Unravelling the Metacognitive Thinking Skills of Engineering Students: Exploring the Role of Age and Gender

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Abstract **- This study aimed to investigate the metacognitive thinking skills among engineering students and explore the influence of age and gender on these skills. The Metacognitive Thinking Skills Scale developed by (Tuncer & Kaysi, 2013) was used to assess four dimensions: thinking skills, reflective skills towards problem-solving, decision-making, and alternative skills of evaluation. A sample of 270 engineering students from private colleges in Delhi NCR was taken for study. The research data was analyzed using IBM SPSS 26 and Smart PLS 4. The questionnaire demonstrated good reliability, with a Cronbach's alpha of 0.891. The data were analyzed using descriptive statistics, reliability analysis, confirmatory factor analysis, discriminant validity analysis, and structural equation modelling. The results showed that age had a significant positive impact on alternative skills of evaluation, decision-making skills, thinking skills, and reflective skills towards problem-solving among engineering students. However, gender had a minimal effect on these cognitive constructs with a slight impact on decision-making skills. The findings suggest that age plays a crucial role in the development of metacognitive thinking skills among engineering students, while gender differences are relatively insignificant in this context. Implications include educational interventions for fostering metacognitive thinking skills among engineering students.**

Keywords **- Metacognitive thinking skills, Thinking Skills, Reflective thinking skills, Problem-solving, Decision-making skills, Engineering students**

JEET Category **- Research**

I. INTRODUCTION

The study of Behavioral Science is considered as the foundational understanding according to (Hanisch & Eirdosh, 2023) for addressing problems related to Educational Sustainable Goals and Metacognition is a key competence for that. Metacognition is always stated as “thinking about thinking”. Metacognition is a system that controls and understands his or her intellectual performance. Metacognition is also known as “executive control” which allows people to control their learning. Metacognition is very important for successful learning and cognitive performance. “Metacognition originally described as the knowledge about and managing of one’s cognitive activities in the learning process” (Flavell, 1979) “Metacognition included awareness of their learning process, assessment of learning needs, developing strategies to meet the demands and then implementing the strategies” (Hacker et al., 2009). John Flavell was the first researcher who divided metacognition into two distinct but interrelated. Metacognitive regulation- is the ability to regulate own thinking processes and metacognitive knowledge- is awareness of one’s thinking. In one of the recent studies conducted by (Punia et al., 2022) the author states that metacognitive skills and logical thinking skills affect problem-solving skills in a significant way. However, the study (Mayer, 1998) elaborates on Metacognitive Skills where the author outlines that these skills are related to reading comprehension, writing and mathematics.

The meta-cognitive skills will help students evaluate intelligence and abilities to reflect on learning processes that tend to be used in various situations. The new education policy (NEP) is also designed to address the changing needs of the education system in the context of the evolving industry landscape, including the rise of Industry 4.0. This policy recognizes the importance of preparing students for a rapidly advancing technological world, where higher-order thinking skills are essential for success. In particular, engineering students involved in software development, infrastructure building, vehicle production, cybersecurity, and other fields require metacognitive thinking skills to excel in their careers. In the study done by (Mekala et al., 2020) the author specifies that there exists a gap between engineering students and workplace preparedness which can be bridged by paying attention to 21st-century professional skills.

The integration of metacognitive thinking skills into engineering education equips students with the tools they need to excel in the industry. According to Expected Skills Needs for the Future of Work by Deloitte, by 2029, several skills will be in high demand in the coming years. These skills are critical for professionals to remain competitive and meet the evolving needs of employers and customers. One of the key skills highlighted in the report is digital literacy. Professionals must be proficient in using digital tools and platforms for effective communication, collaboration, and job performance as technology advances. This encompasses skills like data analysis, coding, and cyber security. Another important skill is cognitive flexibility, which involves the ability to adapt to new situations and think creatively to solve complex problems. Interpersonal skills are also critical for success in the future of work. This includes skills such as communication, collaboration and emotional intelligence. This includes skills such as communication, collaboration, and emotional intelligence. In addition, the ability to learn and adapt quickly is essential in the fast-paced, constantly evolving workplace of the future.

II. NEED AND SIGNIFICANCE OF THE STUDY

The need for this study arises from the growing importance of metacognitive thinking skills in the field of engineering education. Metacognition refers to the ability to monitor and regulate one's thinking processes, which plays a crucial role in problem-solving, decision-making, and learning. Understanding the factors that influence metacognitive thinking skills among engineering students is essential for designing effective educational interventions and promoting their academic success and professional development.

By investigating the influence of age and gender on metacognitive thinking skills, this study addresses a significant research gap in the existing literature. Age-related differences in metacognitive skills are expected due to the developmental nature of cognition. Exploring how these skills evolve across different age groups can provide insights into the optimal timing and strategies for cultivating metacognitive abilities among engineering students. Additionally, gender differences in metacognitive thinking skills have been a subject of interest, as previous research suggests potential variations between males and females. By examining the impact of gender on these skills, this study contributes to the understanding of any gender-related disparities in metacognitive thinking abilities among engineering students. Such insights can inform educational institutions and instructors about potential areas where targeted interventions may be necessary. These interventions aim to bridge the gender gap and promote equal opportunities for all students.

The findings of this study have practical implications for engineering education. They can guide educators in developing curriculum and instructional strategies. These strategies foster metacognitive thinking skills among students, leading to improved problem-solving abilities, enhanced decision-making processes, and more effective learning outcomes. Ultimately, promoting metacognitive thinking skills can contribute to the preparation of competent and reflective engineers who are equipped to tackle complex challenges in their professional careers.

