Boosting STEM Engagement Through Sports-Themed Interventions: Impact on Student Competencies and Skills

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Abstract
Students often face difficulties with engagement and performance in Science, Technology, Engineering, and Mathematics (STEM) fields, which can have significant consequences, such as limited career opportunities and impeded technological innovation. Capitalizing on the increased interest in sports following events like the FIFA World Cup, this research aimed to assess how this enthusiasm could be used to enhance student engagement and performance in STEM. The study examined the effectiveness of a sports-themed intervention on the STEM competencies, cognitive abilities, and interpersonal skills of 107 preparatory school students in grades 8-9. Quantitative data were gathered through pre- and post-intervention questionnaires. Normality tests (Shapiro-Wilk and Kolmogorov-Smirnov) indicated a non-normal data distribution, leading to the use of non-parametric analysis with the Mann-Whitney U test and Spearman's Rho correlation. The results showed significant improvements in students' STEM competencies, cognitive abilities, and interpersonal skills (p<0.05), suggesting a positive overall impact on their STEM learning. Spearman's Rho correlation analysis also indicated a positive correlation between the intervention constructs. The findings suggest that sports-themed educational interventions can effectively boost students' interest and proficiency in STEM subjects, highlighting the need for further research to integrate innovative themed interventions in educational settings to enhance STEM education.

Keywords: STEM Education, Sports-Themed, Quantitative Analysis, Preparatory School Students, Qatar

Introduction

The global shortage of Science, Technology, Engineering, and Mathematics (STEM) field professionals is a critical issue for the economic and social development of the nations (Ali et al., 2020). A recent report by UNESCO highlights that the demand for STEM professionals is increasing day by day especially in cutting edge fields like renewable energy, biotechnology, Artificial intelligence (Ebzeeva & Smirnova, 2023). Despite these growing opportunities, there is a worldwide concern that the students are less interested in STEM disciplines. This issue threatens nations' ability to create and retain skilled STEM workforces (Alashwal, 2020; Ali et al., 2021). As the world faces increasingly complex challenges in STEM work field, creative and innovative solutions are more in demand. Educational systems worldwide have recognized the importance of addressing the issue and identified that strong STEM education is the best solution (AlMuraie et al., 2021). As the demand for STEM professionals grows, traditional methods of teaching STEM often fail to engage students or to demonstrate the practical application of STEM knowledge. This has resulted in a consistent disconnect between classroom learning and real-world problem-solving (Council et al., 2015).

It is crucial for Qatar to cultivate STEM professionals because the nation is heavily relying on expatriates to fill important STEM roles. In order to transform into a knowledge-based economy and achieve the goals of Qatar National Vision 2030 (QNV2030) it is important to take STEM intervention initiatives (Ayuso et al., 2022). Although Qatari students have high aspirations, they are falling behind internationally in math and Science aptitude tests like Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). Moreover, a significant number of students have less interest in STEM disciplines and choose to pursue non-STEM degrees (Council, 2012; Howells, 2018). Several factors contribute to this lack of interest in STEM disciplines. First, many educators and educational systems are struggling to engage students and demonstrate the real-world relevance of STEM field (Kiliánová et al., 2024). Moreover, most of the traditional teaching methods often focus on theoretical knowledge gain rather than providing practical experiences like hands-on learnings (López-Belmonte et al., 2022). As a result, students are struggling to understand the practical value of STEM education and how it connects to potential careers (Council et al., 2015). Additionally, as many other regions, Qatar faces a gender disparity in STEM fields especially in engineering. Even though the academic performance of Qatari women is good, they are less likely to pursue STEM careers because of cultural and traditional gender roles (Alashwal, 2020). These challenges underscore the importance of the urgent need for innovative and engaging educational interventions.

