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Effectiveness of Middle School STEM Career Education for STEM Knowledge, Efficacy, and Interest

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ABSTRACT

The purpose of this study was to test STEM career interventions through a theoretically integrated STEM Career Education (SCE) Module. The effectiveness of SC education was tested on STEM Career (SC) interests, self-efficacy, and knowledge of students from two middle schools. The sample included middle school students from two private schools (N=33) in Islamabad, Pakistan. By using a mixed-method sequential explanatory research design, quantitative data were obtained before and after the intervention while qualitative focus group discussions were conducted post-intervention. A significant increase in SC interest, self-efficacy, and knowledge after participating in the SCs Program is reported, even after statistically controlling key variables. The training seems to be more effective for those with low SC knowledge. Findings indicate a need for robust interventions to target math self-efficacy. Results provide further directions for effective STEM interventions. By pinpointing limitations and future directions, this pilot study contributes to STEM education in Pakistan and provides a model of CE for other countries.

Keywords: social cognitive career theory, STEM self-efficacy, STEM career, interest, middle schools

INTRODUCTION

Global challenges, such as climate change require STEM professionals to address such issues (Tawbush et al., 2020). STEM career (SC) programs are used to encourage students towards STEM professions by enhancing student's critical thinking skills, problem solving (Seage and Türegün, 2020; Blanchard et al., 2020), students' knowledge related to STEM subjects and increase STEM self-efficacy (SE). However, despite such efforts, lack of knowledge of SCs and lack of interest in SCs persists (Reiss and Mujtaba, 2017).

Factors that determine the choice of SC include grade level, knowledge about SCs, learning opportunities, and gender (Drymiotou et al., 2021). However, a major critical driver is interest and knowledge/awareness of SCs (Vela et al., 2020; Drymiotou et al., 2021).

Interest in SCs is affected by the knowledge about SCs and SC self-efficacy (Franz-Odendaal et al., 2020). While the SC programs provide the opportunity of hands-on STEM learning and outline the utility of STEM subjects in everyday life, interventions on increasing SCs knowledge are scarce (Reiss and Mujtaba, 2017). Hence, this study elaborates on the concept presented by Reiss and Mujtaba (2017) about embedding career education in STEM education (SE) as a viable solution to enhance student's interest and awareness of SCs.

The questions that guided this research are the following:

- What will be the effectiveness of an integrated SCs module developed by integrating Social Cognitive Career Theory (SCCT) and Kolb's theory for SCs knowledge, interest, and self-efficacy for middle school students?

- How are STEM interventions influenced by the school-based factors which can lead to the success of the intervention?

CONTEXTUAL BACKGROUND

STEM education has resulted in improved higher order thinking skills, academic learning achievement, student engagement in science, increased interest in STEM subjects, and improved STEM self-efficacy in the UK and the US (Togou et al., 2019; Wahono et al., 2020). Developed countries within Asia such as Malaysia, Thailand, Korea, Singapore, and China have also focused on SE. However, SE is still at a budding stage in many developing countries.

Interest in SE has recently emerged due to low interest of students in SCs and increased global competitiveness which points at the dire need to promote SE (Wahono et al., 2020; Togou et al., 2019). However, SE in Pakistan is struggling due to a lack of SE resources (Hali et al., 2021). A need to focus on STEM policy and STEM education is recognized more than ever. Therefore, this study was conducted to provide empirical support for the effectiveness of SC intervention by developing a systematic, well-designed, and theory-based program and by integrating careers education in SE as a feasible solution to teach SC knowledge which in turn may lead to improved SC interest and SC self-efficacy.

LITERATURE REVIEW

Factors that determine students' likelihood to pursue SCs include knowledge about SCs, grade level, and participation in STEM programs (Vela et al., 2020). Reasons behind not pursuing a SC usually include student's perceptions about STEM as too hard, or uninteresting (Halim et al., 2018). STEM self-efficacy and learning experiences are major sources of interest in SCs. Mohtar et al. (2019) reported that SCs interest is largely determined by self-efficacy while self-efficacy can be enhanced by offering engaging learning experiences to students.

Social Cognitive Career Theory (SCCT) states that there are two major determinants of self-efficacy which include environmental factors and outcome expectations. Impact of media, family, and learning experiences are included in Environmental factors (Halim et al., 2021). Thus, based on this premise, most of the STEM interventions and programs have been developed to offer meaningful STEM learning experiences. Therefore, engaging in STEM learning experiences can help students to increase their SC self-efficacy and interest.

Outcomes of STEM programs have been studied in relation to various demographic variables. Literature suggests that students who have parents in STEM occupations are more likely to pursue a SC as compared to students with parents with non-STEM occupations (Bahar and Adiguzel, 2016; Moakler and Kim, 2014). Academic achievement affects STEM interest as students with higher grades are more interested in SCs (Bottia et al., 2015). Furthermore, male students are more inclined towards SCs than females (Yerdelen et al., 2016).

