Cognitive Agility and Science Motivation as Predictors of Secondary School Students' Science Achievement Indistrict Lahore

Dr. Zainab Qamar
Research Associate, Faculty of Social Sciences and Humanities, Minhaj University Lahore
Zainab Kamran
PhD Scholar, Institute of Education and Research, University of the Punjab, Lahore, Pakistan
Paper Number: 240136

Abstract:

The current study investigated the combined effect of secondary school students' cognitive agility and science motivation on science outcomes in district Lahore. Under quantitative research and positivist paradigm, correlation design was employed to answer the research questions. A total of 2,1459th graders from 39 schools of district Lahore were selected as a sample by using multistage sampling process which include stratified and cluster sampling techniques. Validated and reliable research instruments based on 5-point Likert type scale were used to survey selected sample. The findings revealed moderate levels of perception regarding both psychological constructs. Moreover, strong and moderate correlation were found among all three study variables. The findings of regression analysis showed that combined effect of cognitive agility and science motivation explained approximately 61% of variance in students' achievement in science, with cognitive agility acted as stronger predictor than motivation. These results signified the need to promote, reinforce, and boost these psychological constructs to strengthen the learning outcomes of students in the subject of science.

Keywords: *Academic Achievement, Cognitive Agility, Educational Psychology, Intrinsic Drift, Learner Engagement, Motivation, Problem-solving.*

Introduction

The academic achievement of students in secondary school has been the main focus of educators and policymakers especially in areas such as science that underlie technological and economic advancements. At this level of education, the learners are not merely expected to acquire facts but also acquire levels of thinking and interest in science that will be maintained in the long-term. Two psychological terms, cognitive agility and science motivation are more widely specified as important factors in student achievement. Cognitive agility is characterized by both flexibility in thinking and adapting to new circumstances with the possibility of taking different perspectives into consideration when resolving a problem (El-Kasaby et al., 2024). Science motivation, in its turn, is a definition of the motivation, interest, and perseverance that a student demonstrates in terms of learning scientific knowledge (Elahi et al., 2025). Together these constitute the cognitive and affective skills of students to learn.

The importance of cognitive agility is that it provides students with the mental flexibility to deal with new, ambiguous, and problems. Research has shown that academic performance is strongly related to the cognitive ability and cognitive aptitude in particular in academic subjects, which require conceptual knowledge and logical reasoning, such as mathematics and science (Shi & Qu, 2022). Not only are more agile students more apt at solving problems and making decisions, but they are also able to use their knowledge to solve problems in other settings and other fields (El-Kasaby et al., 2024). This translates to science education to mean that agile thinkers are normally in a better position to analyze experiments, negotiate between the abstract theories and how they can be used in real life situations, and to generate more innovative solutions to real life problems. Deficiency in cognitive agility, however, usually leads to memorization, superficial learning and inability to transfer the knowledge to new or unrelated circumstances. In the end, without developing agility, students would be passive learners who would not perform excellently in higher education and in workplaces where agility and innovation are required.

Science motivation is the other important factor that helps maintain the engagement, perseverance, and resilience of learners in the context of the challenges. As per the academic literature, motivation has always emerged as a powerful predictor of academic success in fields (Steinmayr et al., 2019). Engaged learners will put more effort in the task, show curiosity in the scientific concepts and will stay persistent even when presented with complex or abstract tasks. In particular, intrinsic motivation has been associated with more substantial engagement and higher achievement in the long term (Steinmayr et al., 2019).

In the Pakistani study, research has added that the student succeed significantly in science when they see it as relevant and meaningful (Elahi et al., 2025). On the contrary, low motivated students are also usually not interested, will not want to do and have fear of the subject of science. Hence do not perform well and will not be willing to engage in science related subjects. Motivation is thus the psychological fuel that assists the student to put mental ability in a practical accomplishment. It poses grave consequences when cognitive agility and motivation to science are not researched and practiced, on the one hand, with regard to students, and, on the other, the education systems. Unless cognitive agility is strengthened, science education would turn to be a more of a memorization practice such that learners will be incapable of critical thinking, using their knowledge and responding to real life challenges. This is not only suffocating academic performance, but suffocating this is also suffocating acquisition of essential skills in the 21st century such as innovation, creativity and flexibility. Similarly, the lack of science motivation consideration means the disregard of the affective motivation of learning. Unmotivated students are less likely to continue with science courses, poorly perform, and have increased dropout and decreased involvement in science, technology, engineering, and mathematics (STEM) career types. On a greater scale, neglecting these variables can destroy national education policies, reinforce poor teaching methods, and retard the development of a scientifically literate and technologically competent workforce.

