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"The Effect of Sleep Timing on Metacognition and Sleep Quality of Adolescents"

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Abstract: The present investigation aimed to study the metacognitive skills and sleep quality among male and female adolescents. The total sample comprises 108 adolescents who are divided into 4 groups on the basis of sleeping timing (A & B) and gender (F & M). Group A represents the participants who sleeps before 11:00 pm and group B represents the participants who sleeps after 1:00 am. Various metacognitive skills are measured by using Metacognitive Awareness Inventory (MAI) and quality of sleep is measured by Sleep Quality scale (SQS). Descriptive statistics and 2x2 ANOVA is performed on the scores obtained. The results found on that females are high as compared to males on declarative knowledge, planning, conditional knowledge and debugging strategies. Group based results shows that group A is high as compared to group B on various meta-cognitive skills (declarative knowledge, procedural knowledge, conditional knowledge, planning, debugging strategies, evaluation), whereas group B is high on sleep quality as compared to group A. Furthermore, it is also observed that females of group A are high as compared to other groups on meta cognitive skills, but males of group B are high as compared to other groups on sleep quality. Therefore, it is concluded that those who sleep early have higher meta cognitive skills as compared to those who sleep late.

Keywords: Sleep quality, meta-cognitive skills, sleep timing, adolescents, descriptive statistics, analysis of variance.

I. INTRODUCTION

Sleep*:* Sleep is a unique aspect of consciousness which constitutes behaviors such as laying down, closing of the eyelids, resting and being relatively unaware of the environment. It is a biological process which is regulated by circadian rhythms. Circadian rhythms are a kind of 24-hour biological clock dependent on the cyclic process of day and night (Vitaterna et al., 2001). Sleep consists of various stages. Hasan, Y. M. et.al., (2015) divided stages of sleep into two parts i.e NREM-Non-Rapid Eye Movement and REM-Rapid Eye Movement. Approximately 70% of sleep occurs during NREM-Non-Rapid Eye Movement, which has five stages.

In Stage 1, NREM, also known as light sleep, individuals experience drowsiness and can be easily awakened. This stage, which makes up 5–10% of the entire sleep cycle, is characterized by a gradual slowing of eyes and muscle movements and a transition from alpha (α) waves, with ranging from 4 to 7 Hz for theta (θ) waves to 8 to 13 Hz for theta waves. In this stage, people may experience fleeting visual images or sensations. Stage 2 NREM involves a deeper sleep where the eyes remain closed, and brain wave activity slows further. This stage constitutes 45 to 55% of total sleep and is marked by theta waves and sleep spindles (12 to 14 Hz). Muscle activity decreases, and awareness of the external environment diminishes. In Stage 3 NREM, brain activity continues to slow, and muscle activity is minimal. This stage represents a transition to deeper sleep. Stage 4 NREM, often referred to as deep sleep, involves the production of delta waves, which are slow-frequency brain waves which accounts for 15–25% of all sleep, is characterized by deep relaxation and is difficult to awaken from. The body's organs and muscles are fully relaxed. Stage 5 NREM, observed mainly in the morning, is a transitional phase where an individual is somewhat aware of their surroundings but remains asleep. This stage accounts for around 1% of total sleep time. REM sleep, It makes up 20–25%

of all sleep which is characterized by rapid eye movements, elevated heart rate, and increased blood pressure. During REM sleep, the body experiences temporary paralysis of limb muscles to prevent self-injury due to vivid dreams. REM sleep is not subdivided into stages but is often categorized into tonic and phasic components and a complete sleep cycle lasts approximately 90 minutes

Sleep quality refers to the extent of rest-fulfillment after sleeping. Poor sleep quality can result in repercussions such as inattention, lack of focus, sleepiness, dizziness, etc. It can have various factors like sleeping late. Perceived stress appears to be a major factor in low sleep quality among students (Ahrberg et al., 2012). Sleep quality is a crucial determinant of overall well-being and cognitive functioning. Previous studies have demonstrated that inadequate sleep quality can lead to reduced attention, memory deficits, and diminished executive functions (Hsu & Chang, 2022). Furthermore, sleep quality is essential for the effective consolidation of memory and cognitive skills, with research indicating that disruptions in sleep can impair learning and information processing (Zhou et al., 2023).

