



Original Article

Spatial Cognition and Learners' Readiness toward STEM in Post-Pandemic

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Abstract

Spatial Cognition plays a very significant role towards the success of various scientific disciplines, as literature has demonstrated clearly that these skills are highly demanded for learning and pursuing STEM fields. This study was carried out to explore the level of spatial cognition among high school students and examine the learners' readiness towards STEM subjects. The study was descriptive and a quantitative research method was applied. A standardized tool was utilized to assess the spatial cognition of the students of the science group of grades 9 to 12th. 130 students from 13 to 18 years with an average age of 15.5 were administered the Mental Rotation Test (MRT) for measuring spatial cognition and readiness was measured through statements using a 5-point Likert scale. The results were analyzed using the SPSS-21 version. It was found that the majority of the students had low level of spatial cognition, which hindered their readiness regarding STEM in post-pandemic situations. There was a positive linear relationship between spatial cognition and readiness of the learners' regarding STEM subjects. Moreover, it was concluded that there was a significant impact of spatial cognition on the readiness of the learners towards STEM. Therefore, it was recommended that the science curriculum should be designed in such a way that incorporates spatial reasoning skills among students. This study's findings serve as a baseline to attract the science educationists towards a challenging predictor.

Keywords: High school, mental rotation, science education, spatial cognition, STEM

INTRODUCTION

Spatial cognition is recognized as the mental process to manipulate the visual information including visualizing objects from multiple perspectives concerned with the processes of how humans acquire, organize, and use the spatial information, that is, readily presented. Spatial cognition is an important component for predicting success in STEM (Atit et al., 2020). Spatial cognition enables students to organize, reason about, and help to make sense of information regarding imagined space as well as the real (Wai et al., 2009). Spatial cognition influences the learners' readiness towards STEM courses (Gagnier & Fisher, 2016). The cognitive researcher, Hegarty and Tarampi (2015) believe that cognitive psychology primarily deals with the understanding of how the human brain represents and processes the given spatial information thus, spatial cognition is concerned with how humans acquire, re-organize, and make use of acquired spatial knowledge. According to Hegarty and Tarampi (2015), the basic area of education in which spatial cognition was required is STEM, which is an acronym for science, technology, engineering, and mathematics. Wai et al., (2009) also concluded that spatial cognition is an important predictor for success in STEM subjects.

In the course of pandemic, there has been an abrupt global shift of education towards online or distance education, which may exert physiological, psychological, and mental pressure, . As a result, students' readiness towards STEM subjects could be hindered. This shift has brought about new challenges that were potentially hindering students' readiness towards STEM subjects (Khine, 2017). This shift underscores the importance of understanding the interconnection between spatial cognition and STEM success in the context of evolving educational landscapes. Khine (2017) discusses the spatial cognition tests for the selection of learners in STEM subjects. The literature has elaborated the strong interconnection of spatial cognition and STEM success; therefore, this study aims to investigate the relationship between spatial cognition and STEM success in the context of online and distance education during the COVID-19 pandemic. Specifically, we seek to examine how spatial cognition influences students' readiness towards STEM courses in the new educational paradigm. By addressing this gap in the literature, we aim to provide insights into effective strategies for enhancing spatial cognition skills and promoting STEM success in the era of online learning.

Problem Statement

A plethora of longitudinal research studies claim that spatial cognition is strongly related to students' entrance and success into STEM disciplines. The pandemic outbreak forcibly transformed the way students were learning which may have affected the readiness of the learners' towards STEM in post-pandemic situations. The sudden and abrupt change in the teaching and learning during the pandemic has affected the spatial cognition of learners' and tends to be hooked more over visual which needs

spatial cognition than usual. Therefore, this study was focused on presenting the current view of spatial cognition and readiness of learners towards STEM subjects. In the context of Pakistan, spatial cognition is not widely focused, especially in the STEM subjects. Moreover, there is very scarce literature available that connects spatial cognition concerning pandemic leading towards the STEM readiness of the learners.

LITERATURE REVIEW

Pandemic has globally altered the ways and means of education. Simultaneously, many cognitive functions have been directly impacted by the onset of online and distance education due to the emergency response to COVID-19 (Organisation for Economic Co-operation and Development, 2020). According to Gagnier and Fisher (2016), a scientific phenomenon often requires spatial thinking such as comprehending moon phases in astronomy, understanding chemical structures in chemistry, graph reading in mathematics, and studying genetic structure in biology. Gagnier and Fisher (2016) concluded that spatial thinking is an important building block of scientific thinking but very little research at K-12 educational practices.