SC knowledge, interest, and self-efficacy are interrelated. STEM Knowledge and self-efficacy increase the likelihood of SC interest (Blotnicky et al., 2018). Literature suggests students with more knowledge about SCs are more likely to pursue SCs (Franz-Odendaal et al., 2020) and higher SC knowledgeable is linked to higher self-efficacy. Furthermore, STEM self-efficacy is reported to increase in SC interest (Ocumpaugh et al., 2016).

An appropriate duration for STEM interventions is reported to be 12 weeks, which implies a total of 10-12 weekly sessions per STEM intervention (Fan and Yu, 2017; Falco and Summers, 2017; Ogle et al., 2017; Siew and Ambo, 2018). In addition, middle school is said to be the appropriate level for STEM programs as it pays attention to the role of STEM for career aspirations and a newly developed interest in STEM can be maintained throughout high school (Christensen et al., 2014; Young et al., 2017).

STEM interventions that have impact on STEM career choices are often based on Social Cognitive Career Theory (SCCT) as this theory relates self-efficacy, interest and how people make career choices. Recently, an SCCT-based STEM module was developed which resulted in enhanced STEM self-efficacy among students (Drymiotou et al., 2021). Also, Kolb's experiential learning cycle is often applied in STEM modules to offer students comprehensive hands-on (and not just theoretical) learning experiences. Kolb-based modules for Math and Science were already developed and resulted in increased interest in SCs (Zainal et al., 2018). However, literature suggests to have a Kolb-based module for all STEM subjects.

Studies have identified several reasons for lack of interest in STEM. Firstly, many students have negative perceptions about SCs because they lack knowledge/awareness about SCs. Students will not pursue a career if they do not have any knowledge about those careers (Mohtar et al., 2019). This indicates the significance of SC knowledge in enhancing students' interest in SCs.

Negative perceptions about SCs are linked with lower STEM self-efficacy among students, which is another challenge. To address this lack of SCs knowledge, literature emphasizes integrating STEM education and careers education (Jung et al., 2017; Reiss and Mujtaba, 2017; Shin et al., 2018; Yusoff et al., 2020). One such module for SCs education was developed in Malaysia for secondary school students (Yusoff et al., 2020). Needs of integrated and systematic approaches to motivate students towards STEM careers in South Asian context is reported (Shobhana et al., 2023).

Rationale of Study

Literature shows that STEM modules are aligned with either Social Cognitive Career Theory (SCCT) or Kolb's experiential learning theory. Kolb's experiential learning theory provides pedagogical elements to STEM interventions such as hands-on learning (Zainal et al., 2018) while SCCT expands STEM education with factors that impact student's career choices and interest (Ogle et al., 2017). Given the distinct benefits of both theories, the current study utilizes both.

Han et al. (2021) conducted a STEM intervention and pointed at the need to incorporate all three domains of Bloom's taxonomy (Cognitive, Affective, and Psychomotor). Thus, the STEM careers education module developed in the current study effectively incorporates all three domains of Bloom's Taxonomy.

Additionally, it is evidenced in the literature that a low STEM career interest among students is related to a lack of STEM careers knowledge. Despite this, STEM programs usually focus on hands-on activities for STEM yet ignore STEM career knowledge provision. For this reason, following Reiss and Mujtaba's (2017) recommendation to combine STEM and Careers education to effectively offer STEM careers knowledge along with STEM hands-on experience, the current study has developed a STEM careers education module and implemented it as an intervention as well.

Another reason identified for low STEM interest is lack of connections between industry and Academia. To build this connection, role models of STEM industry are involved in STEM interventions following SCCT to enhance STEM self-efficacy. To further support these findings, role models were involved in STEM careers education intervention in the current study through showing videos of STEM professionals working in their fields. It also lends additional support to conduct STEM interventions with middle school students as it is a time when students have to make career choices. Finally, the current study offers a rich resource in the form of a module that offers STEM education based on SCCT and Kolb's learning cycle.

METHODOLOGY

Social Cognitive Career Theory (SCCT) and Kolb's Experiential Learning Cycle have lent theoretical support to the current study. SCCT suggests three factors that determine career choices: self-efficacy, personal goals and interest and outcome expectations. These three primary factors were addressed in each lesson. Two levels of interaction will be considered in this study to determine career interest. The first level of interaction involves the primary variables (self-efficacy beliefs, outcome expectations, and personal goals) interacting with the person characteristics of the participants. In the second level, the three primary variables interact with the individual's environment (Drymiotou et al., 2021).

