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Relationship between Cognitive flexibility, Tolerance of Ambiguity and Mindfulness among Mathematics' students

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Abstract
Students are the future of any society, ensuring their psychological well-being is optimal goal. This study aimed to investigate the relationship between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics' students. Sample size of 300 students (M=150, F=150) was used in the study. The data was collected through purposive convenient sampling from different universities of Karachi. The study tested three hypothesis (1) There will be a positive relationship between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics' student. (2) There will be a gender difference between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics' student. (3) There will be a significant impact of mindfulness on academic performance among mathematics' student. The scales used were Cognitive flexibility inventory questionnaire (CFIQ), Dennis, J. P., & Vander Wall, J. S. (2010), Budner's questionnaire of tolerance of ambiguity (Budner's, 1962) and Mindfulness awareness attention scale (Brown & Ryan, 2003). Descriptive statistical analysis and correlation coefficients were employed to explore this relationship. Finding revealed that Cognitive flexibility has significant positive relationship with mindfulness (r=.142, p<0.01). However, tolerance of ambiguity has moderate significant relationship with mindfulness (0.196, p<0.05). For gender difference, result showed that female scored higher on cognitive flexibility as compared to male (t= 2.922). Whereas, Male scored high on tolerance of ambiguity as compared to female participants (t=3.784). Impact of mindfulness was insignificant on academic performance. In future this study will contribute to the development of effective strategies in educational setting, underlying problem-solving and mathematical learning.
Keywords: Cognitive Flexibility, Ambiguity, mindfulness, University Students, Gender Difference

Introduction
Cognitive flexibility refers the ability to switch quickly between two or more tasks

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or conditions by adapting the different situations simultaneously (Fuchet al.,2023). It is commonly used for executive functioning; cognitive flexibility also refers the tailoring of cognitive processing strategies. Cognitive flexibility plays an important role in academic performance or success and make learning easier for learners to change their perspective and adapt new situations or tasks (Hacatrjana, 2022). Research evidences shows that there is an important association between executive functioning and cognitive flexibility, but the nature is still remain poorly unspecified (Blakey et al., 2016). Cognitive flexibility and affects that contribute flexibility of mathematics college students. Interestingly, it support the change-resistant theory and suggest that flexibility in Mathematics is a different contract that cannot be easily developed through traditional instruction methods (Shaw et al., 2020).

Tolerance of ambiguity refers one's ability to manage or adapt to change on being comfortable with the situation even not knowing the clarity (Tao, Y., 2024). In this fast-changing era, tolerance of ambiguity is getting increasingly relevant. Whether it is from educational setting an individual frequently have to make decision in unclear setting with no clear rules (DuBRin, 2022). Moreover, other important psychological constructs, such as openness to experience, cognitive flexibility, and emotional intelligence are linked to tolerance of ambiguity. By developing understanding about these traits give deeper understanding of how this trait impact or influence behavior and mental processes (Jach & Smillie, 2021).

Mindfulness refers the practice of being present, nonjudgmental and aware with the current moment cultivating the sense of curiosity and openness (Kabat-Zinn, J. (2003). Cognitive flexibility is the essence of mindfulness and more importantly, distinguished intelligent flexibility from mindful flexibility (Moore, A., et al., 2009). Mindfulness is conscious awareness and attention with roots in Theravada Buddhism. The study reported positive correlation between mindfulness and academic achievement of math students in math test (Zenner, et al ., 2014) Introduced the idea or understanding of the Ambiguity Tolerance Interface (ATI), findings highlighted that leaders with high ambiguity tolerance are better equipped to take decisions in uncertain environments, maintain effectiveness, and adapt strategies as needed despite incomplete information (Furnham & Marks, 2013) The study investigated that individual characteristics including negative and positive affect ,and tolerance of ambiguity, do not influence on accounting students ethical decision making on the other hand there is significant positive relationship between negative affect and ethical decision making in management students it refers that management students are more likely to make better decision when they experience negative emotions however there is a significant negative relationship between higher level of ethical decision-making and decision making, which indicates, management students who are more comfortable with uncertainty has chances to make poorer ethical decisions (Mahdi Moardi et al., 2016). Cognitive flexibility is the essence of mindfulness and more importantly, distinguished intelligent flexibility from mindful flexibility (Holes et al., 2013). In educational setting mindfulness and tolerance of ambiguity gained significant attention for their role in particularly in disciplines, learning experiences, requiring problem-solving skills such as mathematics (Hyland, T., 2011). Applying mindfulness and tolerance of