Previous research has highlighted the importance of spatial skills in shaping career trajectories, particularly in STEM-based fields. In a longitudinal study, researchers gave high school students four different spatial tests. Then they linked the students' spatial scores to the occupations they had 11 years later. Students who pursued STEM-based careers, such as engineering and computer science, had better spatial skills in high school than those who pursued less STEM-focused careers (Wai et al., 2009). Building upon this foundation, recent studies have further elucidated the role of spatial abilities in predicting success in science-related careers. According to Hodgkiss et al., (2018), spatial abilities particularly mental folding abilities emerged as unique and strong predictor for science related careers. Their findings emphasized the significance of spatial cognition in preparing students for the demands of STEM fields in today's rapidly evolving educational landscape. By synthesizing findings from both historical and recent research, a clearer understanding emerges of the enduring relevance of spatial cognition in shaping students' trajectories in STEM education and careers.

Research literature indicates that spatial cognition is highly malleable (Uttal & Cohen, 2012; Uttal, et al., 2013; Newcombe, 2017) and depends upon the frequency of the use of spatial information (Pruden, et al., 2011). According to Newcombe (2017), spatial cognition strongly predicts the entrance of students into the STEM field and conclude that low levels of spatial cognition lead to other subjects than STEM subjects. Wai et al., (2009) solidify that spatial ability plays a critical role in developing expertise in STEM spatial ability. Modern talent searches would identify many adolescents with potential for STEM who are currently being missed out. Spatially enriched education could pay substantial dividends in increasing participation in mathematics, science, and engineering (Uttal et al., 2013). Spatial skills are predictive of science achievement and these skills make a similar contribution to performance for each age group (Hodgkiss et al., 2018). Spatial ability and success in science and engineering related fields demonstrates a clear link between spatial cognition and STEM success (Khine, 2017).

Early spatial skills predict later success in STEM disciplines and demonstrate that STEM readiness is influenced by spatial cognition (Zimmermann et al., 2019). Spatial cognition scaffolds and supports the needs of learners to become experts in STEM fields (Atit et al., 2020). Recent research literature also favors the spatial cognition for STEM fields (Yang et al., 2020) and significantly predicts educational achievements in such fields (Berkowitz & Stern, 2018; Khine, 2017; Wai et al., 2009). According to Dundar-Coecke et al., (2020), the spatial cognition improves casual reasoning among students to comprehend many scientific concepts included in STEM subjects Buckley, et al., (2018). The empirical research studies involving longitudinal research cements the significance of spatial cognition for STEM fields generally (Buckley et al., 2018). Spatial cognition provides foundation of success performance for scientific as well as technological fields (Vasilyeva & Lourenco, 2012).

There is a wide range of cognitive tools for measuring spatial cognition in which mental rotation test is most widely used for measuring spatial cognition of the learners in high school students (Yüksel & Bülbül, 2015). According to Campos (2012), image rotation tests were highly correlated to tests assessing rotation on the whole comprising spatial cognition. Vandenberg and Kuse's MRT is one of the most widely

used measures for spatial cognition (Caissie, et al., 2009). According to Khine (2017), there are a variety of tests that measure different spatial abilities including Mental Cutting Test, Mental Rotation Test, Purdue Spatial Visualization Test, and Heinrich Spatial Visualization Test. Nonetheless, Khine (2017) suggests the Mental Rotation Tests for grades 9 to 12 as the widely used measure of spatial cognition.

According to Gagnier and Fisher (2016), spatial cognition acts as a significant component of school readiness particularly for STEM subjects and in general as well. Khine (2017) opines that in developed countries, talented students are identified based on spatial cognition and these students were later encouraged to pursue STEM subjects to perform well in this techno-centric world. The awareness of STEM related careers should be imparted to the learners as soon as they reach the secondary school level (Razali, et al., 2018). Spatial cognition is widely recognized as the STEM success predictor and therefore it can impact the readiness of the learners towards STEM subjects (Buckley, et al., 2019). However, the abrupt impact of the Pandemic created stress (Choudhary, et al., 2020) and witnessed unpreparedness due to the sudden shift to virtual or distance learning globally. This hassle may disturb spatial cognition due to the emergency response of pandemic. This sudden shift causes many flaws in teaching and learning which leads to poor understanding of various scientific concepts (Choudhary, et al., 2020) with the absence of practical and concrete experiences in the absence of regular classes during COVID-19. The inadequate and poor digital resources during COVID-19 cause cognitive decline and increased burden on student learning (Choudhary, et al., 2020). Consequently, these circumstances put demarcations on learners' readiness towards STEM subjects. However, there were very scarce research resources that concluded the effects of a period of stress due to social isolation on spatial cognition and exploration. Nonetheless, Ramirez (2021) conclude that the pandemic has also impacted spatial cognition and produced a change in the construction of spatial cognition.