Kolb's experiential learning theory offered support in designing an engaging program of intervention. Kolb's experiential learning theory assumes that knowledge is created because of transformation of experiences (Konak et al., 2014). For experiential learning, Kolb proposed a four-stage learning cycle which includes concrete experience, reflective observation, abstract conceptualization, and active experimentation (Zainal et al., 2018). According to Kolb, successful learning is only possible when the student goes through all stages and completes the learning cycle. Moreover, each stage of Kolb's learning cycle accommodates students with different learning preferences. In the first stage, i.e., concrete experience, the student observes or goes through an experience. In reflective observation, the student reflects and thinks about the experiences and makes sense of it. Consequently, in abstract conceptualization, the student develops a personal model or version of the experience that fits in his or her concepts. Finally, in active experimentation, the student applies the model derived from experience in an authentic setting. In this way, Kolb's learning cycle helps the student to process and learn from an experience.

In the current study, a module was designed so that students gained STEM-based knowledge and information about related careers through informative power point slides and tutorial videos (concrete experience), then students did worksheets to reflect and think about the concepts (reflective observation), planned how to do the STEM project (abstract conceptualization) and finally executed the projects (active experimentation).

This study was conducted in two stages: Stage One: Module Development and Stage Two: Main Study.

Stage One: Module Development

For the development of the module, the Bitara STEM module development framework was used. This has four stages: Needs analysis, Design, Implementation, and Evaluation (Mohd Shahali et al., 2016).

Table 1. Descriptive statistics and psychometric properties of all study variables (N = 33)

Scale	No. of items	A	Mean	SD	Range	Skewness	Kurtosis
SCIS	44	.91	158.64	22.504	105	-.846	1.669
SCIS-S	11	.82	41.42	7.071	28	-.263	-.453
SCIS-T	11	.82	39.67	6.877	30	-.092	.337
SCIS-E	11	.87	42.15	7.779	30	-.761	-.122
SCIS-M	11	.90	35.39	9.437	38	-.615	-.150
SCSE	56	.96	165.48	41.556	156	.264	-.670
SCSE-S	25	.95	75.52	23.973	88	-.250	-.785
SCSE-T	10	.92	29.61	10.398	38	.232	-.948
SCSE-E	12	.90	32.18	10.391	39	.130	-.764
SCSE-M	8	.89	28.18	8.844	31	.446	-.502
SCKT	14	.60	7.70	2.456	10	-.260	.090

Note. SCIS = SC interest scale; SCSE: SC self-efficacy; SCKT: SC knowledge test; n: Number of items; & SD: Standard deviation

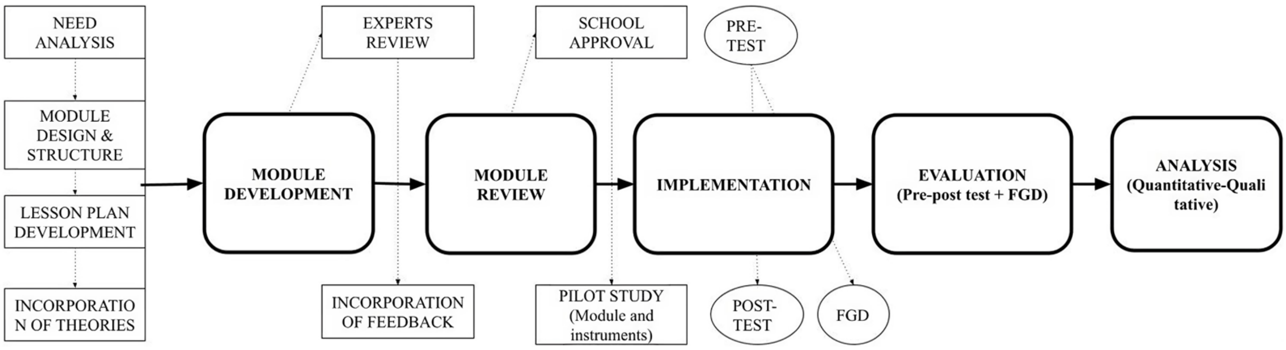

Figure 1. Research design

In stage one (Needs Analysis) the Single National Curriculum for General Science, Computer, and Mathematics (Ministry of Federal Education & Professional Training, Islamabad, 2020) for Grade 8 students was reviewed and relevant STEM topics were identified by grade 8 teachers.

In stage two (Design) the module was outlined in 12 lessons (Siew and Ambo, 2018). The division of lessons and topics was balanced for the different STEM subjects i.e., three topics each for Science, Technology, Engineering, and Mathematics. The module was structured using Kolb's experiential learning theory and Social Cognitive Career Theory (SCCT). Students could go through all four stages of Kolb's experiential learning cycle to foster hands-on and active learning. Each lesson covers one of the three components of SCCT, i.e., self-efficacy, outcome expectations, and personal goals. Bloom's cognitive, affective, and psychomotor domains were covered in each lesson. The lesson planning template developed by Brown and Trusty (2005) was used.

After the development of Module, module was sent for review to seven experts (Implementation stage). Specific feedback was obtained from the experts which was incorporated into the module. Table 1 shows descriptive statistics and psychometric properties of all study variables (N = 33).