III. LITERATURE REVIEW AND DEVELOPMENT OF HYPOTHESIS

The study (Ling & Venesaar, 2015) clearly outlines that mere technical knowledge would not suffice for career enhancement for technical students, meta cognitive skills play a decisive role. A study was conducted by (Van de Kamp et al., 2015) to investigate the effect of explicit instruction of metacognition on divergent thinking. A total of 147 students at secondary school participated in visual art education. The results indicated a positive effect of metacognitive knowledge on fluency and flexibility only. This study suggests that metacognitive knowledge about divergent thinking may enhance creative processes.

In a research study by Coskun (2018) involving university students from various disciplines, it was found that overall, the level of metacognitive skills was high. Specifically, theology students exhibited higher levels compared to other branches. Caratozzolo et al. (2020) suggest that supervised practice of thinking skills is particularly effective for engineering students. In one of the studies conducted (Senthil, 2020) the authors outline that students' involvement in learning enhances their competency. In the study (Diaz, 2015) the author evaluates the effects of metacognitive tactics to help young learners.

The finding indicates that metacognitive training has positively contributed to vocabulary acquisition skills. Subjects were able to advance their consciousness about learning strategies and the use of metacognitive tactics to enhance their vocabulary learning. In the report by Karaali (2015), he examined the role of metacognition in the mathematics classroom through a case study. He found positive changes in the students over the semester, indicating that they trust that effective cognitive performance not only depends on knowledge but also awareness and control of knowledge, as noted by Garofalo and Lester (1985).

In a distinct study by Veenman and Spaans (2005), the authors sought to establish a relationship between intellectual and metacognitive skills. The study concluded that metacognitive skills supersede intellectual skills when it comes to learning performance. The findings revealed that metacognitive skills are supreme in guiding the cognitive learning process (Sáiz Manzanares & Carbonero Martín, 2017). Various studies have exposed that metacognitive plays a major role in the academic performance of students (Zhao & Mo, 2016). Metacognitive skills support students to be self-directed, self-responsible and self-regulated (Listiana et al., 2016; Sonowal & Kalita, 2017).

IV. HYPOTHESIS

Based on the preceding Literature Review, the following hypotheses are formed

H_1: There is a relationship between gender and thinking skills (TS).

H_2: There is a relationship between gender and reflective skills towards problem-solving (RTS).

H_3: There is a relationship between gender and decision-making skills (DMS).

H_4: There is a relationship between gender and alternative skills of evaluation (AES).

H_5: There is a relationship between age and thinking skills (TS).

H_6: There is a relationship between age and reflective skills towards problem-solving (RTS).

H_7: There is a relationship between age and decision-making skills (DMS).

H_8: There is a relationship between age and alternative skills of evaluation (AES).

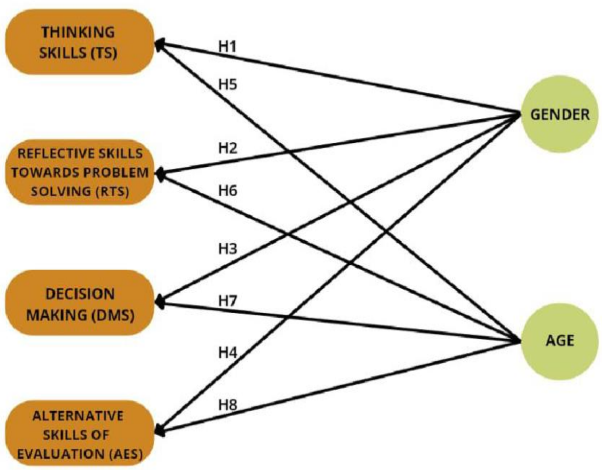

Fig. 1. REPRESENTS THE CONCEPTUAL MODEL FOR RESEARCHTop of Form

V. RESEARCH METHODOLOGY

In this study, the authors have tried to identify the MTS that influences the students of engineering and the healthcare domain. For the study, the following skills were included, thinking skills (TS), reflective thinking skills (RTS) intended for problem-solving, decision-making skills (DMS), and alternative evaluation skills (AES).

A. Research Design

A comparative research design was employed to investigate the differences in metacognitive thinking skills across gender and age. This design facilitated the examination of variations in metacognitive thinking skills among different groups, allowing for meaningful comparisons and insights.

B. Research Instrument:

A self-report measure was utilized to assess metacognitive thinking skills. This instrument served as a reliable and valid tool for capturing individuals' self-perceived levels of metacognitive thinking abilities. By employing a self-report measure, participants were able to reflect on their metacognitive processes and provide valuable insights into their cognitive strategies. The questionnaire used in this study consisted of the following constructs:

Total Score (TS), Reflective Thinking Skills (RTS), Decision-Making Skills (DMS), Alternative Evaluation Skills (AES), and demographics. The questionnaire used for the study was developed by Murat Tuncer and Feyzi Kaysi and contains 18 items. Its well-established psychometric properties provided a robust assessment of metacognitive thinking skills among engineering students.

C. Sampling Method:

Nonprobability convenience sampling was employed to select participants for this study.

D. Sample Size and Unit:

The study recruited a sample of 270 engineering students from private universities in the Delhi NCR region. This sample size was determined based on the suitability of the chosen research instrument and the available resources. The inclusion of engineering students from private universities in Delhi NCR provided a specific and focused context for investigating metacognitive thinking skills within this academic domain.