Recent studies show that integrating sports into STEM disciplines can boost students' STEM Interest (Drazan, 2020; Drazan et al., 2017). Football (soccer), with its global popularity, is particularly effective for this approach (Dyakova et al., 2017). It was historic milestone for Qatar to host the FIFA World Cup 2022 as the first Arab nation to host this international sporting event (Al-Emadi et al., 2022). Qatar gained global attention during the FIFA World Cup and achieved national pride and unity due to its association with football (Ishac, 2018). By leveraging the excitement of major events like the FIFA World Cup, educators can connect students' love for sports with STEM content, making lessons more engaging and relatable (Hill et al., 2014). According to Almarri (2020), large-scale events such as the World Cup represent a great opportunity for educational programs that incorporate real-world STEM applications to them (Almarri, 2020). Students' attention and enthusiasm can be captured through the FIFA activities in STEM workshops.

Additionally, integrating modern technologies like 3D printing and Arduino allow students to design and prototype can solve problems by promoting creativity and technical skills (Arvanitidi et al., 2019; Lin et al., 2018; Pabuçcu Akiş & Demirer, 2023). Moreover, to be successful in STEM fields requires strong 21st century skills such as critical thinking, teamwork, and communication (Quieng et al., 2015). These skills are essential for the personal growth of the students and their career readiness (Berkowitz & Stern, 2018). A sports-themed, project-based approach to STEM learning by connecting to the real-world can help the students to develop these skills.

The purpose of this study is to explore the effects of sports-themed STEM workshops to foster STEM Interest and Competency. The intervention leverages the widespread appeal of sports, particularly the FIFA World Cup 2022, as a platform to engage students. By integrating sports with cutting-edge technologies such as Arduino and 3D printing, the workshops emphasize experiential learning to enhance STEM Interests, Competencies, Cognitive Abilities, and Interpersonal Skills (Drazan et al., 2017; Kiliánová et al., 2024).

The significance of this work lies in its potential to transform STEM education. While addressing the specific challenges of Qatar, it offers an innovative and culturally relevant approach that aligns with global best practices. This intervention aims to improve STEM literacy by fostering STEM Interest and developing STEM Competencies, Cognitive Abilities, and Interpersonal Skills. This also seeks to prepare for their future career by giving early STEM learning experiences.

Research Question and Objectives

The following primary research question guiding this study:

- What is the impact of sports-themed STEM workshops on students' STEM Interests, Competencies, Cognitive Abilities, and Interpersonal Skills?

The objectives of the studies are:

- Assess changes in students' STEM competencies and interest before and after the Sports-themed STEM interventions.
- Explore the effectiveness of sports-themed activities to improve problem-solving, teamwork, curiosity and critical thinking skills.
- Provide culturally relevant recommendations for implementing STEM interventions in Qatar and beyond.

Methodology

To evaluate the effectiveness of the sports-themed STEM workshops, a quantitative research design was employed. The sample of study was selected through non-random sampling. This sample consisted of 107 preparatory school students from grade 8 and 9. These students participated in a five-day interactive STEM workshop that integrated sports-related activities. The activities included building sports gadgets with Arduino, designing sports equipment with 3D-printing, and solving real-life sports related engineering challenges. These experiences helped the students to foster STEM Interest and skills using sports and technology themes from the FIFA World Cup 2022 as educational tools.

This structured workshop was designed to student engagement in STEM fields, included hands-on, project-based activities. Technologies like Arduino were integrated to enhance

student engagement and understanding of the STEM concepts. Arduino, a microcontroller board, offers a user-friendly platform for hands-on project building and learning programming fundamentals alongside testing different sets of sensors (Sarı et al., 2022; Sun et al., 2023). This approach allows students to overcome the limitations of traditional classrooms, by offering practical experiences like sensor testing and 3D printing. These activities help students to deeper understanding of the subjects while fostering creativity and technical skills (Lin et al., 2018; Zadorozhnyi, 2020). As a result of this, students are better prepared to pursue careers in STEM and contribute to scientific and technological progress.