Content of the module

Students could relate to the module context because the topics of lessons were taken from their classroom textbooks. There were engineering challenges which allowed students to complete the project in limited time. The activities were designed in a way that students had opportunities to reattempt the activities at home in case of failure. The content was taken from the Standard curriculum taught in Pakistan. The module was student-centered as students could imagine themselves in those STEM careers. Lastly, some activities were designed to foster collaboration and teamwork.

Stage 2: Main Study

Research strategy

This study employed an explanatory sequential design in which in the first step quantitative data were obtained through a same group pre-post-test design (Grimshaw et al., 2000). In the second step qualitative data were collected to interpret the quantitative data and explain the effectiveness of the intervention. This method was

Table 2. Research timeline

Activity	Timeline
Need analysis	Week 1
Module design and development	Week 2-6
Module review	Week 7
Pilot study	Week 8-10
Implementation	Week 12-16
Pre-post-test evaluation	Week 17-18
Data analysis	Week 19-22

adopted from Creswell (2013) and a similar study on SC maturity programs by Karan et al. (2021). **Figure 1** depicts research design.

Two schools were approached for the intervention after the approval of the research proposal by the Ethics Committee at the School of Social Sciences and Humanities (National University of Sciences and Technology, Islamabad). Permission was granted for data collection and research from the school principals. Two separate studies were conducted to test the effectiveness of the same module through two different studies. Before the intervention, written consent for children's participation was obtained from the parents. Initial briefing sessions with the participating students were organized to inform them about ethics, purpose of the study and to mentally prepare them for the intervention. This included a presentation of the entire module and showed what the students can learn by the programme. Students were instructed not to approach any STEM materials through the internet or other means during the intervention. For qualitative data, four focus group discussions were conducted, two in each school.

Hypotheses

- H1: There will be a significant positive influence on students' SC knowledge, self-efficacy, and interest as a result of SC intervention.
- H2: SC self-efficacy will increase significantly for students who score high on prior STEM knowledge.
- H3: SC interest will increase significantly for students who score high on prior STEM self-efficacy.
- H4: There will be a significant positive effect on student's SC knowledge, self-efficacy, and interest post-intervention while statistically controlling for parents' STEM occupation, gender, and academic achievement.

Population and sample

Data collection was done in the pre-intervention and post-intervention phase in Grade 8 of two private schools where the SCs education programme was implemented. Using the purposive sampling technique two school with a similar curriculum, equivalent teacher education level and student fee structure were selected. The sample consisted of a total of 33 students, 26 boys and 7 girls.

Procedure

The population of this study consisted of Grade 8 students of two private schools of Islamabad, School A and School B. Private middle schools were approached and from those schools who granted permission to conduct STEM program, those students (N = 33) who completed parental informed consent participated.

Before conducting this research, ethical Approval was obtained from the National University of Sciences and Technology. The study measures were administered at two-time intervals i.e., before (pre) and after the intervention (post).

Duration of intervention

The current study comprised a total of 12 lessons (sessions) and each lesson was about 60 minutes long. The lessons were delivered consecutively from Monday to Friday for two and a half weeks while the remaining two days were utilized for focus group discussion and Certificate distribution. Participants attended the program during after-school hours. The research timeline is shown in **Table 2**.

Participants were informed that they should not use any online STEM resources or engage in any other STEM learning experience during the period of intervention i.e., 3 weeks. In addition, variables including parent's STEM occupation, academic achievement, and gender were statistically controlled using ANCOVA to minimize their effect on the outcome variables.

Four focus group (FGD) discussions post-intervention were conducted involving 4-9 students per FGD (in line with (Cardoso et al., 2018) while the duration was about 30-45 minutes for each FGD.

Instruments

To assess STEM career knowledge, a 14 multiple choice questions test was developed with a single best answer framework (Al-Rukban, 2006). A similar test called mechanical conceptual knowledge test was developed to assess STEM content knowledge (Fan and Yu, 2017).

STEM-CIS, developed by Kier et al. (2014), was used to assess students' interest in STEM professions. It is comprised of 44 Likert scale items. It has four subscales for each discipline i.e., Science, Technology, Engineering, and Mathematics. SC Self-Efficacy Test (SCS-ET) was adapted from tests by Milner et al. (2014) who developed measures to assess self-efficacy in five areas, namely, engineering, information technology, mathematics, life science, and physical science. This corresponds roughly to the STEM acronym, with physical and life sciences represented by separate scales. Items with domains corresponding to STEM were taken from the Basic Interest Marker Scale following Milner et al.'s (2014) work. The reliability (Cronbach's alpha) of each measure was found in the range between 0.6 to 1.0 (Kalaycı, 2010).