The data collection was done in different institutions located in Delhi NCR. As for the demand of the study institutes focusing on courses belonging to engineering students were included in the study. After the completion of the pilot study, the data was evaluated, and Cronbach's alpha was obtained at 0.891 which falls under the acceptable value. The questionnaire was designed as a Likert scale covering the personalized state of the subject covering from their opinion on a five-point scale starting from strongly disagree to strongly agree.

VI. DATA ANALYSIS

The data was analyzed by the researcher using the standard statistical package namely IBM SPSS 26 and Smart PLS 4. All the data was collected, organized and then properly tabulated for the study.

TABLE I
RELIABILITY ANALYSIS

Reliability Statistics

Cronbach's Alpha	N of Items
.891	21

The Cronbach's alpha was calculated to see the reliability of the questionnaire. The Cronbach's alpha was found to be 0.891, which falls under the acceptable category. Therefore, the questionnaire was taken for the further purpose of the study.

TABLE II
RESPONDENT FREQUENCY TABLE (GENDER)

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	134	49.6	49.6	49.6
	Females	136	50.4	50.4	100.0
	Total	270	100.0	100.0	

TABLE II provides information on the gender distribution among the respondents. The table shows that out of the total sample of 270 respondents, 134 (49.6%) identified as male, while 136 (50.4%) identified as female. The analysis of the gender distribution reveals a relatively balanced representation, with a slight majority of female respondents. This suggests that the sample adequately captures the perspectives and experiences of both male and female individuals.

The interpretation of the data suggests that the study's findings can be generalized to both genders within the target population. The relatively equal representation of males and females strengthens the validity and reliability of the study's conclusions. It accounts for potential gender-related differences in the observed variables and their relationships.

TABLE III
RESPONDENT FREQUENCY TABLE (AGE WISE)

Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	17- 21 years	136	50.4	50.4	50.4
	22 - 26 years	134	49.6	49.6	100.0
	Total	270	100.0	100.0	

TABLE III provides information on the age distribution among the respondents. The table shows that out of the total sample of 270 respondents, 136 (50.4%) were aged between 17 and 21 years, while 134 (49.6%) were aged between 22 and 26 years. The analysis of the age distribution reveals a relatively balanced representation across the two age groups. This indicates that the sample includes a diverse range of participants from different stages of early adulthood.

The interpretation of the data suggests that the study's findings can be generalized to individuals within the age range of 17 to 26 years. This age distribution allows for an exploration of potential age-related differences in the observed variables and their relationships, as well as an examination of developmental aspects within this particular stage of early adulthood.

TABLE IV
RESPONDENT EDUCATION LEVEL

Education Level					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under Graduate	135	50.0	50.0	50.0
	Post Graduate	135	50.0	50.0	100.0
	Total	270	100.0	100.0	

TABLE IV provides information on the education level of the participants. The table shows that out of the total sample of 270 respondents, 135 (50.0%) were undergraduate students, while the remaining 135 (50.0%) were postgraduate students.

The analysis of the education level distribution indicates an equal representation of participants from both undergraduate and postgraduate backgrounds. This suggests that the study includes a balanced sample in terms of educational attainment, encompassing individuals at different stages of their academic journey.

MODEL MEASUREMENT

TABLE V
DIMENSIONS, FACTOR LOADINGS, RELIABILITY AND AVE

Dimensions and items	Factor Loading	Cronbach's Alpha	Average Extracted (AVE)	Composite Reliability (CR)
Thinking skills (TS)		0.791	0.536	0.851
TS 1	0.719			
TS 2	0.809			
TS 3	0.727			
TS 4	0.614			
TS 5	0.778			
Reflective skills towards problem-solving (RTS)		0.813	0.569	0.868
RTS 1	0.793			
RTS 2	0.668			
RTS 3	0.782			
RTS 4	0.807			
RTS 5	0.711			
Decision making (DMS)		0.855	0.696	0.902
DMS 1	0.820			
DMS 2	0.853			
DMS 3	0.830			
DMS 4	0.835			
Alternative skills of evaluation (AES)		0.802	0.618	0.866
AES 1	0.842			

AES 2	0.748
AES 3	0.822
AES 4	0.726

The above TABLE V provides valuable insights into the "Metacognitive Thinking Skills Scale" developed by (Tuncer & Kaysi) 2013, Each dimension, namely Thinking skills, Reflective skills towards problem-solving, Decision making, and Alternative skills of evaluation, exhibits strong associations between the items and their respective factors, as indicated by the high factor loadings. All the factor loadings were above the acceptable level of 0.5. This suggests that the items effectively capture the intended constructs. The dimensions also demonstrate acceptable internal consistency reliability. Cronbach's alpha values range from 0.791 to 0.855, indicating consistent measurement within each dimension.

Additionally, the high average extracted variance (AVE) values support the construct validity of the scale, indicating that a substantial proportion of the variance in the items is explained by their respective factors. The CR values further strengthen the assessment of reliability. With Composite reliability (CR) values ranging from 0.851 to 0.902, all dimensions surpass the commonly accepted threshold of 0.7, indicating good internal consistency and reliability. This implies that the "Metacognitive Thinking Skills Scale" is a reliable tool for measuring metacognitive thinking skills across the assessed dimensions.

TABLE VI
DISCRIMINANT VALIDITY USING HTMT

	AES	AGE	DMS	GENDER	RTS	TS
AES						
AGE	0.168					
DMS	0.703	0.176				
GENDER	0.074	0.022	0.049			
RTS	0.881	0.270	0.670	0.034		
TS	0.876	0.276	0.622	0.047	0.423	

Discriminant validity is a measure of the distinctiveness of each latent variable and indicates the extent to which variables measure different constructs. It is assessed by examining the correlations between variables and ensuring that they are lower than the square roots of the average extracted variances (AVE) of each variable.