Throughout the program, the students got a chance for prototyping and testing using the engineering process for two weeks. These learning experiences can foster interest and engagement in STEM fields (Rogers, 2009). The results were documented in a poster showcasing the design process, material selection, and testing results. The following week, the projects were evaluated, and the best ones were selected to participate in the final competition with other schools. The total duration of the program was one month. A schematic diagram of the Science in Sports program has been shown in Figure 1.

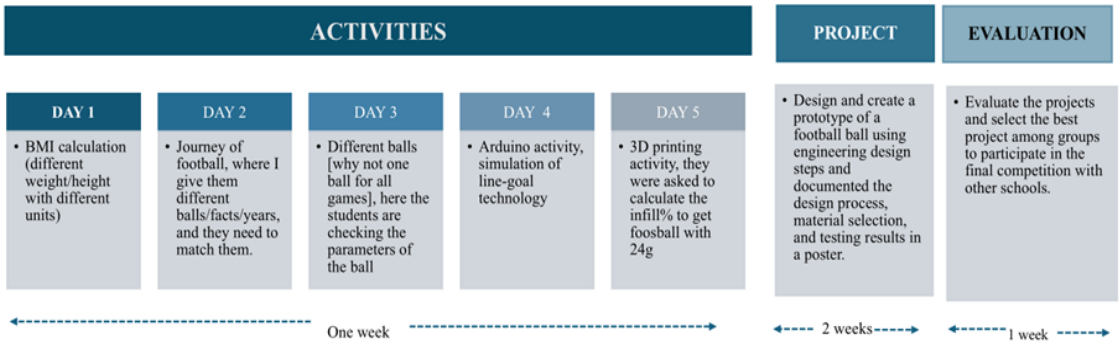

Figure1: The Schematic Diagram of the Science in Sports Program

Instruments and Measures

To assess the effectiveness of our intervention, a set of questionnaires were developed based on existing literature (Howells, 2018; Unfried et al., 2015). These questionnaires were used to measure both pre and post data based on factors such as STEM Interest (6 items), Technology Readiness (4 items), Hands-on Skills (4 items), Subject Knowledge (4 items), Curiosity (4 items), and Collaboration (4 items). A three-point Likert Scale (Yes, No, I don't know) was used to ensure clarity for students. The questionnaires were pilot tested with 107 students, and revisions were made to improve clarity. The factor analysis confirmed the reliability of the instruments, with a KMO measure of 0.792 and Bartlett's Test of Sphericity being significant (p<0.001). This value indicates that the data is suitable for further analysis and the factors were extracted meaningfully. The validated tool effectively captured the targeted constructs. Table 1 summarizes the key constructs assessed by the Questionnaire, the number of items associated with each construct and the response options used for each measure.

Table 1: Questionnaire Constructs, Factors, Items, and Response Options

Construct	Factors	Number of Items	Response Format
STEM Interest	STEM Interest	6	Yes/No/I do not know
STEM Competencies	Technology Readiness	4	Yes/No/I do not know
	Hands-on Skills	4	Yes/No/I do not know
	Subject Knowledge	4	Yes/No/I do not know
Cognitive Abilities	Curiosity	4	Yes/No/I do not know
Interpersonal Skills	Collaboration	3	Yes/No/I do not know

Data Analysis

To ensure the reliability and validity of the questionnaire, Cronbach's Alpha (α) was conducted for each factor. All the α values above 0.7 for both pre and post data indicating that internal consistency was high. This is because of strong agreement among the items within each factor (Field, 2024). Table 2 shows the Reliability Statistics of both pre and post questionnaires.