RESULTS

Data analysis was conducted in two phases: quantitative and qualitative. For the quantitative data analysis, the Statistical Package for Social Sciences (SPSS) was used to analyze the data and test the hypotheses through a reliability analysis and a paired sample t-test to compare means of the participant's scores for all three variables before and after the intervention. Mixed ANOVA and analyses of covariance (ANCOVA) were performed to determine the differences between pre- and post-test scores after statistically controlling for parental and other demographic variables. For the qualitative data, content analysis was conducted to explore the effectiveness of intervention in depth.

Effectiveness of Intervention

A paired sample t-test was performed to test the difference in means before and after the intervention. Table 3 indicates significant t values ($p < .05$) for all three variables i.e., SC interest, SC self-efficacy, and SC knowledge.

Table 3. Results of paired sample t-test at Time 1 and 2 on SCIS, SCSE, and SCKT (both schools, school A and school B)

Variable	Mean	Standard deviation	T	p	Cohen's d
SCIS					
Time 1→Time 2	30.576	20.628	8.5150	**.000**	1.48
School A	13.000	18.970	3.0640	**.006**	0.68
School B	28.000	27.240	3.3706	**.003**	1.02
SCSE					
Time 1→Time 2	30.091	30.090	5.7450	**.000**	1.00
School A	22.400	26.050	3.8440	**.001**	0.85
School B	41.920	32.990	4.5810	**.001**	1.27
SCK					
Time 1→Time 2	2.242	2.969	4.3390	**.000**	0.76
School A	2.200	2.960	3.3170	**.004**	0.74
School B	2.231	3.004	2.6770	**.020**	0.74
SCIS-Science					
Time 1→Time 2	3.515	7.942	2.5430	**.016**	0.44
School A	1.650	8.331	.8860	.387	0.19
School B	6.385	6.602	3.4870	**.004**	0.96
SCIS-Technology					
Time 1→Time 2	4.909	8.837	3.1910	**.003**	0.56
School A	4.050	9.567	1.8930	.074	0.42
School B	6.231	7.758	2.8960	**.013**	0.80
SCIS-Engineering					
Time 1→Time 2	12.969	7.875	9.4600	**.000**	1.64
School A	1.200	7.295	.7360	.471	0.16
School B	4.308	8.957	1.7340	.109	0.48
SCIS-Mathematics					
Time 1→Time 2	9.303	11.274	4.740	**.000**	0.82
School A	7.150	10.429	3.066	**.006**	0.68
School B	12.615	12.128	3.750	**.003**	1.04

Table 3 (Continued).

Variable	Mean	Standard deviation	T	p	Cohen's d
SCSE-Science					
Time 1→Time 2	18.394	22.644	4.666	**.000**	0.81
School A	12.300	21.411	2.569	**.019**	0.57
School B	27.769	22.000	4.549	**.001**	1.26
SCSE-Technology					
Time 1→Time 2	4.212	8.104	2.986	**.005**	0.52
School A	3.400	8.312	1.829	.083	0.41
School B	5.642	7.933	2.482	**.029**	0.71
SCSE-Engineering					
Time 1→Time 2	6.667	9.848	3.889	**.000**	0.67
School A	6.100	9.296	2.935	**.009**	0.65
School B	7.538	10.974	2.477	**.029**	0.68
SCSE-Mathematics					
Time 1→Time 2	2.606	8.902	1.682	.102	0.29
School A	2.150	9.438	1.019	.321	0.22
School B	3.308	8.331	1.432	.178	0.39

Note. SCIS = SC interest scale; SCSE = SC self-efficacy; SCK = SC knowledge
$p < .05$

Table 4. Mixed ANOVA with pre-SCKT as between-subject factor, ANCOVA for SCIS, SCSE, and SCKT with parental STEM occupation, gender, academic achievement as covariate

Variables	F	p	η_p^2
SCIS total	10.516	**.000**	.412
Science	2.244	.120	.130
Technology	1.344	.270	.082
Engineering	10.434	**.000**	.410
Mathematics	3.185	**.060**	.175
SCSE total	.591	.560	.038
Science	.411	.660	.027
Technology	1.673	.200	.100
Engineering	.244	.780	.016
Mathematics	.289	.750	.019
Parental STEM occupation (covariate)			
SCIS total	.090	.766	.003
SCES total	.348	.560	.011
SCKT total	2.25	.146	.083
Academic achievement (covariate)			
SCIS total	.718	.496	.046
SCES total	.523	.598	.034
SCKT total	.042	.959	.070
Gender (covariate)			
SCIS total	.165	.687	.005
SCES total	.106	.747	.003
SCKT total	.175	.679	.003

Note. SCIS = SC interest scale; SCSE = SC self-efficacy

This suggests that the mean scores were significantly higher after the intervention compared to prior. Effect sizes were large. Therefore, the results support the first hypothesis of this study.

Analysis of the subscales showed that all post-test scores were significantly higher than pre-test scores except for self-efficacy mathematics (SCSE M).

Differences between the two schools were insignificant for most variables. Only for Pre-SC Knowledge, School B scored significantly lower than School A at the baseline level, suggesting that the two student groups were not quite homogeneous. However, this difference disappeared in the post. This also indicates the effectiveness of the intervention.