In TABLE VI, the diagonal values represent the square roots of the AVE for each variable. These values are highlighted in bold. The off-diagonal values represent the correlations between the latent variables.

Looking at the correlations between the latent variables, it is observed that the correlations between each variable and others are generally lower than the square roots of their respective AVEs. This indicates discriminant validity, suggesting that the latent variables (AES, Age, DMS, Gender, RTS, TS) measure distinct constructs within the context of engineering.

Overall, the tables indicate that the latent variables (AES,

Age, DMS, Gender, RTS, TS) within the engineering domain

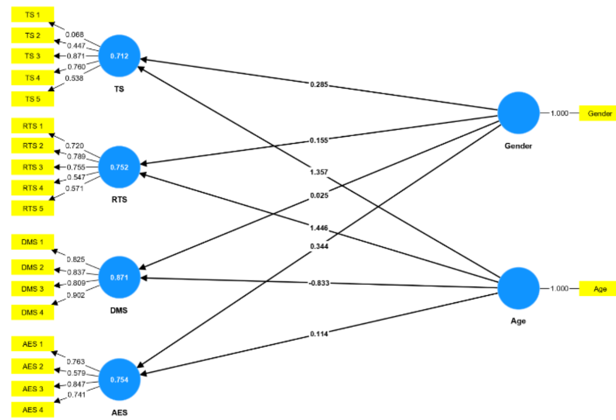

Fig. 2. STRUCTURAL MODEL (COMPLETE)

exhibit discriminant validity, suggesting that they measure distinct constructs. This supports the reliability and distinctiveness of each latent variable in the measurement model.

The complete MCTS model in Fig. 1. was created and evaluated through Smart PLS 4. The path coefficients and p-values in the model describe the relationships between the observed variables (Age, Gender) and the latent variables (AES, DMS, TS, RTS) within the context of engineering students.

The analysis of age and meta-cognitive constructs among engineering students reveals several significant findings. Firstly, a positive and statistically significant relationship is observed between age and alternative skills of evaluation (AES: 0.322, p = 0.006). This indicates that as engineering students' age increases, they tend to develop and enhance their ability to critically analyse different options and alternatives, which is crucial in the engineering domain. Additionally, a positive relationship is found between age and decision-making skills (DMS: 0.328, p = 0.004), suggesting that as students grow older, their decision-making abilities in the engineering domain improve. This is essential for making informed choices in technical and practical scenarios. Moreover, a strong positive relationship is identified between age and thinking skills (TS: 0.537, p = 0.000), highlighting the positive impact of age on critical thinking, analytical abilities, and the application of theoretical knowledge to real-world situations. Furthermore, age is found to significantly influence reflective skills towards problem-solving (RTS: 0.510, p = 0.000), indicating that as engineering students age, their ability to engage in reflective thinking and effectively address complex engineering challenges strengthens.

In contrast, the analysis of gender and cognitive constructs shows different results. Gender does not significantly predict alternative skills of evaluation (AES: 0.107, p = 0.493), indicating that gender does not play a substantial role in determining these skills among engineering students. However, a positive and statistically significant relationship is found between gender and decision-making skills (DMS: 0.098, p = 0.005), suggesting a slight influence of gender on this aspect. The effect size, however, is relatively small. Gender does not significantly predict thinking skills (TS: -0.059, p = 0.650) or reflective skills towards problem-solving (RTS: -0.032, p = 0.797) among engineering students in the given domain. These findings indicate that gender does not have a significant impact on these cognitive constructs.

Analysis of the constructs

The model also presents the T statistics and associated p-values for the relationships between the latent variables (TS, RTS, DMS, AES) and their corresponding indicators. These results are derived from an analysis conducted on a sample of engineering students within the domain of alternative skills assessment.

The T statistics for all five indicators of thinking skills (TS 1-5) about the latent variable TS demonstrate highly significant values, ranging from 6.729 to 19.459, with p-values of 0. These findings indicate a robust and significant relationship between the observed variables and the latent variable of thinking skills. It can be inferred that the indicators effectively capture the various facets of thinking skills in the context of the engineering domain.

Similarly, the T statistics for the relationships between the reflective skills indicators (RTS 1-5) and the latent variable RTS are highly significant, ranging from 9.356 to 19.114, with p-values of 0. These results provide strong evidence of a significant association between the observed variables and the latent variable of reflective skills towards problem-solving. This suggests that the chosen indicators aptly represent the reflective abilities necessary for effective problem-solving in engineering contexts.

The T statistics for the relationships between the decision-making skills indicators (DMS 1-4) and the latent variable DMS also indicate a significant association. The T values range from 10.211 to 12.976, with p-values of 0, emphasizing the substantial relationship between the observed variables and the latent variable of decision-making. These results indicate that the selected indicators appropriately capture the diverse aspects of decision-making skills relevant to engineering students.

For the alternative skills of evaluation indicators (AES 1-4), the T statistics reveal significant relationships with the latent variable AES. The T values range from 5.078 to 7.576, with p-values of 0. These outcomes suggest a noteworthy association between the observed variables and the latent variable of alternative skills of evaluation. It can be inferred that the indicators effectively encompass the range of evaluation skills necessary for engineering students to explore and consider multiple alternatives.