Metacognition: John Flavell (1979) established the idea of metacognition, which he defined as people's awareness and knowledge of their own cognitive processes. He described metacognition as *"knowledge and cognition about cognitive phenomena,"* emphasizing learners' understanding of their own thinking. Metacognitive awareness is the state of being aware, understanding and controlling one's own cognitions, including thinking. It consists of knowledge, experiences, (Flavell, 1979) and regulation of metacognition. According to Schraw and Dennison (1994) there are 2 elements of metacognitive awareness i.e. knowledge about cognition and regulation of cognition. Knowledge about cognition involves being conscious about one's thinking patterns and fallacies. It consists of three aspects of knowledge- declarative, procedural and conditional knowledge (Young & Fry, 2008). Declarative knowledge (DK) means to be conscious about the factual knowledge acquired through learning and experiences, procedural knowledge (PK) is the knowledge utilized in performing tasks; skill-based knowledge and Conditional knowledge (CK) is a more practical knowledge which constitutes the situational awareness of applying any specific knowledge. Metacognitive experiences are conscious events which take place alongside cognitive or affective processes. They may or may not contain and involve the use of metacognitive knowledge (Flavell, 1979). Regulation of cognition is also a part of metacognition. It involves the executive processes involved in cognitive control. It mainly comprises five skills- planning, information management strategies, comprehension monitoring, debugging strategies and evaluation. Planning (PL) refers to finding the best possible cognitive strategies for optimum performance, information management strategies (IMS) refers to the methods and techniques (such as organising, elaborating, summarising, and selective focussing) utilised to process information more quickly, comprehension monitoring (CM) refers to evaluation of one's knowledge or application of a strategy, debugging strategies (DS) refers to fix errors in understanding and performance and lastly, evaluation (EV) which means the evaluation of performance and the effectiveness of strategies following a learning experience.

II. LITERATURE REVIEW:

Zhou, Liu, and Wang (2023) conducted a longitudinal study published in the *Journal of Sleep Research* to examine the effects of sleep quality on metacognitive abilities in adolescents. The research focused on how fluctuations in sleep quality over time influence various metacognitive skills, including planning and comprehension monitoring. Their findings indicate that adolescents experiencing poor sleep quality tend to have lower levels of metacognitive awareness and regulation. Specifically, these individuals show diminished capabilities in planning and monitoring their comprehension processes. This study underscores the crucial role that sleep quality acts in the development and maintenance of effective metacognitive skills during adolescence.

Bowers and Wang (2023), in their article published in *Sleep Medicine Reviews*, explore the relationship between sleep duration, sleep quality, and metacognitive monitoring and control among young adults. Their study reveals that both insufficient sleep and poor sleep quality have detrimental effects on metacognitive skills, particularly in areas such as self-monitoring and the application of cognitive strategies. The researchers found that reduced sleep duration and lower quality of sleep impair individuals' ability to effectively monitor their own cognitive processes and utilize appropriate strategies, highlighting the critical role of adequate and high-quality sleep in maintaining robust metacognitive functions.

Hsu and Chang (2022) investigated the impact of sleep quality on metacognitive strategies in college students, as detailed in their study published in *Educational Psychology*. Their research indicates that better sleep quality is associated with more effective use of metacognitive strategies, including planning and self-evaluation. The findings suggest that students who experience higher sleep quality are better able to engage

in strategic thinking and self-regulation, which enhances their overall academic performance and learning processes. This underscores the importance of maintaining good sleep habits to optimize cognitive and metacognitive functioning in academic settings.

Johnson and Smith (2022) explored the relationship between sleep and metacognitive functioning across various age groups in their study published in *Developmental Psychology*. Their research highlights that sleep significantly influences metacognitive skills across all age groups, from children to adults. However, the impact of sleep on metacognitive functioning is found to be more pronounced in younger individuals. The study suggests that disruptions in sleep can impair metacognitive abilities more substantially in children and adolescents compared to adults, emphasizing the critical role of sleep in the developmental trajectory of metacognitive skills. This underscores the importance of promoting good sleep hygiene, especially in younger populations, to support optimal cognitive and metacognitive development.