Table 2: Reliability Statistic (Pre- and Post-questionnaire)

Factors	No. of Items	Pre questionnaire Cronbach's alpha (α) value	Post questionnaire Cronbach's alpha (α) value
STEM Interest	6	0.713	0.703
Technology Readiness	4	0.828	0.805
Hands-on Skills	4	0.787	0.798
Subject Knowledge	4	0.876	0.703
Curiosity	4	0.715	0.847
Collaboration	3	0.763	0.866

Normality tests (Shapiro-Wilk and Kolmogorov-Smirnov) were conducted to assess data distribution(Shapiro & Wilk, 1965). The non -parametric tests were conducted for further analysis because of non-distribution of data, which is confirmed by Shapiro-Wilk and Kolmogorov-Smirnov tests (Field, 2024). The pre and post data were compared by conducting the Mann-Whitney U test (Mann & Whitney, 1947). Spearman's Rho correlation analysis was conducted to explore the relationship between different variables (Spearman, 1987). This methodology evaluated the sports-themed interventions thoroughly. The findings indicated statistically significant positive correlations (p<0.01) between several educational factors. Notably, Subject Knowledge was positively correlated with both Technology Readiness (r=0.64) and STEN interest (r=0.51). Additionally, significant correlations were found between STEM Interest and Skills (r=0.60) and Curiosity (r=0.63). According to Cohen's guidelines for interpreting effect sizes, these correlations can be considered large (r>0.5), suggesting strong and significant relationship between these factors.

Conclusion

This study demonstrated that sports-themed STEM interventions significantly enhance students' STEM Interest, Technology Readiness, Hands-on Skills, Subject Knowledge, Curiosity and Collaboration. By integrating experiential learning with sports and technology,

this approach offers a promising solution to increasing STEM engagement. The study quantitatively analyzed the main constructs STEM Interest, Competencies, Cognitive abilities and Interpersonal skills using the Mann-Whitney U test and Spearman's Rho correlation analysis. The correlation between the STEM factors suggests that enhancing one aspect of STEM education, such as Subject Knowledge or Technology Readiness could positively influence students' STEM Interest and related Competencies. These findings are particularly important in culturally relevant contexts like Qatar. The study highlighted the need to strengthen these connections to improve STEM programs and support students' development. The following sections discuss the Mann-Whitney U test findings in detail.

STEM Interest

STEM Interest increased by 19%, as the mean ranks rose from 98.04 to 116.96 with U value equal to 6737.00, after the workshop with a significant *p*-value ($p<0.022$). These results suggest that incorporating sports into STEM education can make the subjects more interesting and engaging. By linking learning activities to students' personal interests, the intervention helped to maintain long-term enthusiasm for STEM field. This interpretation aligns with Middleton et al.2019, who found that engaging students through everyday experiences and challenging tasks helps transition situational interest to long-term career aspirations (Middleton et al., 2019).

Technology Readiness

Technology readiness showed the most significant improvement, increasing by 73%, which means a substantial rise from a pre-workshop mean rank of 78.76 to 136.24 with U value=8799.50 with a significant *p*-value ($p<0.001$). Hands-on activities with tools like Arduino and sensors gave the chance to the students to experience technology effectively, enhancing their technological confidence and competence. These findings supported the existing research on the importance of practical, technology-driven learning experiences (Organtini, 2018; Sarı et al., 2022).

Hands-on Skills

Hands-on skills improved from 96.89 pre-workshop to 118.11 post-workshop and a U value = 6859.50, with a significant *p* value ($p=0.011$). Project based tasks such as designing foosball balls using 3D printing and recyclable materials helped students to apply theoretical knowledge, reinforcing their problem-solving and technical skills. These results aligned with the previous study conducted by Lin (2018), who explored the use of 3D printing in STEM project-based learning. This previous study showed that hands-on activities, like designing and creating models helped the students to improve their technical and problem-solving abilities (Lin et al., 2018). This supports the current study results, where the tasks like designing foosball balls with 3D printing and recyclable materials also improved students' hands-on skills and technical abilities.

Subject Knowledge

Subject Knowledge increased the mean rank from 83.86 to 131.14 with 56% improvements and a U value=8254.50, with a significant *p* value ($p<0.001$). These results indicated that practical application of theoretical concepts deepened students' understanding of STEM concepts (Alashwal, 2020).

Table 3 illustrates the Mann-Whitney U Test Results for STEM Interest and Competencies including the factors, STEM Interest, Technology Readiness, Hands-on Skills and Subject Knowledge. Figure2: shows the visual representation of Mann-Whitney U Test Results for STEM Interest and Competencies.