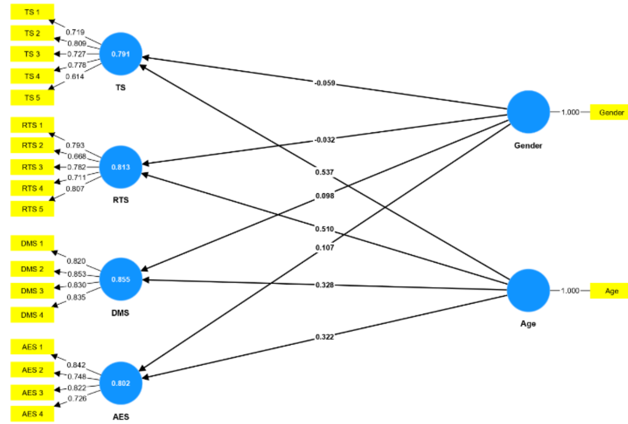

Fig. 3. STRUCTURAL MODEL (UG STUDENTS)

The analysis of relationships between latent variables and observed variables among UG students in the total sample of UG and PG students from private colleges in Delhi NCR provides valuable insights into skill development in the given domain.

Age emerges as a significant factor in shaping various skills. As UG students advance in age, their alternative evaluation skills show a slight improvement (0.114), indicating an increasing ability to employ alternative evaluation methods. Thinking skills exhibit a substantial positive influence (1.357), indicating enhanced critical thinking and analytical abilities as students grow older. Moreover, UG students' reflective skills towards problem-solving demonstrate a significant positive association (1.446), highlighting an increased capacity for engaging in reflective thinking to tackle complex problems. However, it is important to note that age has a substantial negative impact on decision-making skills (-0.833), indicating a decline in this particular area as students mature.

When considering gender, the analysis reveals weak and statistically non-significant relationships between gender and the skills under investigation. While a slight positive relationship between gender and alternative evaluation skills among UG students is observed (0.344), it does not reach statistical significance. Similarly, gender does not significantly influence decision-making abilities (0.025), thinking skills (0.285), or reflective skills towards problem-solving (0.155) among UG students. These results suggest that gender does not play a substantial role in shaping these skills within the given domain. The focus should be on other factors that may contribute to the development of these skills among UG students, independent of gender. Based on the path coefficient table, we analyzed the relationships between the latent variables (AES, DMS, TS, RTS) and the observed variables (Age, Gender) among PG students in the total sample of UG and PG students from private colleges in Delhi NCR. The findings reveal valuable insights into the development of various skills within the engineering domain.

In terms of age, significant positive relationships were observed. The path coefficient values indicate that as the age of PG students increases, their alternative evaluation skills (AES) show a moderate positive influence (0.59), decision-making abilities (DMS) display a relatively weaker impact (0.37), thinking skills (TS) exhibit a strong positive association (0.547), and reflective skills towards problem-solving (RTS) demonstrate a substantial positive influence (0.747). These results suggest that with increasing age, PG students in the engineering domain tend to develop improved abilities in alternative evaluation, decision-making, thinking, and reflective problem-solving skills.

On the other hand, gender was found to have a minimal impact on skill development among PG students in the given domain. The path coefficients indicate weak and non-significant relationships between gender and the latent variables. Specifically, gender does not significantly influence alternative evaluation skills (AES) or thinking skills (TS), as evidenced by path coefficient values of -0.053 and -0.241, respectively. Similarly, gender has a slight but non-significant effect on decision-making abilities (DMS) and reflective skills towards problem-solving (RTS), as indicated by path coefficients of 0.157 and -0.14, respectively. Therefore, it can be inferred that gender does not play a substantial role in the development of these skills among PG students in the engineering domain.

TABLE VII
DESCRIPTIVE STATISTICS OF THE VARIABLES

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
TS	270	1.00	5.00	3.8185	.69397
RTS	270	1.00	5.00	3.8830	.70279
DMS	270	1.00	5.00	4.0361	.82921
AES	270	1.00	5.00	3.8907	.78887
Valid N (listwise)	270				

The descriptive statistics in TABLE VII reveal important insights about the variables. The variable TS (thinking skills) has a mean of 3.8185 (SD = 0.69397), RTS (Reflective skills towards problem-solving) has a mean of 3.8830 (SD = 0.70279), DMS (Decision making) has a mean of 4.0361 (SD = 0.82921), and AES (Alternative skills of evaluation) has a mean of 3.8907 (SD = 0.78887). These values indicate that, on average, the participants demonstrate moderate to high levels of these cognitive constructs. The variability in the scores suggests individual differences among the participants. These descriptive statistics provide a foundation for further analysis and interpretation of the relationships between these variables and other factors within the study.

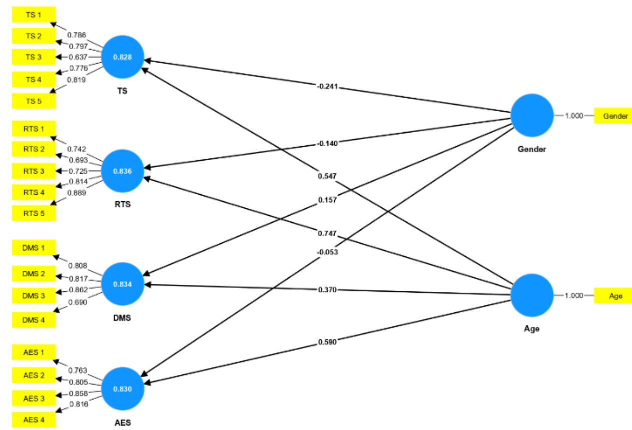

Fig. 4. STRUCTURAL MODEL (PG STUDENTS)