Mixed ANOVA was performed with prior SC knowledge as between-subject factor. Table 4 showed there was no significant interaction of SC self-efficacy with prior SC Knowledge. This suggests that all students, whether they were low, average, or high on Prior SC knowledge, increased comparably with respect to STEM self-efficacy post intervention. This finding does not support hypothesis 4.

Table 5. Independent sample t-test comparing two school groups

Variables	Group				T	df	p	95% CI	
	School A		School B						
	M	SD	M	SD				LL	UL
SCI-Pre	161.710	18.912	145.620	21.934	2.995	31	.986	6.854	36.115
SCI-Post	180.100	13.642	173.620	15.305	1.272	31	.755	-3.912	16.881
Science-Pre	44.000	6.553	37.460	6.105	2.875	31	.894	1.900	11.177
Science-Post	45.650	5.461	43.850	5.129	.949	31	.601	-2.072	5.680
Technology-Pre	41.250	6.616	37.230	6.796	1.687	31	.991	-.839	8.878
Technology-Post	45.300	5.292	43.460	4.926	1.001	31	.335	-1.906	5.583
Engineering-Pre	43.750	6.496	39.690	9.150	1.492	31	.083	-1.489	9.604
Engineering-Post	44.950	4.947	44.000	5.244	.527	31	.831	-2.729	4.629
Mathematics-Pre	38.100	8.303	31.230	9.867	2.157	31	.461	.373	13.366
Mathematics-Post	45.250	6.332	43.850	7.186	.590	31	.587	-3.447	6.254
SCSE-Pre	178.550	43.004	145.380	30.899	2.401	31	.127	4.996	61.335
SCSE-Post	200.950	27.017	187.310	23.124	1.497	31	.574	-4.945	32.229
Science-Pre	83.700	23.815	62.920	18.737	2.652	31	.587	4.800	36.740
Science-Post	96.000	10.498	90.690	9.123	1.492	31	.521	-1.950	12.565
Technology-Pre	31.900	9.754	26.080	10.743	1.611	31	.974	-1.551	13.197
Technology-Post	35.300	8.380	31.540	8.550	1.250	31	.969	-2.375	9.898
Engineering-Pre	33.800	11.335	29.690	8.567	1.114	31	.151	-3.414	11.629
Engineering-Post	39.900	8.441	37.230	6.559	.965	31	.356	-2.974	8.313
Mathematics-Pre	29.150	9.588	26.690	7.685	.775	31	.256	-4.009	8.924
Mathematics-Post	31.300	7.241	30.000	5.462	.552	31	.174	-3.502	6.102
SCK-Pre	8.550	1.638	6.380	2.959	2.709	31	.027	.535	3.795
SCK-Post	10.750	2.337	8.620	2.663	2.428	31	.482	.341	3.928

Note. SCI = SC interest; SCSE = SC self-efficacy; SCK = SC knowledge; M = Mean; SD = Standard deviation

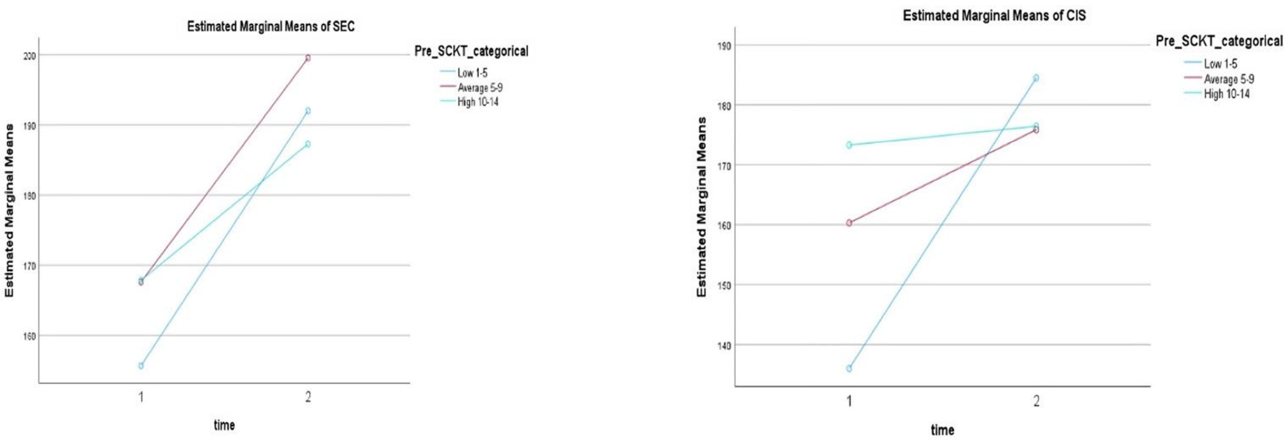

Figure 2. Interaction of pre-SCKT with SCSE and SCIS

Interestingly, prior SC knowledge had a significant interaction with SC interest. This suggests that students with low, average, and high SC knowledge score differently on SC interest. Students with lower levels of SC knowledge showed greater gains in SC self-efficacy. **Table 5** shows independent sample t-test comparing two school groups.