Rationale

The pandemic has created extreme demarcations in teaching and learning, which bolster many cognitive distractions among students. Therefore, the study is significant to help remap STEM education subjects for educationists and students concerning the pandemic. It is evident from the literature that spatial cognition is very important for success in sciences. In the context of Pakistan, spatial cognition has not gained widespread recognition particularly for high school students. Therefore, this research is carried out to explore the current situation of spatial cognition of the students. In addition, education throughout the country was forcefully shifted to online mode as an emergency response of COVID-19 that might result in decline of the learners' participation in academic activities, which could affect the students' readiness towards STEM subjects. Therefore, this study was carried out to explore the spatial cognition in post pandemic situations, and readiness of students for STEM subjects.

Research Questions

The following research questions were formulated to achieve the objectives of the study:

- How can the level of spatial cognition among students in post-pandemic situations be assessed?
- What methods can be used to measure the readiness of learners towards STEM subjects in post-pandemic situations?
- Which STEM subject/s are students interested in?
- What is the nature of the relationship between spatial cognition and readiness towards STEM subjects in the context of post-pandemic education?
- How does spatial cognition impact learners' readiness towards STEM subjects in post-pandemic educational settings?

Research Hypotheses

H₁: There is no significant correlation between spatial cognition abilities and readiness towards STEM subjects in the post-pandemic educational context.

H₂: There is no significant impact of spatial cognition of learners on the readiness towards STEM subjects in post-pandemic educational settings.

Delimitations of the Study

The research was limited to high school students from classes 9 to 12. The research participants were also delimited to the science students of Islamabad city only.

METHODOLOGY

The quantitative research method was used for this research using standardized measure along with a questionnaire. The research follows a non-experimental research design. The science students from classes 9 to 12 served as the population for this study. A standardized measure of spatial cognition was used developed by Shepard and Metzler (1971) and the reliability of the test was 0.88. The test was administered on 233 students of age ranges 12-17, providing evidence that this instrument had good internal consistency and reliability.

Sample and Sampling Technique

The sample was selected through a convenient sampling technique. The students who volunteered to participate in this research served the sample. The participants' selection criteria were limited to the students of classes 9 to 12 with the combination of science subjects. Informed consent was taken from the participants. There were 130 students who volunteered for this research. However, the final sample comprised 100 science students after a thorough scrutiny of the data.

Instrumentation

The instrument comprised three sections, the first section was of demographic information, the second section had spatial cognition measures, and the third section consisted of readiness towards STEM subjects. Spatial cognition was measured by using Mental Rotation Test by Shepard and Metzler (1971) consisting of 18 items. Since the measure was standardized, it was considered valid and reliable, but given the socio-demographic considerations, pilot testing was carried out before administering the test on a large scale. The pilot testing was carried out on 60 students who did not participate in the actual study. The internal consistency value was dropped to 0.73 but it maintained the satisfactory level. Each question carried 1 mark for correct response and 0 mark for each wrong response or no response. This test had 0-18 range of marks for each participant. Readiness was measured through a scale developed by the researcher having 3 sub-domains. These sub-domains were likeliness, satisfaction, and perceived self-efficacy. The statements were graded through 5-point Likert Scale with (least agreed =1) up to (highly agreed =5).

Data Analysis

The quantitative analysis of the data was done using SPSS-21 version, whereas descriptive analysis of frequencies and percentages was employed. The Pearson's Correlation value was measured using bivariate correlation model. Regression analysis was performed to determine the impact of the variables.

Table 1

Percentage distribution regarding spatial cognition and readiness towards STEM

Variables	Percentage Distribution	
	High	Low
Spatial Cognition	13%	87%
Readiness towards STEM	15%	85%

Table 1 shows that 87% of learners possess a low level of spatial cognition and 13% of the learners possess high spatial cognition. It was obvious from Table 1 that the majority of the students possess a low level of spatial cognition. Table 1 also shows that 85% of learners possess a low level of readiness towards STEM and 15% of the learners possess a high level of readiness. It is illustrated in Table 2 that a majority of the students have a low level of readiness towards STEM.