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ambiguity in educational setting helps to create a supportive environment for students to enhance their cognitive and emotional ability. However, many students have fear of math or to solve math questions that come unexpectedly in exam, students who practice mindfulness are better able to create calm and supportive classroom environment, help them to reduced class room stress and enhance their learning (Zelazo & Lyons, 2012). In today's world, people use so many electric devices such as phone, laptop and mobile and try to often do multi-tasking. This study finds positive link with mindful and math grades. Many university students face psychological and academic challenges significantly, such as ill-structure problems or tasks, complex questions, stress management and coping with unclear or uncertainty (Beilock & Carr, 2005) These challenges can impact on their academic performance outcomes and overall well-being (Conley, Durlak, & Dickson, 2013). The relationship between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics student help to design interventions and strategies for students and help students to polish their personal skills and improve performance. Mindfulness based interventions improves cognitive flexibility (Zeidan et al ., 2010)However , this study helps to understand the influence of these variables on students' academic outcomes and it's still remained unclear how these variables interact and influence students' academic performance and outcomes (Saeedi Mobarakeh et., 2013).

Hypotheses

1. There will be a positive relationship between cognitive flexibility, tolerance of ambiguity and mindfulness among Mathematics' student.
2. There will be no gender difference among cognitive flexibility, tolerance of ambiguity and mindfulness.
3. There will be a significant impact of mindfulness on academic performance among mathematics' student.

Methodology

Research Design

It's a Quantitative research correlational survey design was used to measure cognitive flexibility, tolerance of ambiguity and mindfulness among Mathematics' students. All data were analyzed on IBM SPSS.

Participants

The research target population was students, studying from different private or government universities. Therefore, using a purposive convenience sampling technique, the sample of this study was consist of 300 participants. (M=150, F=150) from different universities was select.

Conceptual frame work

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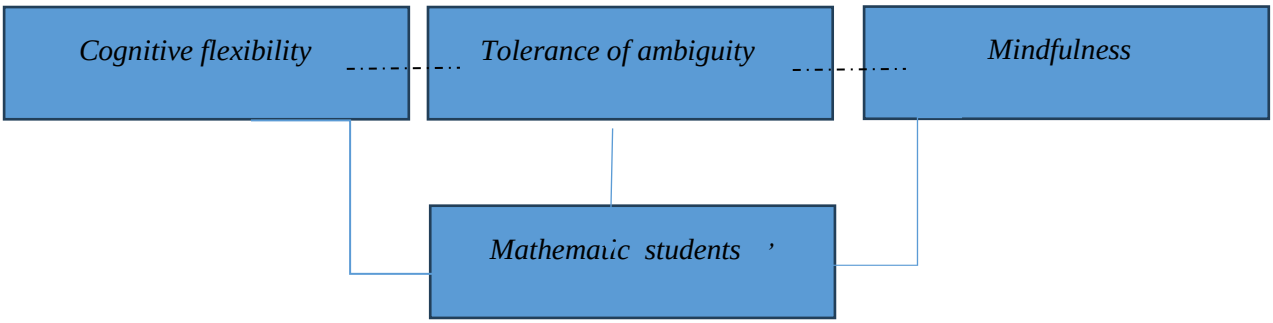