Significance of the study: By examining the impact of gender on the relationship between sleep quality and metacognitive skills, the study provides insights into how male and female adolescents might differently experience and manage these factors. Understanding these gender-based differences can inform more tailored and effective interventions to address the unique needs of each gender, potentially improving educational and developmental outcomes for both groups. This study contributes to the current research landscape by specifically examining the relationship between gender, sleep quality, and metacognitive skills. It fills a gap in the literature by providing empirical evidence on how these variables interact in adolescents, thereby contributing valuable knowledge to the fields of developmental psychology, education, and sleep research. The insights from this study can guide future research directions by highlighting areas where further investigation is needed. It provides actionable insights that can inform educational practices, enhance adolescent well-being, and contribute to the scholarly discourse on these important topics.

III. OBJECTIVES OF THE STUDY:

In the above context, the principal objectives of the present study are:

1. To examine the difference on various meta-cognitive skills on the basis of gender among adolescents.
2. To examine the difference on various meta-cognitive skills on the basis of sleeping time among adolescents.
3. To examine the difference on various meta-cognitive skills and sleep quality in all groups.

IV. HYPOTHESES:

H. 1. There exists a difference among adolescents in meta cognitive skills on the basis of gender.
H. 2. There exists a difference among adolescents in meta cognitive skills on the basis of sleeping time.
H. 3. There exists a difference among adolescents in sleep quality on the basis of gender.
H. 4. There exists a difference among adolescents in sleep quality on the basis of sleeping time.
H. 5. There exist differences among all the groups of adolescents on meta cognitive skills and sleep quality.

V. RESEARCH METHODOLOGY:

4.1.Sample: For the present investigation, 108 adolescents from various institutions from Chandigarh and Mohali were participated. The sample was divided into 4 groups based on gender (males 'M' & females 'F') and sleeping time (A & B). Group 'A' consists of respondents who go to bed before 11:00 pm, while Group 'B' includes those who sleep after 1:00 am. The age of the participants ranged between 16-19 years. The selected sample belonged to middle to higher socio-economic strata. Data was collected through purposive sampling and informed consent was obtained from all subjects involved in the study.

4.2.Instruments: Along with the demographics (*age, gender, parents' income, sleeping time etc.*), the meta cognitive skills were measured by using *'Metacognitive Awareness Inventory (MAI)*' developed by Schraw and Dennison (1994). The inventory has 52 items which measure two dimensions: 1. "Knowledge about Cognition" viz. *Declarative knowledge-DK, Procedural knowledge-PK, Conditional knowledge-CK*. 2. "Regulation of Cognition" viz. *Planning-PL, Information management strategies-IMS, Comprehension monitoring- CM, Debugging strategies-DS, Evaluation-EV*. The dimension scores are calculated by adding the scores on questions related to each of the factors. Higher scores correspond to greater metacognitive knowledge and greater metacognitive regulation. In addition to the knowledge of cognition score and the regulation of cognition score a MAI total score is derived by summing responses to all 52 questions. The Cronbach's alpha (internal consistency) of the scale is 0.90. The 'Sleep Quality Scale (SQS)' developed by Chol Shin et al., (2006) was used to measure quality of sleep among adolescents. The scale has 28 items and responses were collected by using a 4-point Likert-type scale

(*3=almost always, 2=often, 1=sometimes, 0=few*) for each item. An internal consistency of the scale is .92, with a test-retest reliability of .81. Total scores range from 0 to 84, with higher scores demoting more acute sleep problems.

4.3.Inclusion Criteria: The study included adolescents aged 16 to 19 years, with both male and female participants. Participants were categorized into two sleep groups based on their sleep timing: Group A, consisting of adolescents who sleep before 11:00 pm, and Group B, consisting of adolescents who sleep after 1:00 am. To ensure sample uniformity, only adolescents from middle to higher socio-economic backgrounds were included. Additionally, all participants provided informed consent to take part in the study.

4.4.Exclusion Criteria: Adolescents under 16 years of age or over 19 years of age were excluded from the study. Additionally, participants who did not have consistent sleep patterns, meaning those who did not fall into either Group A or Group B, were excluded. Those who were diagnosed with sleep disorders, such as insomnia or sleep apnea, were excluded to avoid potential confounding effects on sleep quality. Additionally, those with documented learning disabilities or cognitive impairments that might affect their ability to complete the questionnaires were also excluded. Participants who had difficulty understanding or completing the questionnaires due to language barriers or other reasons were excluded. Lastly, adolescents who did not provide informed consent to participate were excluded from the study.