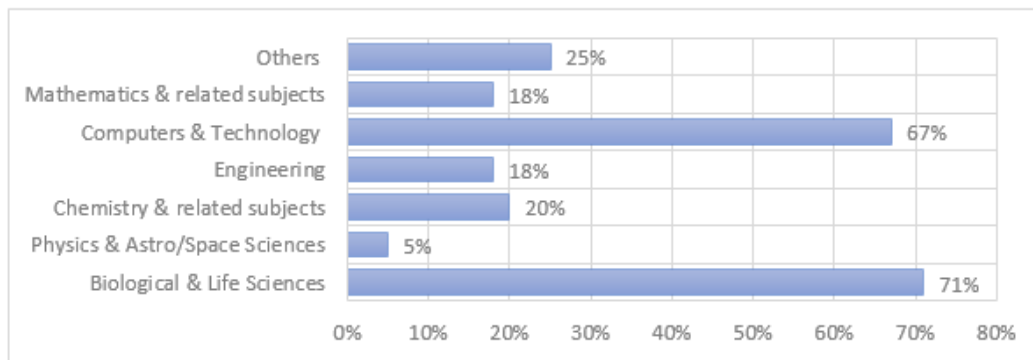


Fig. 1. Percentage Distribution Regarding STEM Subjects Likeliness

Figure 1 shows that biological sciences have the most likeliness to be chosen with 71% likeliness, then comes computers and technology subjects with 67% likeliness. Other STEM subjects have a 25% likeliness to be opted, chemistry and physical sciences come with 20% likeliness, engineering and mathematics possess 18% likeliness, physics and space-related subjects possess the least likeliness to have opted with 5% likeliness.

Table 2

Relationship between Spatial Cognition and Readiness towards STEM subjects

Variables	Readiness to STEM
Pearson Correlation	.459**
Sig. (2-tailed)	.000
N	100

Table 2 shows that there was a moderate positive correlation between spatial cognition and readiness towards STEM subjects with Pearson's correlation coefficient value of $r=0.459$ which is significant at $p<0.01$ for $N=100$. It can be concluded that an increase in spatial cognition tends to increase in readiness of learners toward STEM subjects.

Table 3

Impact of Spatial Cognition on Readiness of Learners towards STEM

Regression Weights	Beta Coefficient	R-square	F-value	t-value	p-value
Sp. Cog. → STEM Read.	0.712	0.449	79.983	8.943	.000*

Table 3 shows that there is a significant impact of spatial cognition on the readiness of learners towards STEM subjects as $P < 0.05$ at $F(1,98 = 79.983)$, which indicates that the readiness towards STEM was significantly regressed over the spatial cognition. Table 4 also shows that there was the value of regression co-efficient $R^2 = 0.449$, which means that the impact of spatial cognition on STEM readiness was 44.9% significant.

Discussion

Spatial cognition is not focused in the context of Pakistan's educational setting (Tufail, 2022). The literature shows that spatial cognition is imperative for predicting success in STEM fields. In this study, a significant positive correlation is found between STEM readiness and spatial cognition. It was noticed that in Pakistan, there is no place for spatial activities in the science curricula. The study does not focus on gender differences, but the literature (Newcombe, 2017) shows gender difference. Future research could be carried out to highlight this factor. Tufail (2022) studied spatial cognition in Pakistan at primary level and found that students have a low level of spatial cognition and the main causes were overcrowded classes and inexperienced teachers. These results indicate in this study at high school level. The findings of the study suggest that science students of Pakistan at high school level have low spatial cognition as they progress to higher grades, which ultimately leads to a low level of readiness towards STEM.

The study discussed with particular reference to post-COVID times, which may be due to abrupt shift from physical mode of teaching into online mode. The confusing educational state may become one of

the significant reasons for low readiness as students may lose interest due to irregular classroom culture at that specific time.

CONCLUSION

Overall, the study revealed that the majority of learners possess low level of spatial cognition and readiness towards STEM subjects. Biology and life sciences have the most likeliness to be chosen. Physics and related subjects have the least likeliness to be chosen. There was a positive linear relationship between spatial cognition and readiness of the learners towards STEM showing a significant impact of spatial cognition on the readiness towards STEM subjects.

Competing Interest

The authors had no competing interests.

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