Table 3: Mann-Whitney U Test Results for STEM Interest and Competencies

Construct	Factors	Pre-Mean Rank	Post- Mean Rank	Mann-Whitney U	*p*-value
STEM Interest	STEM Interest	98.04	116.96	6737.00	0.022
STEM Competencies	Technology Readiness	78.76	136.24	8799.50	< 0.001
	Hands-on Skills	96.89	118.11	6859.50	0.011
	Subject Knowledge	83.86	131.14	8254.50	<0.001

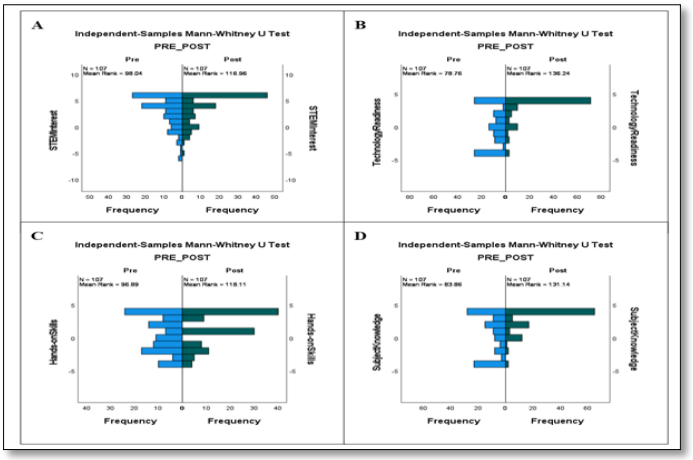

Figure 2: Mann-Whitney U Test Results for STEM Interest and Competencies

Cognitive Abilities

The Mann-Whitney U test revealed a significant improvement in curiosity following the intervention (U=6844.00, *p*=0.008). Pre-workshop, participants had a mean rank of 97.04 on curiosity, which increased to a mean rank of 117.96 post-workshop, with an increase of over 20%. These findings aligned with the study conducted by Abdurrahman and colleagues (2019), emphasizing that inquiry-based learning stimulates curiosity (Abdurrahman et al., 2019).

Interpersonal Skills

The intervention also led to positive results for interpersonal skills, particularly in collaboration, with a U value=6440.50, and a significant *p*-value (*p*=0.060). The participants' collaboration skills increased from a mean rank of 100.81 to 114.19 after the workshop. Even though the increase was not statistically significant, the increase in post mean rank after the intervention suggested the possible trend toward improved collaboration skills following the intervention. Group projects and team-based challenges might have fostered teamwork and communication, which are crucial for academic and professional success. These results

aligned with the study Zhang and Ma (2023) by highlighting the benefits of collaborative, experiential learning on interpersonal skills (Zhang & Ma, 2023). Table 4 shows the Mann-Whitney U Test Results for Cognitive Abilities & Interpersonal Skills. Figure 1 is the visual repesentation of Mann-Whitney U Test Results for Cognitive Abilities & Interpersonal Skills.

Table 4: Mann-Whitney U Test Results for Cognitive Abilities & Interpersonal Skills

Construct	Factors	Pre- Mean Rank	Post- Mean Rank	Mann-Whitney U	*p*-value
Cognitive Abilities	Curiosity	97.04	117.96	6844.00	0.008
Interpersonal Skills	Collaboration	100.81	114.19	6440.50	0.060