Therefore, cognitive agility and science motivation cannot be avoided among the students of secondary schools. Because cognitive agility provides the learners with the intellectual abilities to analyze, judge and innovate, science motivation keeps the learners interested and focused during the learning process. They do this together so that students not only pass the test but also have a good and lasting relationship with science. Absence of research and integration of these constructs in the educational strategies will inescapably water down the essence of science education, particularly in such a place as Lahore where the achievement in secondary education becomes the defining factor in the future of higher education and future jobs (Kamran & Akram, 2025). The careful consideration of these variables may therefore result into the individual success of the students and the development of the nation in the field of sciences and technologies.

Literature Review

Academic achievement is a multidimensional construct which is determined by a set of cognitive and motivational factors. When applied to secondary education, the achievements of students in the science subjects not only rely on their intellectual capabilities but also on the psychological temperaments of the learning subjects. The cognitive agility, described as the skills of pupils to change their point of view, adapt to difficulties, and think flexibly, is one of the psychological aspects that contribute to the improvement of problem-solving skills (El-Kasaby et al., 2024). Motivation, specifically in science education context, offers the emotional advantage to keep pace and stay engaged in the process of overcoming academic difficulties (Steinmayr et al., 2019). Collectively, these constructs make up two complementary dimensions, i.e., cognitive and affective, which influence the manner in which students learn, perform, and project their future in science education. Unless both of these factors are incorporated, the improvement of achievement could be left incomplete because skills and will to learn of students have to work together to achieve long-term learning outcomes.

Cognitive Agility and Academic Achievement

Cognitive agility is described as the ability of a person to be flexible in thinking, manage ambiguity, change problem-solving strategies when necessary, and incorporating new information into the existing mental models. Cognitive agility, in learning institutions, helps students to act appropriately to new and difficult tasks instead of actions based on memorization. An emerging literature indicates that the students with a higher cognitive agility perform better in the sciences and other related fields, in particular, at the secondary level.

Shi and Qu (2022) established that cognitive ability, such as mental flexibility and self-monitoring had a significant predictive power on academic success in biology, mathematics, and language among secondary students. Their results indicated that the higher the students scored in the tasks that needed changing attention and mechanism adjustment, the higher the overall academic achievement. In an Indonesian sample, Safitri et al. (2019) also found strong correlations among critical thinking, metacognitive awareness, and achievement in biology. The more aware students were of their own thinking processes and able to control their learning performance, the more they likely to comprehend scientific material and achieve well in tests. El-Kasaby et al. (2024) contributed to the body of work by pointing out that cognitive agility, as the author defines it not merely as problem solving, but as a way of working with digital tools, has certain additional advantages to digitally-enriched environments. Agile learners are able to integrate both scientific and digital resources to deepen their knowledge and produce more effective work.

In a study by Martinez et al. (2021) in Latin America, cognitive flexibility of secondary students was evaluated and the result showed that the students who could change between various problem-solving strategies scored substantially higher in science reasoning assessment tests than students with low cognitive flexibility. In the same way, Kim and Lee (2023) studied South Korean high school science students and discovered that the relationship between working memory and science conceptual understanding was mediated by shifting ability (one of the aspects of cognitive agility).The students that could change their thinking to solve new problems performed better in science. Brown et al. (2022) in another study among various European countries have found that cognitive flexibility and openness to experience correlated with higher scores in international science assessments (PISA), particularly, in questions demanding creative or divergent thinking.

However, as evidence is being enriched internationally, in Pakistan itself comparatively little empirical research has directly quantified cognitive agility per se. There are related constructs studied such as Qamar and Hashmi (2024) evaluated the perceptions of secondary school students towards their cognitive agile and found that there are gender differences in perception, although perceptions were not directly correlated with science grades. Khan et al. (2024) discovered that physics achievement among secondary school students in Lahore and Sheikhupura region is strongly predicted by problem-solving skills and conceptual knowledge, indicating that something about agility (the ability to flexibly apply knowledge) is important, but not applying the label of cognitive agility or the broader tests.