4.5.Statistical analysis: After obtaining the responses, raw scores were scored by scoring instructions given in respective manuals. The obtained scores were analysed using descriptive statistics, 2x2 ANOVA and Tukey's HSD conducted to identify which specific groups differ from each other in terms of metacognitive skills and sleep quality.

VI. RESULTS:

To meet the research objectives of the present investigation, the obtained data were processed to describe statistics viz. Mean, SD, Kurtosis and Skewness. Kurtosis and skewness were computed to verify the normality of the data and it was found to be normal as the range of skewness and kurtosis lie between -2 to +2 (George & Mallery, 2019). A parametric test was proceeded further. The results i.e. 2x2 analysis of variance (ANOVA) were emerged into main (*Gender M-F, Sleeping Time A-B*) and interaction effects (*Gender*Sleeping Time F_A, M_A, F_B, M_B*). The tests of between subjects effects showed in Table 1 and post-hoc results are showed in Table 2.

VI.1. Gender: The results (Table 1) shows that there exist significant gender differences in meta-cognitive skills i.e. Declarative knowledge-DK {F(1,107)=8.39,p<0.01}, Planning-PL {F(1,107)=5.07,p<0.02}, Comprehension monitoring-CM {F(1,107)=8.58,p<0.01} and Debugging strategies-DS {F(1,107)=3.46, p<0.05}. Pairwise comparison shows that females are high *on Declarative knowledge-DK* {MD (I-J)=1.02,p≤0.01}, *Planning-PL* {MD(I-J) =0.73,p≤0.02}, *Comprehension monitoring-CM* {MD(I-J)=0.88,p≤0.01} and *Debugging strategies-DS* {MD(I-J)=0.41,p≤0.05} as compared to males.

TABLE-1: Tests of Between-Subjects Effects (Main effect: Gender)

DV	Type III SS	df	MS	F	(I)	(J)	MD (I-J)
DK	28.69	1	28.69	8.39**	F	M	1.02**
PL	14.83	1	14.83	5.07*	F	M	.73*
CM	21.44	1	21.44	8.58**	F	M	.88**
DS	4.51	1	4.51	3.46*	F	M	.41*

VI.2. Sleeping time: The results (Table-2) of between-subjects effects showed that there exist significant difference on the basis of sleeping time in meta-cognitive skills i.e. Declarative knowledge-DK {F(1,107)=8.09,p<0.01}, Procedural knowledge-PK {F(1,107)=6.61,p<0.01}, Conditional knowledge-CK {F(1,107)=6.53,p<0.01}, Planning-PL {F(1,107)=4.65,p<0.03}, Debugging strategies-DS {F(1,107)= 8.67, p<0.01}, Evaluation-EV{F(1,107)=4.41,p<0.03} and Sleep quality-SQ {F(1,107)=7.51,p<0.01}. Pairwise comparison shows that 'Group A' of sleeping time is high on *Declarative knowledge-DK* {MD(I-J)=1.01,p≤0.01}, *Procedural knowledge-PK* {MD(I-J)=0.54,p≤0.01}, *Conditional knowledge-CK* {MD(I-J)=0.56, p≤0.01}, *Planning-PL* {MD(I-J)=0.71,p≤0.03}, *Debugging strategies-DS* {MD(I-

J)=0.64,p≤0.01}, Evaluation-EV {MD(I-J)=0.56,p≤0.03} and 'Group B' is found be high on *Sleep quality-SQ* {MD(I-J)=0.5.13,p≤0.01}.

TABLE-2: Tests of Between-Subjects Effects (Main effect: Sleeping time & Tukey's HSD)

DV	Type III SS	df	MS	F	(I)	(J)	MD (I-J)
DK	27.65	1	27.65	8.09**	A	B	1.01**
PK	8.13	1	8.13	6.61*	A	B	.54*
CK	8.83	1	8.83	6.53*	A	B	.56*
PL	13.59	1	13.59	4.65*	A	B	.71*
DS	11.29	1	11.29	8.67**	A	B	.64**
EV	8.91	1	8.91	4.41*	A	B	.56*
SQ	725.1	1	725.1	7.51**	B	A	5.13**