The conceptual framework shows the relationship between cognitive Flexibility, Tolerance of Ambiguity and Mindfulness among Mathematics students learning results. Cognitive flexibility, independent variable show positive impact on tolerance of ambiguity, help students to handle complex and uncertain events. Both Cognitive flexibility and Tolerance of ambiguity influence Mathematics learning outcomes directly. It highlights their role in improving problem solving and academic performance. Furthermore, Tolerance of Ambiguity fosters Mindfulness, which mediates the association between independent variables and academic results. This shows that mindful focus and open to uncertainty in students perform better in mathematics, underscoring the importance of emotional skills and cognitive skills in academic outcome or success.

Measures

Consent Form: A consent form was attached with the form and was to make sure that their information would be kept confidential. It was also briefed that they have the right to quit if they feel uneasy to give their information at any time. Participants were also guaranteed that the information provided by them would be only used for research purposes. Written instructions were given to the respondents to fill the questionnaire appropriately and accurately.

Demographic Form: Demographic form based on basic information about age, education, no of siblings, birth order, academic grades and marital status.

Cognitive flexibility questionnaire (Dennis, J. P., & Vander Wal, J. S, 2010): To assess
cognitive flexibility we use cognitive flexibility inventory questionnaire (CFIQ) .It has 20items to measure , it is also consider as self-reported to measure or monitor how often an individual engaged in cognitive behavioral thoughts and challenging interventions. Whereas, High scores refers higher level of cognitive flexibility .This scale High internal consistency (Cronbach's alpha = 0.80-0.90).

Tolerance of ambiguity (Budner's, 1962): To examine tolerance of ambiguity we used
Burner's questionnaire of tolerance of ambiguity. It is 16-items scale and rated on 7-point
Liker scale range 16 to 80 indicates greater tolerance of ambiguity .This scale has high internal consistency with (Cronbach's alpha = 0.83).

Mindful attention awareness scale (Brown & Ryan, 2003) to assess the level of mindfulness
We used mindfulness awareness attention scale. It is 15-items scale and rated on 6-point

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.This scale has high internal consistency with (Cronbach's alpha = 0.70-0.90).

Procedure

To measure the relationship between cognitive flexibility, tolerance of ambiguity and mindfulness. The data was collected through purposive sampling. An informed consent were given to participants and told them that their participation is voluntary and they can withdraw from the study at any time while there is no risk for participate. It was informed that their personal provided information was just to study the purpose of this study and it can only be used in this study. Their personal information has access only to the students that are included in this research and their supervisor. After signing the inform consent the participant were given a package of questionnaires to fill out. These included; cognitive flexibility (20-item scale) and tolerance of ambiguity (16 items scale) mind fullness awareness attention (15 -item scale).

Results

The result section comprised of socio-demographic characteristics of the sample, calculated the psychometric properties of the scales. For the analyze SPSS version 2 use for both descriptive and inferential statistics. Descriptive statistics, such as mean, frequency, standard deviation and percentage is compute. Inferential statistics is use for present hypothesis, including correlation, regression and the T-test. For every test, the significance level is fixed at 0.05.

Table 1: Frequencies and Percentages of Demographic Variables (N = 300)

Variables	*n*	%
Ages		
18-22	271	83.9
23-27	26	8.0
28-30	3	.9
Gender		
Female	150	46.4
Male	150	46.4
Qualification		
Undergraduate	289	89.5
Graduate	10	3.1
Other	1	.3
Employment status		
Working	53	16.4
Non -working	247	76.5
Birth order		
Elder child	107	33.1
Second child	89	27.6
Middle child	55	17.0
Younger child	22	6.8
Last born	16	5.0
Only child	9	2.8
Marital status		

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UN married	287	88.9
Engaged	6	1.9
Married	7	2.2

Note: *n* = Frequency; *%* = Percentage; *M* = Mean; *SD* = Standard Deviation; k = Thousand.