TABLE VIII
GENDER WISE DESCRIPTIVE STATISTICS FOR THE UNDER GRADUATE STUDENTS

Group Statistics						
	Gender	N	Mean	Std. Deviation	Std. Error Mean
TS	Male	67	3.9403	.66334	.08104
	Female	68	4.0206	.56372	.06836
RTS	Male	67	4.0299	.63842	.07800
	Female	68	4.0765	.55291	.06705
DMS	Male	67	4.1791	.81511	.09958
	Female	68	4.2500	.87032	.10554
AES	Male	67	4.2239	1.07055	.13079
	Female	68	4.2353	.93230	.11306

The descriptive statistics in TABLE VIII based on gender for undergraduate engineering students reveal interesting findings. In terms of thinking skills (TS), males (N=67) have a mean of 3.9403 (SD=0.66334) while females (N=68) have a slightly higher mean of 4.0206 (SD=0.56372). When it comes to reflective skills towards problem-solving (RTS), males have a mean of 4.0299 (SD=0.63842), and females have a slightly higher mean of 4.0765 (SD=0.55291). In terms of decision-making skills (DMS), males have a mean of 4.1791 (SD=0.81511), and females have a slightly higher mean of 4.2500 (SD=0.87032). Lastly, regarding alternative skills of evaluation (AES), males have a mean of 4.2239 (SD=1.07055), and females have a similar mean of 4.2353 (SD=0.93230).

These findings suggest that, in general, both males and females demonstrate high levels of these cognitive constructs. The small differences observed between genders indicate that there might be slight variations in the strengths of these skills, but overall, both genders display comparable levels of proficiency.

TABLE IX
GENDER WISE DESCRIPTIVE STATISTICS FOR THE POST GRADUATE STUDENTS

	Gender	N	Mean	Std. Deviation	Std. Error Mean
TS	Male	67	3.7343	.75989	.09284
	Female	68	3.5794	.70150	.08507
RTS	Male	67	3.7493	.79646	.09730
	Female	68	3.6765	.72814	.08830
DMS	Male	67	3.8806	1.13515	.13868
	Female	68	4.0000	1.07897	.13084
AES	Male	67	3.8358	1.03860	.12689
	Female	68	3.9853	1.05791	.12829

Analyzing the descriptive statistics in TABLE IX based on gender for postgraduate engineering students, we observe the following patterns. In terms of thinking skills (TS), males (N=67) have a mean of 3.7343 (SD=0.75989), while females (N=68) have a slightly lower mean of 3.5794 (SD=0.70150). For reflective skills towards problem-solving (RTS), males have a mean of 3.7493 (SD=0.79646), and females have a slightly lower mean of 3.6765 (SD=0.72814). Moving to decision-making skills (DMS), males have a mean of 3.8806 (SD=1.13515), and females have a slightly higher mean of 4.0000 (SD=1.07897). Finally, concerning alternative skills of evaluation (AES), males have a mean of 3.8358 (SD=1.03860), while females have a slightly higher mean of 3.9853 (SD=1.05791).

These findings suggest that both males and females exhibit competence in these cognitive constructs at the postgraduate level. While there are slight variations in the mean scores, indicating potential differences in the strengths of these skills between genders, overall, both genders demonstrate comparable levels of proficiency in these cognitive domains.

TABLE X
T TEST

One-Sample Test						
	Test Value = 2.5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
TSN	90.415	269	.000	3.81852	3.7354	3.9017
RSN	90.787	269	.000	3.88296	3.7988	3.9672
DMS	79.980	269	.000	4.03611	3.9368	4.1355
AES	81.042	269	.000	3.89074	3.7962	3.9853

The above findings in TABLE X show that all the variables will significantly affect the overall MCTS of the students.

Thinking Skills (TS): The one-sample t-test revealed a highly significant result ($t = 90.415$, $df = 269$, $p < 0.001$) for thinking skills. The mean difference was 3.81852 (95% CI: 3.7354 to 3.9017), indicating that the participants' mean scores for thinking skills significantly exceeded the test value of 2.5. This suggests that the sample population displayed a remarkable level of proficiency in critical thinking, analytical reasoning, and problem-solving abilities.

Reflective Skills towards Problem Solving (RTS): The one-sample t-test showed a highly significant result ($t = 90.787$, $df = 269$, $p < 0.001$) for reflective skills towards problem-solving. The mean difference was 3.88296 (95% CI: 3.7988 to 3.9672), indicating that the participants' mean scores for reflective skills significantly surpassed the test value of 2.5. This implies that the participants demonstrated strong abilities in critically analysing problems, identifying alternative solutions, and evaluating the effectiveness of different approaches.

Decision-Making Skills (DMS): The one-sample t-test yielded a highly significant result ($t = 79.980$, $df = 269$, $p < 0.001$) for decision-making skills. The mean difference was 4.03611 (95% CI: 3.9368 to 4.1355), indicating that the participants' mean scores for decision-making significantly exceeded the test value of 2.5. This suggests that the participants exhibited a high level of competence in assessing information, considering various factors, and making informed choices in technical and practical scenarios.

Alternative Skills of Evaluation (AES): The one-sample t-test showed a highly significant result ($t = 81.042$, $df = 269$, $p < 0.001$) for alternative skills of evaluation. The mean difference was 3.89074 (95% CI: 3.7962 to 3.9853), indicating that the participants' mean scores for alternative skills of evaluation significantly surpassed the test value of 2.5. This suggests that the participants possessed strong abilities in critically analysing different options and alternatives when solving complex problems or making decisions.