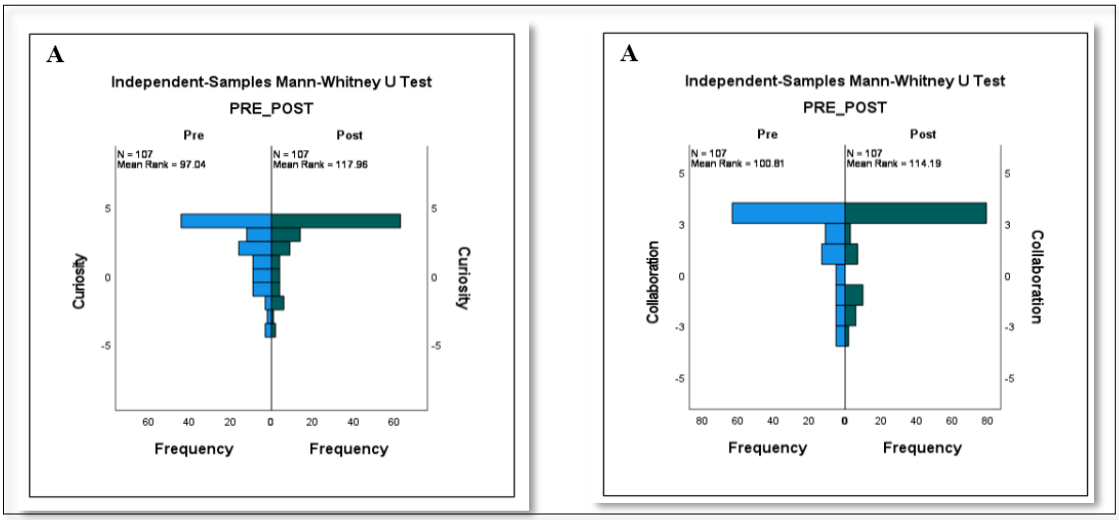

Figure 2: Mann-Whitney U Test Results for Cognitive Abilities & Interpersonal Skills

Implications of Findings

The findings have several important implications for educators, curriculum developers, and policymakers who seek to improve STEM education. Integrating students' personal interests, such as sports, into STEM learning makes education more engaging and relevant. This approach helps to address the decline in STEM Interest during middle and high school. This approach demonstrates that students can engage in STEM activities and maintain their enthusiasm if they can connect the STEM subjects and problems with their personal interests.

Firstly, practical, hands-on learning helps the students to understand the theory in a better way and develops important skills such as problem-solving, creativity and technological skills. Educational institutes should focus on project-based learning in STEM to give real-world experiences. Also providing technological tools like sensors, microcontrollers and 3D printers can improve students' Technology readiness. By providing teachers' training to the educators to use this technology in students learning can help the students to prepare for the technological challenges by becoming experts in these fields.

Secondly, promoting curiosity through inquiry-based learning helps the students to build a mindset crucial for scientific discovery. Teachers should create environments that promote exploration and critical thinking. Including group projects in STEM education helps students

to better prepare for collaborative working environments, which are essential for todays' workforce.

Limitations and Recommendations

Despite the promising outcomes, the limitation of the study also needs to be addressed. Firstly, the absence of a control group makes it difficult to determine whether the observed improvements can be exclusively attributed to the intervention. Future studies should include a control group to strengthen the validity of the findings. Additionally, even though the sample size (n=107) was sufficient for initial analysis, it may not be large enough to generalize the result. A larger sample size in future research would increase the reliability of the results.

The study only included male students, which may lead to the gender bias. Future studies should include female students as well to provide the complete understanding of the effectiveness of the intervention. These programs could help to create supportive networks, address cultural barriers, and feature female role models in STEM to inspire young women.

The participants of this study were from Qatar government schools. As it was conducted in a particular cultural and educational setting, the findings may not be easily generalized. To assess the broader applicability of the interventions in other environments, needs to be replicated in other environments including public schools and other countries. Furthermore, this research primarily focused on short-term outcomes. Further studies need to be tracked to understand the long-term effects. Monitoring students' progress over the period could help to understand the lasting impact of the intervention on STEM interest and career paths.

These findings indicate that STEM programs should include activities that align with students' personal interests. Encouraging inquiry-based learning will help to foster curiosity and critical thinking. Collaborative projects should be prioritized to develop teamwork and communication skills. To make the STEM education more inclusive, all students, regardless of gender or cultural backgrounds, need to get equal opportunities.

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