Science Motivation and Student Outcomes

The motivation to learn science is central to how students' approach, persist and finally succeed in science education. Students who are intrinsically motivated are more engaged, do not give up when faced with challenges, and have improved learning outcomes as compared to their less-motivated counterparts (Steinmayr et al., 2019). Empirical and meta-analytic studies indicate that the purposeful development of intrinsic motivation through instruction, including instruction based on inquiry and student-centered active learning, enhances interest, persistence, and achievement of students in science (Celik, 2019; Meulenbroeks et al., 2024). This effect can be observed in the recent classroom research, an inquiry-based physics practical approach increased the intrinsic motivation of the secondary level students towards science practical work, which mediated the improvements in conceptual understanding (Meulenbroeks et al., 2024).

Investigations of teaching practice and motivation also find consistent relationships between interactive and student-centered teaching and greater levels of motivation, which subsequently predict better course performance (Lees-Murdock et al., 2024; Stieha et al., 2024). The large-scale syntheses and reviews also conclude that interventions aimed at supporting the intrinsic motives of students provide consistently positive gains to achievement regardless of the situation (Walker et al., 2024). South Asian and Pakistani samples have found that motivational beliefs such as academic self-efficacy are strong predictors of science achievement, and teacher support and classroom practices that promote student confidence and autonomy lead to improvement in motivation and achievement (Aslam & Ali, 2023; Khan et al., 2024). Collectively, these results suggest that motivation is directly (by influencing effort and persistence) and indirectly (by influencing engagement with efficacious pedagogies) enhance student learning outcomes.

Elahi et al. (2025) discovered that students tend to be positively motivated by science, particularly by valuing science and keeping the self-efficacy. In line with this, Khan et al. (2024) showed that motivational support provided by teachers contributes to better science achievement of students in secondary level. These effects are also brought out in intervention-based research conducted by Shahzad and Qureshi (2023), who noted that the Jigsaw method enhanced motivation and the attainment of secondary students in Azad Jammu and Kashmir. Thus, programs that address motivation along with the development of cognitive skills are most likely to yield the most significant gains in science at the secondary level.

The previous research has conducted investigations on cognitive agility and motivation as independent variables in predicting learning outcomes, there is limited empirical research on the combined impact of these variables on science achievements, particularly at the secondary level in Pakistan. A majority of the research in existence has been carried out in the western or technologically progressive contexts with a gap in the comprehension of how these constructs work in the local educational contexts. Moreover, there is not much information regarding the interaction between cognitive agility and motivation to influence the performance of students in science subjects, a field that has not been fully explored yet despite the significance in equipping the learners to respond to the contemporary scientific and technological challenges. This paper fulfills this gap by examining the predictive value of both cognitive agility and science motivation in academic achievement of secondary school students in District Lahore.

Self-Determination Theory (SDT) proposed by Deci and Ryan (1985, 2000) is a strong construct of science motivation. SDT states that as a person has the satisfaction of the three fundamental psychological needs, i.e., autonomy, competence and relatedness. In science education, when students have a sense of independence in their learning, feel that they are competent enough to achieve success and have positive relationships with teachers and classmates, they become intrinsically motivated which improves persistence, engagement and achievement. Various researchers have used SDT to specify why motivated students put in more effort in difficult scientific activities and exhibit elevated levels of success in contrast to students motivated by extrinsic factors alone.

The Cognitive Flexibility Theory (CFT) developed by Spiro et al., (2012) serves as a theoretical basis of cognitive agility. CFT assumes that within complex fields like science, students should be capable of restructuring knowledge, changing mindsets and flexibly applying concepts to contexts. Cognitive agility is an expression of these principles, in that cognitive agility is about flexibility, problem-solving as well as ability to cope with newness and unpredictability in learning contexts. Learners with greater cognitive agility will be more able to approach scientific enquiry and assimilate the various sources of knowledge in order to build up meaning.

The studyintegrates the theory that combines Self-Determination Theory with Cognitive Flexibility Theory. The SDT describes the motivation processes involved in motivating the students to put efforts in learning science and the CFT describes the cognitive process involved in adapting, solving problems and transferring knowledge. Both of these theories suggest that the motivated students are better placed to succeed in science because they are cognitively agile. Thus, the framework defines cognitive agility and science motivation as the complementary predictors of the academic achievement at the secondary level that can be regarded as the holistic perspective that could be employed to examine the impact of psychological and cognitive factors on the learning outcomes simultaneously.

Significance of the Study

This research is significant as it mediates two key constructs named cognitive agility and science motivation to the success of secondary school science students. Although the two variables have been analyzed separately, not much has been done to explore how they interact within the Pakistani context. These results are applicable in the educational psychology because it illuminates on the dynamics of flexible thinking and inspiration in learning science. At the real-life level, the research educates teachers and curriculum developers about how they can come up with strategies that can enable flexibility, problem solving and long-term interest in the science classes. It also makes policy makers aware of the importance of taking into consideration practices that improve motivation and cognitive skills in the education curriculum and training of teachers. Ultimately, strengthening these aspects has the potential to improve the achievement of students in science and prepare them better to face the dynamics of the knowledge-based society, which is rapidly changing in 21stcentury.