TABLE XI
HYPOTHESIS TESTING

		Path Coefficient	P-Value	Result
H_1	Gender -> TS	-0.059	0.650	Not Supported
H_2	Gender -> RTS	-0.032	0.797	Not Supported
H_3	Gender -> DMS	0.098	0.005	Supported
H_4	Gender -> AES	0.107	0.493	Not Supported
H_5	Age -> TS	0.537	0.000	Supported
H_6	Age -> RTS	0.510	0.000	Supported
H_7	Age -> DMS	0.328	0.004	Supported
H_8	Age -> AES	0.322	0.006	Supported

H_1: There is a relationship between gender and thinking skills (TS).

The path coefficient is -0.059, and the p-value is 0.650. The relationship between gender and thinking skills (TS) is not statistically significant ($p > 0.05$). Therefore, the hypothesis is not supported, indicating that there is no significant association between gender and TS.

H_2: There is a relationship between gender and reflective skills towards problem-solving (RTS).

The path coefficient is -0.032, and the p-value is 0.797. The relationship between gender and reflective skills towards problem-solving (RTS) is not statistically significant ($p > 0.05$). Hence, the hypothesis is not supported, suggesting that there is no significant association between gender and RTS.

H_3: There is a relationship between gender and decision-making skills (DMS).

The path coefficient is 0.098, and the p-value is 0.005. The relationship between gender and decision-making skills (DMS) is statistically significant ($p < 0.05$). Hence, the hypothesis is supported, suggesting that gender has a positive and significant impact on DMS. However, further analysis and exploration may be needed to understand the nature of this relationship.

H_4: There is a relationship between gender and alternative skills of evaluation (AES).

The path coefficient is 0.107, and the p-value is 0.493. The relationship between gender and alternative skills of evaluation (AES) is not statistically significant ($p > 0.05$). Therefore, the hypothesis is not supported, indicating that there is no significant association between gender and AES.

H_5: There is a relationship between age and thinking skills (TS).

The path coefficient is 0.537, and the p-value is 0.000. The relationship between age and thinking skills (TS) is highly statistically significant ($p < 0.001$). Therefore, the hypothesis is strongly supported, indicating that age has a positive and significant influence on TS. As individuals grow older, their thinking skills tend to enhance.

H_6: There is a relationship between age and reflective skills towards problem-solving (RTS).

The path coefficient is 0.510, and the p-value is 0.000. The relationship between age and reflective skills towards problem-solving (RTS) is highly statistically significant ($p < 0.001$). Thus, the hypothesis is strongly supported, suggesting that age has a positive and significant effect on RTS. As individuals age, their reflective skills towards problem-solving improve.

H_7: There is a relationship between age and decision-making skills (DMS).

The path coefficient is 0.328, and the p-value is 0.004. The relationship between age and decision-making skills (DMS) is statistically significant ($p < 0.05$). Thus, the hypothesis is supported, indicating that age has a positive and significant impact on DMS. As individuals age, their decision-making skills tend to improve.

H_8: There is a relationship between age and alternative skills of evaluation (AES).

The path coefficient is 0.322, and the p-value is 0.006. The relationship between age and alternative skills of evaluation (AES) is statistically significant ($p < 0.05$). Therefore, the hypothesis is supported, suggesting that age has a positive and significant effect on AES. As individuals grow older, their ability to employ alternative evaluation skills increases.

VII. MAJOR FINDINGS

- The study found a significant positive association between engineering students' age and the development of metacognitive skills. These skills include alternative skills of evaluation, decision-making, thinking skills, and reflective skills towards problem-solving. This highlights the importance of experience and maturity in enhancing these cognitive abilities within the engineering domain.
- Gender was found to have a limited influence on the development of metacognitive skills among engineering students. While there was a slight positive relationship between gender and decision-making skills, it was not statistically significant. This implies that gender does not play a substantial role in shaping these cognitive constructs within the given domain.
- The study demonstrated the reliability and validity of the "Metacognitive Thinking Skills Scale" developed by Tuncer and Kaysi (2013) for measuring metacognitive thinking skills in engineering. The scale showed strong factor loadings, acceptable internal consistency reliability (Cronbach's alpha), high average extracted variance (AVE), and composite reliability (CR), supporting its reliability and construct validity.
- Discriminant validity analysis using HTMT (Heterotrait-Monotrait ratio) confirmed that the latent variables (AES, Age, DMS, Gender, RTS, TS) in the study measured distinct constructs within the engineering domain. The correlations between the variables were generally lower than the square roots of their respective average extracted variances, indicating discriminant validity.
- The findings suggested that UG students' age positively influenced their alternative evaluation skills, thinking skills, and reflective skills towards problem-solving. However, there was a negative relationship between age and decision-making skills among UG students, indicating a decline in this area as students mature.
- Among PG students, age was found to have a significant positive impact on alternative evaluation skills, decision-making abilities, thinking skills, and reflective skills towards problem-solving. These results suggest that as PG students progress in their academic journey, they tend to develop and enhance their metacognitive skills within the engineering domain.
- The study provided evidence that the observed variables effectively captured the different facets of metacognitive thinking skills. The indicators for thinking skills, reflective skills towards problem-solving, decision-making skills, and alternative skills of evaluation demonstrated strong associations with their respective latent variables, indicating that they aptly represented the intended constructs.
- The results of the study contribute to the understanding of metacognitive skill development in the engineering domain and emphasize the importance of fostering these skills among students. The findings can be used to inform educational interventions and curriculum

design aimed at enhancing metacognitive thinking abilities, ultimately improving students' problem-solving, decision-making, and critical thinking skills in engineering.

VIII. DISCUSSION

The present study aimed to investigate the metacognitive thinking skills of engineering students and explore the potential influences of age and gender on these skills.