Table 1 describes the demographic variables reported by participants. The participants have reported about age, education, gender, birth order, employment status, marital status etc. . . . The age of participants showed that 83.9are from 18-22 years and 8.0% are from 22-27years and .9% are from 28-30 years .Similarly the level of education shows that 89.5% are undergraduate and 3.1% are graduate and other are .9%. For gender 46.4% participants are male and 46.4% of participants are female, for birth order related 33.1 % are elder , 27.6% are second child , 17.0% middle child , 6.8% are younger child , 5.0 % are last born and 2.8% are only child . For marital status 88.9% are unmarried, 1.9 % are engaged and 2.2 % are married.

Table 2: Descriptive and Alpha Coefficients For all Study Variables (N = 300)

Scales	*k*	*M*	*SD*	α	Range		*Skew.*	*Kurt.*
					Potential	Actual		
Cognitive Flexibility Inventory	20	91.70	16.983	.824	20-140	32-130	-.832	1.310
Tolerance of Ambiguity Scale	16	52.58	15.181	.810	16-112	21-100	.713	.306
Mindfulness Awareness scale	15	166.84	11.492	.775	15-90	19-79	-.163	-.032

Note: *Skew* = Skewness; *Kurt* = Kurtosis; *M* = Mean; *SD* = Standard Deviation; *k* = Number of items.

Table 2 describes the psychometric properties of the scale of all the study variables. The variables are all sound to be used in the main study. The psychometric properties like reliabilities of the scale are in acceptable range. The actual range falls under the potential range of the scales. Further, the values of skewness and kurtosis is within the range of -1 to +1, which is acceptable.

Table 3: Correlation among Study Variables (N = 300)

S. no.	Variables	*n*	*M*	*SD*	1	2	3
1	Cognitive flexibility	300	91.70	16.983	-		
2	Tolerance of ambiguity	300	49.21	14.394	.056	-	
3	Mindfulness	300	51.14	10.814	.142*	.196**	-

Note: *M* = Mean; *SD* = Standard Deviation; *n* = Number of items. P <0.01

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Table 3 shows the correlation between the study variables. The results showed that cognitive flexibility has significant positive relationship with Mindfulness (r= .142, p <0.01). However, cognitive flexibility weak, positive relationship with tolerance of ambiguity. Tolerance of ambiguity has significant positive correlation with Mindfulness (r= .196, p= 0.01).

Table 4: Independent Sample T-Test Based on the Gender of Participants on Study Variables (N = 300)

Variables	Male (n = 150)		Female (n = 150)				Cohen's d
	M	*SD*	*M*	*SD*	t	*p*	
Cognitive flexibility	88.87	17.872	94.53	15.597	-2.922	.004	0.337
Tolerance of ambiguity	52.29	15.871	46.13	12.033	3.784	.000	
Mindfulness	0.437 5147	10.556	50.81	11.092	.528	.660	470.6

Note: M = Mean; *SD* = Standard Deviation.

Table 4 describes t-test analysis for the gender difference among participants on basis of cognitive flexibility, Tolerance of Ambiguity and Mindfulness. The results showed that female scored higher on cognitive flexibility as compared to male. On the other hand, Male scored high on tolerance of ambiguity as compared to female participants. However, Mindfulness scores are quite similar in both or it can be slightly higher average.

Regression analysis of Average Marks from Mindfulness for Participants (N = 300)

Variables	*B*	*SE*	*t*	*p*	*95%Cl*
Constant	66.125	3.269	19.699	.000	[57.955,70.820]
Mindfulness	.086	.063	1.061	0.290	[-.057, .189]

R^2 =.004, F=.063, P<0.01

Note: B = Unstandardized Beta; *SE*= Standard Error; *CI* = Confidence Interval p<0.01

Table 5 shows the results of linear regression analysis with Mindfulness as predictors and average marks as outcome. The value of R^2 was .004 which indicated that 0.4% of the variance in average marks can be clarified by mindfulness. However, it is very low %, which means that mindfulness doesn't account meaningful portion in academic performance and value > 0.290, which is greater than 0.05, indicates statistically insignificant

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relationship.