Research Objectives

The study is based on the following research objectives:

1. To measure the perception levels of secondary school students regarding cognitive agility and science motivation.

2. To examine the relationship among cognitive agility, science motivation, and students' academic achievement in science subjects.
3. To determine the predictive effect of cognitive agility and science motivation on students' academic achievement.

Research Questions

Following research questions address the study objectives:

1. What are the perception levels of secondary school students regarding cognitive agility and science motivation?
2. What is the relationship among cognitive agility, science motivation, and academic achievement among secondary school students?
3. To what extent do cognitive agility and science motivation predict the academic achievement of secondary school students

Research Design and Methodology

This study employed a correlational research design within a quantitative paradigm to investigate the predictive roles of cognitive agility and science motivation in enhancing secondary school students' academic achievement. This design was chosen because it allows for examining the strength and direction of relationships between variables as well as the predictive effect of independent variables on the dependent variable.

The population of the study comprised all Grade 9 secondary school students in District Lahore. According to the official records, there were 387 secondary schools in the district Lahore. Multistage random sampling procedure was applied to select the representative sample size. Firstly, stratified sampling was used to divide the schools into two strata, male and female secondary schools. Then 10% schools from each stratum were randomly selected, yielding a total of 39 schools (M = 17, F = 22). Lastly, a cluster sampling approach was employed, and all Grade 9 students present in the selected schools were surveyed. The average number of students present at the time of data collection ranged from 55 to 90 comprising a total of 2,145 students (1,018 males and 1,127 females).

The students' cognitive agility was measured using the Cognitive Agility Questionnaire, self-developed and validated by the researchers. Its reliability coefficient was calculated as .791 which confirmed the internal consistency of the instrument. This instrument consisted of 35 items distributed among five factors named: Problem-Solving Skills, Creativity, Learning Speed and Working Memory, Decision Making, and Open Mindedness. Science motivation was measured using the Science Motivation Questionnaire II (SMQ-II) developed by Glynn et al. (2011). This 25-item instrument measured students' Intrinsic Motivation, Self-Determination, Self-Efficacy, Career Motivation, and Grade Motivation. The perceptions were measured on a five-point Likert scale ranged from 1 (Never) to 5

(Always). The overall reliability of the instrument was 0.92. Lastly, academic achievement of students in science was obtained in terms of students' final examination marks in science.

The school principals or head teachers were informed about the purpose of the study prior to data collection and with their consent data were collected from students. Students were also guided about the nature of the study. The research ethics were ensured through the data collection process. Research ethics were strictly ensured and maintained during data collection. The responses of students were then coded, entered, and prepared for statistical analysis using descriptive as well as inferential statistics in SPSS ver. 26.0.

Results and Interpretations

This part reports the results and interpretation using descriptive and inferential statistics to answer research questions.

Table 1

Levels of Students' Perceptions about their Cognitive Agility

Factors	Mean	Std. Deviation
Problem Solving Skills	3.34	.813
Creativity	3.41	.794
Learning Speed and Working Memory	3.40	.813
Decision Making	3.30	.796
Open-Mindedness	3.39	.788
Cognitive Agility (Overall)	3.37	.651

N = 2,145, Male = 1,018, F = 1,127

The Table 1 present the mean scores of students' perceptions about cognitive agility which ranged from 3.30 to 3.41, indicating a moderate level of agreement across all factors. Creativity (M = 3.41, SD = .794) and Learning Speed and Working Memory (M = 3.40, SD = .813) received the highest ratings, while Decision-Making had the lowest (M = 3.30, SD = .796). The overall mean score (M = 3.37, SD = .651) reflects a generally positive perception of cognitive agility among students. The standard deviations, ranging from .651 to .813, suggest moderate variability in students' responses across all factors.

