, which is a second language to them (Mkimbili, 2019). Consequently, we translated the S-STEM questionnaire from English into Swahili language, with which most students are conversant. Generally, the fact that some of the questionnaire items in the S-STEM did not fit into the Tanzanian context implies that tools or models should not be used blindly in a new context; rather, they should be tested for contextual or ecological validity (Brown et al., 2017; Kyaruzi, 2021).

6. Conclusion

On the overall, the S-STEM can be used to measure attitudes towards STEM and the 21st century skills in the context of Tanzania across gender and different geographical locations (rural and urban). As the country strives to promote social and economic development in a technology-driven world, investing in STEM education, particularly in increasing the size of a competent workforce in the field of STEM, is of paramount importance. While there seems to be more efforts and investments in the cognitive aspects of STEM education, such as raising academic performance in Tanzania, less attention has been paid to affective aspects such as students' interests and attitudes towards STEM, as well as contemporary issues such as the persistent gender gap in STEM. Therefore, the S-STEM should be a precursor to refocusing the attention on the

aforementioned affective aspects of STEM by measuring students' attitudes towards, and interest in STEM so that policy interventions are well-informed. Finally, although our findings suggest that the S-STEM is relevant for measuring the attitudes of both boys and girls towards STEM, it does not mean that the gender gap in the attitudes towards, and interest in STEM has closed. Thus, efforts to close the gender gap in STEM should continue through both research (preferably using the S-STEM tool) and policy responses.

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Appendix

Table A1: Retained Questionnaire Items (as detailed in Figure 1)

Code	Statement	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
M2	I would consider choosing a career that uses math.	□	□	□	□	□	□
M3	Math is hard for me.	□	□	□	□	□	□
M4	I am the type of student to do well in math.	□	□	□	□	□	□
M6	I am sure I could do advanced work in math.	□	□	□	□	□	□
M7	I can get good grades in math.	□	□	□	□	□	□
M8	I am good at math.	□	□	□	□	□	□
S1	I am sure of myself when I do science.	□	□	□	□	□	□
S2	I would consider a career in science.	□	□	□	□	□	□
S3	I expect to use science when I get out of school.	□	□	□	□	□	□
S4	Knowing science will help me earn a living.	□	□	□	□	□	□
S4	I will need science for my future work.	□	□	□	□	□	□
S5	I know I can do well in science.	□	□	□	□	□	□
S6	Science will be important to me in my life's work.	□	□	□	□	□	□
S7	I can handle most subjects well, but I cannot do a good job with science.	□	□	□	□	□	□
T1	I like to imagine creating new products.	□	□	□	□	□	□
T2	If I learn engineering, then I can improve things that people use every day.	□	□	□	□	□	□
T4	I am interested in what makes machines work.	□	□	□	□	□	□
T5	Designing products or structures will be important for my future work.	□	□	□	□	□	□
T6	I am curious about how electronics work.	□	□	□	□	□	□
T7	I would like to use creativity and innovation in my future work.	□	□	□	□	□	□
T8	Knowing how to use math and science together will allow me to invent useful things.	□	□	□	□	□	□
T9	I believe I can be successful in a career in engineering.	□	□	□	□	□	□
TS1	I am confident I can lead others to accomplish a goal.	□	□	□	□	□	□

Code	Statement	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
TS2	I am confident I can encourage others to do their best.	□	□	□	□	□	□
TS3	I am confident I can produce high quality work.	□	□	□	□	□	□
TS4	I am confident I can respect the differences of my peers.	□	□	□	□	□	□
TS5	I am confident I can help my peers.	□	□	□	□	□	□
TS6	I am confident I can include others' perspectives when making decisions.	□	□	□	□	□	□
TS7	I am confident I can make changes when things do not go as planned.	□	□	□	□	□	□
TS9	I am confident I can manage my time wisely when working on my own.	□	□	□	□	□	□
TS11	I am confident I can work well with students from different backgrounds.	□	□	□	□	□	□

Note: Mathematics (M), and Science (S), Engineering and Technology (T), 21st Century Skills (TS)

Table A2: Removed Questionnaire Items

Code	Statement	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
M1	Math has been my worst subject.	□	□	□	□	□	□
M5	I can handle most subjects well, but I cannot do a good job with math.	□	□	□	□	□	□
S8	I am sure I could do advanced work in science.	□	□	□	□	□	□
T3	I am good at building and fixing things.	□	□	□	□	□	□
TS8	I am confident I can set my own learning goals.	□	□	□	□	□	□
TS10	When I have many assignments, I can choose which ones need to be done first.	□	□	□	□	□	□