Discussion

This study explored the relationship between three variables Cognitive Flexibility (CF), Tolerance of Ambiguity (TA) and Mindfulness among Mathematics Students .The sample of 300 participants. The results findings increase the growing body of literature on the psychological factors that are pillars of well-being and adaptive functioning. This section is about deeper in to the study results, Interprets the finding in light of previous literature.

The first hypothesis was "there will be a relationship between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics students". The results shows significant positive correlation between cognitive flexibility and mindfulness. This indicates that individual who are more cognitively flexible are more supposed to be mindful, considered by heightened and non-judgmental and present-moment awareness observation of their experiences (Kiken & Shook, 2011) In aligns with Theoretical frame work that suggest Cognitive flexibility as an essential component of mindfulness. Being flexible in thought process help an individual to detach from rigid thinking patterns , allow them to focus on the present moment becoming overly preoccupied with past event or future worries. The state of mindfulness arises by this adaptability, where an individual can answer to their environment with greater clearance (Moore & Malinowski, 2009) The researches posit the role of CF in improving Mindfulness based practices. An individual with higher cognitive flexibility are more likely to benefit from mindfulness intervention as they easily to switch their attention to present moment. Mindfulness-based Interventions of RCT, meta-analysis reported that there is moderate but significant enhancement of cognitive control especially in attention and memory **(**Zainal, N. H., & Newman, et al., 2023)

Although, the current results shows moderate, significant positive correlation between the variables which are tolerance of ambiguity and mindfulness. The findings suggested that individuals are more likely to practice mindfulness who are more comfortable with ambiguity, it's because of their open and accepting attitude regarding to their experiences. Tolerance of ambiguity refers to the capability to stay calm and composed when faced with uncertainty or complexity. This often necessitates a mindful approach, which encourages people to accept their experiences as they are, without judgment or the urge for quick solutions. Such acceptance can alleviate the anxiety commonly linked to ambiguity, promoting a heightened sense psychological flexibility and adaptability. This finding aligns with previous studies indicating that mindfulness can act as a protective factor against the stress and unease associated with ambiguous situations. By cultivating a non-judgmental and present oriented mindset, mindfulness enables individuals to handle uncertainty and ambiguity more adeptly (Kashdan & Rottenberg, 2010). Furthermore, research has demonstrated that mindfulness training can enhance individuals' comfort with ambiguity by minimizing cognitive biases and encouraging a more balanced view of uncertainty. The important connection between tolerance of ambiguity (TA) and mindfulness indicates that mindfulness interventions may be especially advantageous for those who find it difficult to cope with ambiguity. Techniques

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like mindful meditation and body scanning can assist individuals in recognizing their responses to uncertainty and fostering a deeper sense of acceptance and tranquility. This can ultimately improve their capacity to manage ambiguous or unpredictable situations more effectively.

Despite of it, the results also showed that cognitive flexibility has weak, positive but not significant relation with tolerance of ambiguity. It indicates that both construct relate conceptual adaptability independently. The lack of strong correlation among these two variables suggests that cognitive flexibility doesn't necessarily suggest an individual is more tolerance of ambiguity (Zenasni et al., 2008). There can be numerous different factors may influence these traits, such as, personal experience, cognitive flexibility and the most impact full cultural influences .Despite both variables trait are important for navigating unpredictable and complex environments or situations, the lack of significant co relationship indicates that individual may have tolerance of ambiguity without necessarily being comfortable with cognitively flexible, and vice versa. These results finding are somewhat reliable with previous researches that have also reported non-significant and mixed relationships between Cognitive flexibility and tolerance of ambiguity (Syyed mirzaei S Z, et al., 2022). For example, some studies reported that CF is more strongly linked to adaptability and problem solving in structured situations, task or scenarios. This shows that these traits may depend and interact on situational demands.