Table 2

Students' perception about their Science Motivation

Factors	Mean	Std. Deviation
Intrinsic Motivation	3.25	.831
Self-Efficacy	3.27	.828
Self-Determination	3.30	.834
Grade Motivation	3.28	.837
Career Motivation	3.21	.865
Student Motivation (Overall)	3.26	.690

N = 2,145, Male = 1,018, F = 1,127

The Table 2 shows students' perceptions of their science motivation. The mean scores ranged from 3.21 to 3.30, indicating a moderate level of motivation across all factors. Self-Determination (M = 3.30, SD = .834) received the highest mean, followed closely by Grade Motivation (M = 3.28, SD = .837) and Self-Efficacy (M = 3.27, SD = .828), while Career Motivation had the lowest (M = 3.21, SD = .865). The overall mean score (M = 3.26, SD = .690) reflects a generally positive but moderate level of science motivation among students. The standard deviations, ranging from .690 to .865, indicate moderate variability in students' responses, suggesting some differences in individual levels of science motivation.

Table 3

Relationship between Cognitive Agility (CA) and Student Academic Achievement in Science (SAAS)

		1	2	3	4	5	6	7
1	Problem-Solving Skills	1						
2	Creativity	.644**	1					
3	Learning Speed and Working Memory	.587**	.643**	1				
4	Decision Making	.575**	.548**	.618**	1			
5	Open-Mindedness	.503**	.504**	.527**	.597**	1		
6	Cognitive Agility	.816**	.822**	.833**	.821**	.769**	1	
7	SAAS	.639**	.598**	.628**	.651**	.630**	.775**	1

SAAS = Student Academic Achievement in Science

**. Correlation is significant at the 0.01 level (2-tailed).

The Table 3 presents the correlation analysis between cognitive agility factors and student academic achievement in science. All correlations were positive and significant at the 0.01 level, indicating strong associations among the variables. The factors of cognitive agility, including Problem-Solving Skills, Creativity, Learning Speed and Working Memory, Decision-

Making, and Open-Mindedness, were highly interrelated, with coefficients ranging from r = .503 to r = .644. Student academic achievement in science was significantly correlated with all cognitive agility factors, with coefficients ranging from r = .598 to r = .651, and most strongly with Decision-Making (r = .651). The overall cognitive agility score exhibited a strong positive relationship with achievement (r = .775, p < .01), suggesting that higher cognitive agility is closely associated with improved performance in science subjects.

Table 4

Relationship between Science Motivation (SM) and Student Academic Achievement in Science (SAAS)

		1	2	3	4	5	6	7
1	Intrinsic Motivation	1						
2	Self-Efficacy	.627**	1					
3	Self-Determination	.604**	.619**	1				
4	Grade Motivation	.551**	.576**	.637**	1			
5	Career Motivation	.563**	.555**	.590**	.640**	1		
6	Science Motivation (overall)	.812**	.819**	.838**	.828**	.817**	1	
7	SAAS	.459**	.450**	.453**	.479**	.433**	.553**	1

SAAS = Student Academic Achievement in Science

**. Correlation is significant at the 0.01 level (2-tailed).

The Table 4 presents the correlation matrix illustrating the relationships between the components of science motivation and student academic achievement in science. All correlations were positive and statistically significant at the 0.01 level, indicating meaningful associations among the variables. The factors of science motivation named Intrinsic Motivation, Self-Efficacy, Self-Determination, Grade Motivation, and Career Motivation showed moderate inter-correlations, ranging from r = .551 to r = .640, suggesting that these motivational dimensions are closely related and collectively contributed to students' overall science motivation. Student academic achievement in science was moderately and positively correlated with all motivation factors, with correlation coefficients ranging from r = .433 to r = .479, and most strongly with Grade Motivation (r = .479). The overall science motivation score also showed a significant positive relationship with achievement (r = .553, p < .01), indicating that higher levels of motivation are associated with better academic performance in science subjects.

Table 5

Effect of Cognitive Agility (CA) and Science Motivation (SM) on Student Academic Achievement in Science (SAAS)

Sr. No	Model	*B*	SE	*Β*	*t*	*p*
1	SAAS (Constant)	-12.606	.869		-14.514	.000
2	Science Motivation	1.705	.290	.103	5.870	.000
3	Cognitive Agility	12.477	.308	.710	40.489	.000

Note: $r = .779^a$, $r^2 = .607$; (F (2, 2142) = 1650.906, $p < .05$)

SAAS = Student Academic Achievement in Science

The Table 5 presents the regression analysis showing the combined effect of cognitive agility and science motivation on student academic achievement in science. The overall model was statistically significant, F (2, 2142) = 1650.906, $p < .05$, with a multiple correlation of $r = .779$ and $r^2 = .607$, indicating that 60.7% of the variance in student achievement was jointly explained by the two predictors. Both Science Motivation ($\beta = .103$, $t = 5.870$, $p < .001$) and Cognitive Agility ($\beta = .710$, $t = 40.489$, $p < .001$) significantly contributed to the model, although cognitive agility had a substantially stronger effect. These results suggest that while students' motivation toward science positively influenced their academic achievement in science. Moreover, their cognitive agility reflected in their ability to think flexibly, solve problems, and adapt to new learning situations played a more dominant role in determining their achievement in science.