Figure 2 shows that pre-SCKT has insignificant interaction with STEM Self-efficacy (left) while Pre-SCKT has significant interaction with SC interest (Right) from Time 1 to Time 2.

Analysis of co-variance (ANCOVA) with gender, academic achievement, and parent's STEM occupation as covariates was conducted to statistically control possibly confounding variables. Results show that there is no significant interaction between demographic variables for SC interest, self-efficacy and knowledge. This suggests that students with parents with STEM or non-STEM occupations do not vary in their SC interest, knowledge, and self-efficacy before nor after the intervention. Similarly, high, medium, or low grades, nor gender have influence on SC interest, knowledge, and self-efficacy.

School-Wise Differences

Separate paired sample t-test was also done to study difference between variables for both schools pre- and post-assessment.

Table 3 indicates these results, which suggests that the mean scores for SC interest, SC self-efficacy, and SC knowledge were significantly different before and after the intervention for both schools.

However, at the subscale levels self-efficacy and interest, there were differences. For school A, mean scores were different for Mathematics interest (SCIS-Math) and Science & Engineering self-efficacy (SCSE). For school B, mean scores were different for all subscales except for Engineering interest and Mathematics self-efficacy. Comparison of Cohen's d values for both schools indicates that the effect size for most of the variables for school B were medium to large while for School A, these ranged from small to large. Thus, it shows the intervention was more effective for school B.

Qualitative Analysis

Analysis of the data elicited from the focus group discussions was done to gauge the effectiveness of the intervention. Students indicated that the SCs intervention resulted in an increase in SC interest, self-efficacy and knowledge and it also helped to increase student's interest in previously disliked STEM subjects. Students with low and average prior SC knowledge and students who had not participated in STEM competitions or programs before expressed that the intervention was effective for them. Notably, students recommended longer duration of the lessons and suggested that this should be implemented in the entire school year.

The SCs intervention resulted in an increase in SC interest, self-efficacy and knowledge and it also helped to increase student's interest in disliked STEM subjects. This is evidenced by the following statements of students:

> "I wanted to become a doctor but when I read about different careers and we had different activities my interest was more on the engineering side now, so I explored so many different types of engineering like electrical engineer, mechanical engineer so it's very helpful so now I am more inclined to the engineering side".

> "We studied the DNA structure in detail. It was the, it was my best, my personal favorite part of the activity, as it was challenging hard. And it has taught me a lot of new things even in my science class. When I was studying this chapter, I knew a lot of things, even before the teacher told me and I scored a lot of new. I shared a lot of other new information with my classmates too."

> "It boosted my confidence a lot. Like, whenever I lost that, whenever I thought that I'm not gonna do this activity, like there was something that burned me to do that activity. And I completed that activity".

Students from School B reported that "There were no such activities in our schools before this STEM program and I am glad we got the opportunity to participate in this as it allowed us to learn more about STEM by actually practicing the activities and projects. I think students at all schools should have this opportunity".

STEM careers knowledge

STEM Careers knowledge has three subthemes i.e., Increased information, Career Pathways identification, and Enhanced practical and conceptual STEM Knowledge. Most students reported an increase in STEM careers knowledge during the FGD.

> "Actually, I did not know anything about any careers, just the basics of something and I thought all the careers were boring. At the starting when I was young, I thought all the careers were boring and I don't want to any career I just want to stay home and do nothing but actually when I came to the STEM classes and I started to attend the class and I got the handouts and watch the videos of the career I got to know that what actually an engineer does what actually a mathematician does what actually a doctor does and what actually different people in different career do and how they do it."

STEM careers interest

STEM Careers Interest has four subthemes: Change in Career interest, Development of interest in disliked subject, increased classroom engagement in STEM subjects, and Development of interest in STEM careers. Some students reported that they changed their career interest to STEM career after participating in the program while some of them were also reconsidering their career choice.

> "First, I wanted to be pilot now I am interested in engineering because of it is useful for helping people. And making new things and learning more about engineering and technology. A good experience."

Similar experiences were shared by other students.

STEM career Self-efficacy

STEM Career Self-efficacy has three subthemes i.e., Enhanced Self-efficacy beliefs, Increased confidence and motivation in STEM subjects, and Positive change in perception of STEM careers. A respondent confidently shared that,

> "Actually, the activities we did the videos we watched around the different careers actually made me very confident that yes I can pursue this career if we are having these types of activities and stuff."

Program feedback

Program feedback has four themes i.e., Technical STEM and Soft skills development, Career choice and planning, Need for school-level STEM careers program, and Recommendations for improvement. Several participants expressed in all FGDs that,

> "It was good, and I enjoyed a lot especially as in the spaghetti bridge. I did not know experiments needed to be tested before being made and how it could stand so much weight."