VI.3. Gender*Sleeping time: The results (Table-3) of between-subjects effects showed that there exist significant difference on the basis of sleeping time in meta-cognitive skills i.e. Declarative knowledge-DK {F(3,104)=5.81,p<0.01}, Procedural knowledge-PK {F(3,104)=3.77,p<0.01}, Conditional knowledge-CK {F(3,104)=3.37,p<0.01}, Planning-PL {F(3,104)=3.45,p<0.03}, Comprehension monitoring-CM {F(3,104)=3.91,p<0.05}, Debugging strategies-DS {F(3,104)=4.24,p<0.01}, Evaluation-EV{F(3,104)=2.74,p<0.03} and Sleep quality-SQ {F(3,104)=4.02,p<0.01}.

TABLE-3: Tests of Between-Subjects Effects (Interaction effect: Gender*Sleeping time & Tukey's HSD)

DV	Type III SS	df	MS	F	DV	(I)	(J)	MD(I-J)	DV	(I)	(J)	MD(I-J)
DK	59.62	3	19.87	5.81**	DK	F_A	M_B	2.02**	PL	F_A	M_B	1.43*
PK	13.93	3	4.64	3.77*		F_B	M_B	1.31**		F_B	M_B	.96*
CK	13.68	3	4.56	3.37*		M_A	M_B	1.28**		M_A	M_B	.92*
PL	30.28	3	10.09	3.45*	PK	F_A	M_B	.79*	CM	F_A	M_B	1.31*
CM	29.26	3	9.75	3.91*		F_B	M_B	.65*		F_B	M_B	1.21*
DS	16.57	3	5.52	4.24**		M_A	M_B	.94*	DS	F_A	F_B	.66**
EV	16.59	3	5.53	2.74*	CK	F_A	M_B	.85*			M_B	1.04**
SQ	1164.94	3	388.31	4.02**		M_A	M_B	.88*	EV	F_A	M_B	1.01*
										M_A	M_B	.88
									SQ	M_B	F_A	8.13**
											F_B	5.73**
											M_A	7.87**

Abbreviations: DV, *Declarative knowledge-DK, Procedural knowledge-PK, Conditional knowledge-CK, Planning-PL, Information management strategies-IMS, Comprehension monitoring- CM, Debugging strategies-DS, Evaluation-EV, SQ-Sleep Quality, df-Degree of freedom, F-F Ratio, MD-Mean difference*

Post hoc results shows that on *Declarative knowledge-DK*, females of 'Group A' {MD(I-J)=2.02,p≤0.01} & 'Group B' {MD(I-J)=1.31,p≤0.01} and males of 'Group A' {MD(I-J)=1.28,p≤0.01} significantly high as compared to males of 'Group B'; on *Procedural knowledge-PK*, females of 'Group A' {MD(I-J)=0.79,p≤0.01} & 'Group B' {MD(I-J)=0.65,p≤0.01} and males of 'Group A' {MD(I-J)=0.94,p≤0.01} are significantly high as compared to males of 'Group B'; on *Conditional knowledge-CK*, females {MD(I-J)=0.85,p≤0.01} and males {MD(I-J)=0.88,p≤0.01} of 'Group A' are significantly high as compared to males of 'Group B'; on *Planning-PL*, females of 'Group A' {MD(I-J)=1.43,p≤0.01} & 'Group B' {MD(I-J)=0.96,p≤0.01} and males of 'Group A'{MD(I-J)=0.92,p≤0.01} are significantly high as compared to males of 'Group B'; on *Debugging strategies-DS*, females of 'Group A' are significantly high as compared to males {MD(I-J)=0.66,p≤0.01} and females of 'Group B' {MD(I-J)=1.04,p≤0.01}; on *Evaluation-EV*, females {MD(I-J)=1.01,p≤0.01} and males {MD(I-J)=0.88,p≤0.01} of 'Group A' are significantly high as compared to males of 'Group B'; on *Sleep quality-SQ*, males of 'Group B' are significantly high as compared to females of 'Group A' {MD(I-J)=8.13,p≤0.01}, 'Group B' {MD(I-J)=5.73, p≤0.01} and males of 'Group A' {MD(I-J)=7.87,p≤0.01}.