Table 6

Effect of Cognitive Agility (CA) factors on Student Academic Achievement in Science (SAAS)

	Model	*F*	*r*	*r²*	*B*	SE	*β*	*t*	*p*
1	SAAS (Constant)				-11.070	.824		-13.438	.000
2	PSS	1478.869	.639	.408	3.209	.272	.228	11.800	.000
3	C	1194.941	.598	.358	1.483	.287	.103	5.172	.000
4	LSWM	1395.675	.628	.394	2.319	.280	.165	8.272	.000

5	DM	1576.384	.651	.424	3.051	.281	.212	10.857	.000
6	OM	1412.457	.630	.397	3.635	.259	.250	14.029	.000

Note: r = .779[a], r^2 = .607; (*F* (5, 2139) = 660.059, *p*< .05)

SAAS = Student Academic Achievement in Science, PSS = Problem Solving Skills, C = Creativity, LSWM = Learning Speed and Working Memory, DM = Decision Making, OM = Open Mindedness

The Table 6 presents the regression analysis examining the influence of cognitive agility factors on student academic achievement in science. The overall model was statistically significant, F (5, 2139) = 660.059, p < .05, with a multiple correlation of r = .779 and r^2 = .607, indicating that 60.7% of the variance in student achievement was explained by the combined effect of the five cognitive agility components. Among the predictors, Open-Mindedness (OM) had the strongest effect (β = .250, t = 14.029, p < .001), followed by Problem-Solving Skills (PSS) (β = .228, t = 11.800, p < .001), Decision-Making (DM) (β = .212, t = 10.857, p < .001), Learning Speed and Working Memory (LSWM) (β = .165, t = 8.272, p < .001), and Creativity (C) (β = .103, t = 5.172, p < .001). These results indicate that all dimensions of cognitive agility significantly contributed to students' achievement in science, with Open-Mindedness emerging as the most influential predictors of academic success in science.

Table 7

Predictive effect of various factors of SM on SAAS

	Model	***F***	***r***	***r^2***	***B***	**SE**	***β***	***t***	***p***
1	SAAS (Constant)				4.991	.997		5.006	.000
2	IM	572.568	.459	.211	2.243	.350	.163	6.400	.000
3	SE	545.159	.450	.203	1.710	.358	.124	4.784	.000
4	SD	552.256	.453	.205	1.372	.367	.100	3.744	.000
5	GM	638.667	.479	.230	2.728	.361	.200	7.561	.000
6	CM	493.668	.433	.187	1.130	.337	.085	3.349	.000

Note: $r = .555^{a}$, $r^2 = .308$; (F (5, 2139) = 190.847, $p < .05$)

SAAS = Student Academic Achievement in Science

The Table 7 presents the regression analysis examining the effect of different science motivation factors on student academic achievement in science. The overall model was significant, F (5, 2139) = 190.847, p < .05, with a multiple correlation of r = .55 and $r^2 = .308$, indicating that 30.8% of the variance in student achievement was explained by the combined effect of the five motivational factors. Among these predictors, Grade Motivation (GM) emerged as the strongest contributor (β = .200, t = 7.561, p < .001), followed by Intrinsic Motivation (IM) (β = .163, t = 6.400, p < .001), Self-Efficacy (SE) (β = .124, t = 4.784, p < .001), Self-Determination (SD) (β = .100, t = 3.744, p < .001), and Career Motivation (CM) (β = .085, t = 3.349, p < .001). These findings indicate that while all components of science motivation significantly predicted achievement, Grade Motivation and Intrinsic Motivation had comparatively stronger effects, suggesting that students' drive to perform well in assessments and their inherent interest in science were particularly influential in shaping their academic outcomes in science.