The second hypothesis was, there will be a gender difference among cognitive flexibility, tolerance of ambiguity and mindfulness. The higher average score for females in cognitive flexibility is in line with previous research indicating that females typically outperform males in tasks that require mental adaptability and problem-solving skills. This finding is supported by studies that show females may excel in cognitive tasks related to working memory and emotional processing, which enhance their thinking flexibility (Weiss et al., 2003). These differences could be related to underlying neural mechanisms, as females often exhibit greater connectivity in areas associated with executive function and emotional regulation.

On the other hand, males demonstrated a greater tolerance for ambiguity. These gender differences could arise from evolutionary or social influences, where males may be more drawn to exploratory or less structured environments (Brighetti, G., & Lucarelli, C., 2015). In terms of mindfulness, there was little difference in mean scores between genders. Both males and females demonstrated comparable levels of present-moment awareness, indicating that mindfulness is less affected by gender compared to cognitive flexibility and tolerance of ambiguity. Research indicates that mindfulness interventions are equally beneficial for both genders, improving cognitive control and emotional resilience for everyone (Rojiani et al., 2017) The third hypothesis examining the impact of Mindfulness and Academic performance exposed critical insight. The table 5 finding revealed minimal and statistically non-significant effect on average marks of Mindfulness. The value of R^2 was .004 which indicated that 0.4% of the variance in average marks can be clarified by mindfulness. However, it is very low %, which means that mindfulness doesn't account meaningful portion in academic performance. The unstandardized coefficient (B=0.0660), which indicates slightly positive relationship but this association is no significant

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and p-value > 0.290, which is greater than 0.05. The F= 1.125, which means that mindfulness doesn't elaborate significant portion of the variance in Academic performance in this sample.

The previous researches also examined complex dependent association between mindfulness and Academic outcomes or performance (Shapiro, Brown, & Astin, 2011) for instance, there are factors of mindfulness that effects on academic performance such as, stress management, resilience and emotional regulation, instead of this having direct impact influence on grade. Mindfulness has positive influence on resilience, which in terms enhance academic performance. It means that mindfulness may improve learning strategies and coping mechanisms, which could lead to better academic performance outcome under specific conditions (Hall, 2016)

Further, research by (Alzahrani, A. M., et al, 2020), a study in Saudi Arab explored that mindfulness significantly reduces depression and stress among medical students, but the direct impact on GPA was not evident. This means that mindfulness doesn't directly boost academic performance like grade but may create more conductive learning environment that can be beneficial for them in different areas of academic. However, it could be supposed that for academic and personal growth mindfulness has been recognized as a key competence that raises adaptability and critical thinking. It can be concluded that mindfulness enhanced or support students' learning process by improving emotional competencies and helping them to direct academic challenges more successfully.

Conclusion

The study investigated the relationships between cognitive flexibility, tolerance of ambiguity and mindfulness among mathematics students and give valuable insight of these variables and contribute to the growing frame work of literature .These variables are inter connected and complex in relationship with each other, The results showed that cognitive flexibility weak, positive relation but not significant relation with tolerance of ambiguity. However, Cognitive flexibility has significant positive relationship with Mindfulness. This indicates that these variables traits operates independently, but shared connection with mindfulness. It means adaptability may promotes Present moment awareness. Tolerance of ambiguity has significant positive correlation with Mindfulness and also encouraging the role of well-being and psychological adaptability. Gender differences were significant, with female male students reporting higher cognitive flexibility, while male students scored higher on tolerance of ambiguity. The overall results examined the importance of fostering mindfulness to enhance resilience, direct life's uncertainties and enhance emotional regulation with greater confidence. This study finding suggest the importance of nurturing mindfulness to improve resilience and psychological flexibility in both professional and personal domains.

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