DISCUSSION

The intervention achieved the intended results. SC knowledge, interest and self-efficacy increased significantly and the results were similar over two trials. Furthermore, the intervention supported effectively integrated SE and career education, building on SSCT, Kolb's learning cycle, and Bloom's taxonomy. The results were significant even after statistically controlling for possibly confounding variables. Findings are consistent with other STEM interventions which reported increased SCs knowledge (Drymiotou et al., 2021), increased STEM self-efficacy (Ogle et al., 2017), or increased SCs interest (Mohd Shahali et al., 2016).

In this section we will discuss some unexpected results, which may be of particular interest to SC interventionists and future researchers. The intervention was found equally effective for students with different levels of self-efficacy, whereas the intervention increased SC interest in students with a low level of SC knowledge. These findings deserve attention as exploration of the data also indicated that low SC knowledge in our sample is not related to grades. It seems that the intervention engaged students through simple experiments and that this was especially effective for students with low SC knowledge. Students with high grades and low SC knowledge may require a different type of instruction as they may grasp the STEM concepts and ideas involved I the experiments quickly, and this does not enhance their interest in STEM of STEM careers. These findings have implications for both classroom instruction and intervention.

We noted that a few students changed their SC choices because of the intervention while other students reported more clarity of SC paths. This illustrates that SC knowledge can be integrated with STEM lessons to facilitate students in SC planning because of increased or changed aspirations and SC route information.

The intervention was found effective for both the schools but did not significantly change Mathematics self-efficacy beliefs. This can be explained by the literature as this suggests that Mathematics self-efficacy has multiple sources (Bonne and Lawes, 2016) while in the current study, only one source (learning experiences) was investigated. Future research can investigate other sources of Mathematics self-efficacy. Interventions can be designed to influence mathematics self-efficacy beliefs by focusing on the role of mathematics in complex science experiments and in connection to other subjects.

In this study, school A reported higher pre-SC knowledge than school B. This can be explained by the fact that school A offers STEM competitions and robotics programs to its students while such experiences and opportunities were absent in School B. This is also in line with literature which states that participation in STEM competitions results in an increased interest in SCs as compared to students who do not participate in such competitions (Miller et al., 2018).

The SCs intervention were more effective for school B than for school A. This can also be explained by the fact that school B students had low prior SCs knowledge. The current module proved to be more effective for students with low SC knowledge, which is supported by previous research (Fan and Yu, 2017).

Limitations and Future Directions

The sample size was relatively small which may not have provided enough data to detect all the effects for the interventions. Random sampling was not possible as the sample entirely depended on the school's approval for conducting an after-school STEM program, which is why inferences from the data to all middle school students should be carefully drawn.

The participants of the study included middle school students from two private schools of Islamabad which also challenges the generalization of findings. Moreover, the sample did not include equal number of male and female students.

The present study only considered gender, academic achievement, and parents STEM occupation as covariates. Future research may consider other external factors that can impact STEM interest of students. The current research lacked a control group in the intervention design. Future research may include control groups to have more rigorous findings on the effectiveness of the intervention.

This paper presents a pilot study to test the effectiveness to integrate STEM knowledge and SC information for STEM knowledge, interest, and self-efficacy development. The study can be expanded with other samples from Asia that focus on enhancing science career self-efficacy. The module can prove to be useful for students with lower academic grades because the present study shows that students with low STEM knowledge improved more in SC interest. Long-term SE programs with gradual increase in the difficulty levels may cater needs to diverse students with different levels and types of SC knowledge.

Further interventions may design sessions that target mathematics self-efficacy in a more varied manner. This component, being of central importance to SC programs, requires attention by researchers and school teachers.

Finally, effectiveness of SE programs may be further enhanced if a stimulating learning environment for STEM is implemented in schools. Further exploration of how a school-based learning environments interacts with the intervention and how SE can be designed taking into account the needs of different schools and students with different levels of STEM knowledge may pave a way for STEM career education in Asian countries.

CONCLUSION

In conclusion, the current study presents the significance of theoretically and methodologically integrated STEM intervention. The findings implicitly reflect a possibility of developing mathematics self-efficacy beliefs in students when SCE is started early. Furthermore, whole school approaches and interventions that receive a sound support from the entire schools' learning environment is a way forward for the schools in Asian context. This provides insightful findings to educators in South Asia for embedding STEM education in whole school approaches. Additionally, the current study highlights the importance of STEM careers interventions for grade 8 students as it promotes their STEM career interest, self-efficacy, and knowledge. These findings have implications for the policymakers as the benefits of such interventions will only be reaped with government support for each school. Given the lack of STEM careers education modules, the current study also provides a resource that can benefit teachers, STEM educators, and career educators as well an inspiration to implement STEM careers education.

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