Major Findings

Following are the major findings of the study:

1. Students' perceptions indicated a moderate level of cognitive agility (M = 3.37, SD = .651), showing that they generally viewed themselves as reasonably skilled in applying cognitive strategies during science learning.
2. Students' perceptions revealed a moderate level of science motivation (M = 3.26, SD = .690), indicating that they were moderately driven by intrinsic, extrinsic, and career-related factors in studying science.
3. The results showed a strong and positive relationship between cognitive agility and students' academic achievement in science (r = .775, p < .01). Among the factors, decision-making (r = .651, p < .01) and problem-solving skills (r = .639, p < .01) demonstrated the highest correlations with science achievement.
4. The findings indicated a moderate and positive relationship between science motivation and students' academic achievement in science (r = .553, p < .01). Among the motivation components, grade motivation (r = .479, p < .01) showed the strongest association with achievement.
5. The regression results revealed that cognitive agility and science motivation jointly explained 60.7% of the variance in students' academic achievement in science (r = .779, $r^2 = .607$, F (2, 2142) = 1650.906, p < .05). Cognitive agility (β = .710, p < .001) emerged as a stronger predictor than science motivation (β = .103, p < .001).

6. Among the factors, decision-making ($\beta = .212$, $r^2 = .424$, $p < .001$) from cognitive agility and grade motivation ($\beta = .200$, $r^2 = .230$, $p < .001$) from science motivation explained the highest variance in students' academic achievement in science.

Discussion:

The findings of the present study provide empirical evidence supporting the combined influence of cognitive agility and science motivation on students' academic achievement in science at the secondary level. The results highlighted that both constructs play complementary roles in shaping students' performance, aligning with theoretical perspectives of Self-Determination Theory (Deci & Ryan, 1985, 2000) and Cognitive Flexibility Theory (Spiro et al., 2012). These theories jointly suggested that successful learning in complex domains such as science depends on both motivational and cognitive resources that enable learners to persist and adapt effectively.

The findings also reported significant, positive and significant ($r = .77$, $p < .01$) relation of cognitive agility and students' academic achievement in science. Previous studies in literature also support this significant relationship signifying the important role of cognitive agility in enhancing students' outcomes (Martinez et al., 2021; Shi & Qu, 2022). The results also signified the predictive role of cognitive agility ($b = .710$, $p < .001$) reinforcing the assumption that students with high cognitive agility tend to competently integrate knowledge related to science to solve real life problems.

Science motivation and achievement in science also revealed moderate and positive relationship ($r = .553$, $p < .01$). This highlights that motivation remains an important yet less dominant element compared to cognitive agility in facilitating student outcomes in science. Among various factors of science motivation, grade motivation ($r = .479$, $p < .01$) emerged as the strongest motivational predictor, highlighting that external performance standards play a central role in shaping students' effort and persistence in learning science. These finding aligns with conclusions drawn by Steinmayr et al. (2019) and Meulenbroeks et al. (2024). They noted that motivational factors such as achievement goals and interest are essential for students to be persistent in science learning. The positive predictive effect of motivation ($\beta = .103$, $p < .001$) also strengthen the premise of Self-Determination Theory, which states that competence and goal orientation enhance students' commitment and outcomes when satisfactorily supported and reinforces by autonomy and relatedness.

The combined regression model demonstrated that cognitive agility and science motivation together explained 60.7% of the variance in students' academic achievement in science ($r^2 = .607$, $F(2, 2142) = 1650.906$, $p < .05$). This high proportion of explained variance suggests that both cognitive and motivational components contribute significantly to science performance, providing empirical validation for the interactional framework proposed in the study. Similar patterns were observed by Kim and Lee (2023) and Brown et al. (2022), who found that cognitive flexibility, when supported by motivational engagement, leads to deeper learning and better problem-solving outcomes in science contexts.

Taken together, the findings contribute to the growing body of literature emphasizing the dual importance of cognitive and motivational processes in science achievement. They also extend prior research by demonstrating that, within the Pakistani context, cognitive agility exerts a stronger influence than motivation, though both constructs collectively provide a robust explanatory framework for academic success. The results underscore the need for educational interventions that integrate cognitive agility training with motivational enhancement strategies to cultivate scientifically capable and self-regulated learners.

Recommendations and Future Suggestions

Based on the findings of the study, it is recommended that:

1. Classroom practices should integrate tasks that challenge students to think critically, make informed choices, and reflect on multiple perspectives to strengthen cognitive agility.
2. Science teachers should design learning activities that foster decision-making and problem-solving skills, as these dimensions of cognitive agility showed the strongest links with student achievement.
3. Teachers should emphasize grade-related goals and constructive feedback to enhance students' grade motivation, which was found to be a key motivational predictor of achievement.
4. Professional development workshops for teachers should be conducted focusing on integrating cognitive skill-building strategies with motivational support to sustain students' engagement and achievement in science.