The findings revealed that the questionnaire used to assess metacognitive thinking skills exhibited good internal consistency. This indicates its reliability as a measurement tool within the engineering context. The sample included a balanced representation of male and female participants, reflecting the increasing gender diversity in engineering. Additionally, participants from two distinct age groups were included. This allowed for an examination of age-related differences in metacognitive thinking skills during different stages of engineering education.

The results of the structural model analysis indicated that age significantly influenced various metacognitive constructs. Older engineering students demonstrated higher levels of alternative skills of evaluation, decision-making, thinking skills, and reflective skills towards problem-solving. This suggests that metacognitive thinking skills tend to develop and improve with age and experience in the engineering field. However, gender had minimal impact on metacognitive thinking skills, highlighting the equitable potential for both male and female engineering students to develop these skills.

The study's results emphasize the importance of integrating metacognitive strategies and reflection throughout the engineering curriculum.

Educators and institutions should consider incorporating interventions and activities that promote metacognitive thinking skills at various stages of engineering education. This could involve explicit instruction on metacognitive strategies, such as self-monitoring and self-regulation techniques. Additionally, opportunities for students to engage in reflective practices, such as journaling or group discussions, should be provided. By cultivating metacognitive thinking skills early on and providing ongoing support, engineering students can become more proficient at planning, monitoring, and evaluating their learning and problem-solving processes. This, in turn, can lead to improved performance and success in the field.

Furthermore, the minimal influence of gender on metacognitive thinking skills suggests that efforts should focus on creating an inclusive and supportive learning environment. This environment should encourage the participation and engagement of all students. Educators should promote equitable opportunities for all students to develop metacognitive thinking skills. They can do so by fostering collaborative learning environments, providing diverse examples and perspectives, and addressing potential gender biases or stereotypes. By fostering such an environment, engineering programs can empower all students to develop and apply metacognitive strategies effectively, irrespective of their gender.

The study also revealed that older engineering students exhibited higher levels of alternative skills of evaluation, decision-making, thinking skills, and reflective skills towards problem-solving. This suggests that metacognitive thinking skills may develop and mature as students progress through their engineering education and gain more experience in the field. Therefore, educators should recognize the developmental nature of metacognitive thinking skills. They should design interventions that cater to the specific needs of students at different stages of their engineering education. Providing opportunities for experiential learning, internships, and real-world engineering projects can enhance metacognitive development. This is achieved by exposing students to complex problem-solving scenarios and promoting reflection on their experiences. As students progress in age and experience, they should be provided with opportunities for metacognitive reflection, self-assessment, and goal-setting.

Educators and institutions can incorporate regular metacognitive assessments, feedback mechanisms, and self-reflection exercises. These efforts foster continuous growth in metacognitive thinking skills among engineering students. By nurturing and reinforcing these skills throughout the education journey, students can develop a lifelong metacognitive mindset that extends beyond the classroom and positively influences their professional development as engineers.

IX. LIMITATIONS OF THE STUDY

- The research is restricted to checking the metacognitive skills of engineering of Delhi NCR only.
- The study employed a cross-sectional design, which restricts our ability to establish causal relationships.
- The study focused primarily on age and gender as potential influences on metacognitive thinking skills. While these factors were explored, other variables such as cultural background, educational context, or prior experiences were not considered.

CONCLUSION AND FUTURE SCOPE

This study explored the metacognitive thinking skills of engineering students and examined the potential influences of age and gender on these skills. The findings provide valuable insights into the assessment, development, and application of metacognitive thinking skills within the engineering domain.

The results demonstrated that the "Metacognitive Thinking Skills Scale" used in this study is a reliable and valid tool for assessing metacognitive thinking skills among engineering students. The scale exhibited good internal consistency and discriminant validity, supporting its utility for measuring metacognitive constructs within the engineering context.

Regarding the influence of age, the study revealed that metacognitive thinking skills tend to improve as engineering students progress through their education and gain more experience in the field. Older students exhibited higher levels of alternative skills of evaluation, decision-making, thinking skills, and reflective skills towards problem-solving. These findings emphasize the importance of recognizing the developmental nature of metacognitive thinking skills. They also highlight the need to integrate targeted interventions at different stages of engineering education to promote metacognitive growth.

On the other hand, gender had minimal impact on metacognitive thinking skills within the engineering domain. This suggests that both male and female students possess similar potential for metacognitive development. However, it is crucial to create an inclusive and supportive learning environment. Such an environment should address potential gender biases and promote equitable opportunities for all students to develop metacognitive thinking skills.

The implications of this study highlight the significance of incorporating metacognitive strategies and reflective practices in the engineering curriculum. Educators should consider integrating interventions that promote metacognitive thinking skills early on and provide ongoing support throughout the education continuum. Additionally, creating opportunities for experiential learning and real-world problem-solving is essential. By nurturing and reinforcing metacognitive thinking skills, engineering students can enhance their ability to navigate complex tasks, improve their problem-solving abilities, and contribute effectively to the field.

In addition to the above, further research should explore additional factors that may influence the development and manifestation of metacognitive thinking skills within the engineering student population. Contextual factors, such as educational approaches, learning environments, and instructional strategies, should be investigated to identify potential facilitators or barriers to metacognitive thinking skills. Longitudinal studies tracking the metacognitive growth of engineering students over time could provide valuable insights into the long-term effects of metacognitive interventions. They could also shed light on the trajectories of metacognitive development throughout different stages of engineering education. Such research can inform the design and implementation of targeted interventions to enhance metacognitive thinking skills among engineering students.

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