VII. DISCUSSION: The current study examined the difference between gender and sleeping time on various meta-cognitive skills and sleep quality. 108 adolescents participated in the study. The sample was drawn from various institutions from Chandigarh and Mohali. The sample was divided into 4 groups based on gender (M & F) and sleeping time (A & B). Respondents of group A are those who sleep before 11:00 pm and group B are those who sleep after 1:00 am. The age range of the participants ranged between 16-19 years. The selected sample belonged to middle to higher socio-economic strata. Along with the demographics (*age, gender, parents' income, sleeping time etc.*), the meta cognitive skills were measured by using 'Metacognitive Awareness Inventory (MAI)' developed by Schraw and Dennison (1994) and the quality of sleep is measured by 'Sleep Quality Scale (SQS)' developed by Chol Shin et al., (2006) was

used. Statistical technique 2x2 ANOVA was used to find out the gender differences among males and females on various variables of the study.

The results demonstrated significant main effects for both gender and sleeping time, as well as notable interaction effects. The analysis revealed that gender significantly influences meta-cognitive skills, with females outperforming males in declarative knowledge (DK), planning (PL), comprehension monitoring (CM), and debugging strategies (DS). These results are consistent with previous research highlighting gender differences in cognitive and meta-cognitive processes. For instance, a study by Dewitte et al., (2008) suggested that females often excel in certain cognitive tasks, particularly in verbal and memory-related areas. Additionally, studies have shown that females also often excel in organizational and planning tasks, which align with our findings on planning skills whereas, males are proficient in certain cognitive domains, especially in spatial tasks (Halpern, 2000). The present study's findings suggest that while males may excel in different areas, females show greater proficiency in tasks related to meta-cognitive skills. This can be linked to gender differences in educational experiences and socialization patterns, which often emphasize verbal and organizational skills for females (Hyde, 2005).

The study found that sleeping time significantly affects meta-cognitive skills, with Group A (presumably a longer or more optimal sleeping time) performing better in declarative knowledge-DK, procedural knowledge-PK, conditional knowledge-CK, planning-PL, debugging strategies-DS, and evaluation-EV. Conversely, Group B, likely characterized by shorter or less optimal sleeping time, exhibited lower performance on these measures but higher scores on sleep quality. Previous research has consistently highlighted the importance of adequate sleep for cognitive functions such as memory, problem-solving, and executive functions. For instance, Walker (2017) illustrated that sleep plays a vital role in enhancing declarative memory consolidation and overall cognitive performance.

The interaction effects showed that sleep timing and gender together have a significant impact on metacognitive abilities. Group comparisons showed that males and females in Group A consistently performed better than their counterparts in Group B. This relationship shows that sleep quality and gender are associated variables influencing cognitive function. Previous research supports this interaction, indicating that sleep quality can influence cognitive performance differently across genders. For example, Beebe (2011) found that sleep deprivation affects cognitive functions in ways that may vary between males and females, potentially explaining the differential impact observed in this study. The interaction results in our study highlight the complexity of how these variables interplay and affect meta-cognitive skills.

VII.1. Limitations: No study is without limitations, especially when examining human behavior, which is inherently dynamic. This study's small sample size is a major drawback that might limit how broadly the results can be applied. Additionally, the data was collected exclusively from an urban population, potentially limiting the applicability of the results to rural or diverse demographic groups. A few other drawbacks are the cross-sectional design, which prevents causal inferences, and the reliance on self-reported measurements, which can induce bias. Furthermore, factors such as cultural influences and socio-economic status, which can significantly impact behavior and outcomes, were not fully explored in this study. Future research should explore these relationships further on larger sample. Furthermore, longitudinal studies could also provide insights into how changes in sleep patterns over time affect cognitive development and performance across different genders.

VII.2. Conclusions: The present research investigated the impact of gender and sleeping time on meta-cognitive skills, revealing significant main effects for both factors and notable interaction effects. In practical terms, educators and clinicians should prioritize strategies that ensure adequate sleep for students/adolescents and consider gender differences in teaching methods to enhance meta-cognitive skills and overall cognitive performance. By enhancing our understanding of these dynamics, we can formulate more effective strategies to promote cognitive and academic success in various populations. The study's findings have practical implications for educational and psychological practices. For educators and clinicians, understanding that gender and sleep quality significantly impact meta-cognitive skills can inform tailored interventions to enhance cognitive and academic outcomes. Ensuring adequate sleep for students and considering gender differences in teaching strategies could optimize learning and performance.

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