Suggestions for Future Research

1. Future researchers may employ longitudinal designs to examine how cognitive agility and science motivation interact over time in predicting academic outcomes.
2. Researchers could explore additional mediating or moderating variables, such as classroom environment, teacher feedback, or learning strategies, to better explain the relationship between cognitive agility and science achievement.

3. Expanding the research to different educational levels and cultural contexts could help generalize these findings and identify contextual influences on science learning outcomes.

References:

1. *Aslam, M., & Ali, R. (2023). Effect of academic, social, and emotional self-efficacy on students' science achievement. European Journal of Education Studies, 10(5), 112–124.*
2. *Brown, T., Müller, J., & Hansen, P. (2022). Cognitive flexibility, openness, and performance in international science assessments. Comparative Education Review, 66(1), 112–134.*
3. *Çelik, S. (2019). The impact of active learning on motivation and achievement in science education. Journal of Education and Practice, 10(12), 56–64.*
4. *Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. Springer Science & Business Media.*
5. *Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227–268.*
6. *Elahi, K., Bano, S., Qureshi, A., & Mehmood, A. (2025). Motivation of students toward learning science at secondary school level in Pakistan. Journal for Social Science Archives, 3(1), 1260-1268.*
7. *El-Kasaby, W. H., Badawy, W. B. M., & Shalaby, Y. M. (2024). Digital readiness and cognitive agility as predictors of academic well-being among university students during digital learning. Review of Contemporary Philosophy, 23(1), 1417-1431.*
8. *Kamran, Z., & Akram, M. (2025). Linking secondary school students' ratings of teacher effectiveness with their achievement in Biology. ACADEMIA International Journal for Social Sciences, 4(3), 311-325.*
9. *Khan, S., Salah ud Din, M., & Ikram, A. (2024). Teacher motivational support and its relationship with students' science achievement at secondary level. Pakistan Social Sciences Review, 8(2), 65–77.*
10. *Kim, S., & Lee, J. (2023). Shifting ability mediates working memory and conceptual understanding in science among South Korean high school students. Journal of Educational Psychology, 115(2), 345–359.*
11. *Lees-Murdock, D. J., Khan, D., Irwin, R., Graham, J., Hinch, V., O'Hagan, B., & McClean, S. (2024). Assessing the efficacy of active learning to support student performance across undergraduate programmes in biomedical science. British Journal of Biomedical Science, 81, 12148.*

12. *Martinez, A., Silva, J., & Gomez, R. (2021). Cognitive flexibility and science reasoning outcomes in secondary schools in Latin America. International Journal of Science Education, 43(7), 1056–1074.*
13. *Meulenbroeks, R., van Rijn, R., & Reijerkerk, M. (2024). Fostering secondary school science students' intrinsic motivation by inquiry-based learning. Research in Science Education, 54(3), 339-358.*
14. *Qamar, Z., & Hashmi, M. A. (2024). Perception of secondary school students regarding cognitive agility. Social Science Review Archives, 2(2), 403–411.*
15. *Safitri, D., Irmawanty, I., Bachtiar, S., & Rukman, Y. (2019). The correlation between critical thinking skill and metacognitive awareness with students' cognitive achievement in biology learning outcomes. European Journal of Education Studies, 6(6), 266–278.*
16. *Shahzad, A., & Qureshi, N. (2023). Effectiveness of the Jigsaw strategy on science achievement and motivation among secondary school students in AJK. Kurdish Studies, 11(1), 231–244.*
17. *Shi, Y., & Qu, S. (2022). Analysis of the effect of cognitive ability on academic achievement: Moderating role of self-monitoring. Frontiers in Psychology, 13(2), 996504.*
18. *Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (2012). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In Constructivism in Education (pp. 85-107). Routledge.*
19. *Steinmayr, R., Weidinger, A. F., Schwinger, M., & Spinath, B. (2019). The importance of students' motivation for their academic achievement – Replicating and extending previous findings. Frontiers in Psychology, 10(1), 1730.*
20. *Stieha, V., Earl, B., Hagens, H., Haynes, M., Ulappa, A., Bond, L., & Oxford, J. T. (2024). An exploration of the relationship between active learning and student motivation in STEM: A mixed methods study. Advances in Physiology Education, 48(3), 621-638.*
21. *Walker, A., Aguiar, N., Soicher, R., Kuo, Y., & Resig, J. (2024). Exploring the Relationship*
22. *between Motivation and Academic Performance Among Online and Blended Learners: A MetaAnalytic Review. Online Learning. 28(4), 76-116.*