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Effects of concept mapping strategies on learners' inhibitory control

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Abstract: *This study investigated the impact of concept mapping (CM) on inhibitory control (IC) among secondary school students. A quasi-experimental pretest–posttest design was employed, involving a sample of 60 Class IX students who were assigned to experimental group (EG) and control group (CG). Students in the EG received instruction through CM-based strategies, whereas those in the CG were taught using conventional methods. Data were gathered using a CM-gap test and an IC achievement test.*

Results showed a significant improvement in IC for students taught with the help of CM ($t = -9.699$, $p < 0.05$). Components such as processing-speed, automaticity, and tendency to respond to stimuli were found to be strong predictors of CM performance, whereas selective-attention, Timing and kinematic were not significant effects. The researchers found that CM effectively enhances executive functioning and supports meaningful learning. Despite positive outcomes, the study was limited by a small sample size and short intervention period. Future research should explore the long-term effects of CM on various executive functions across broader educational contexts.

Key Words: *Concept map, inhibitory control, executive function, secondary education, cognitive development.*

1. INTRODUCTION:

In recent years, more educators and researchers have focused on teaching methods that support students' thinking skills and help improve their executive functions. Among these strategies, CM has emerged as a powerful cognitive and collaborative tool that facilitates the organisation, visualization, and synthesis of complex information. By enabling learners to represent relationships among concepts, CM encourages deeper understanding, promotes shared meaning-making, and supports informed decision-making. Its adaptability has led to successful applications across multiple domains- including education, healthcare, and sports psychology - where it has been used to enhance performance, implement evidence-based interventions, and strengthen meaningful learning experiences (Tsui et al., 2024; Vaughn et al., 2013; Reyes, 2023).

Beyond its utility as a learning approach, CM has been documented for its potential to influence higher-order cognitive processes related to executive functions, particularly inhibitory control. IC is an important cognitive mechanism that allows individuals to regulate impulses, resist disturbances, and focus attention on goal-directed tasks (Borst & Borst, 2021). It is vital for self-control and supports other important thinking skills, like working memory and cognitive flexibility. (Palermo & Bartoli, 2020). Research indicates that IC develops progressively across the lifespan and is crucial for academic success, problem-solving, and behavioural adaptation. Conversely, deficits in IC- such as those observed in children with Attention-Deficit-Hyperactivity-Disorder (ADHD) - can impair attention management, decision-making, and overall learning outcomes (Agayeva, 2024).

Recent research works have targeted educational interventions can strengthen IC through structured learning activities that engage metacognitive and self-regulatory processes. CM aligns closely with these principles. By requiring learners to organise information hierarchically, evaluate relationships, and revise their maps through feedback, CM exercises demand focused attention, error monitoring, and suppression of irrelevant information - skills directly linked to IC

(Welter et al., 2022; Campbell, 2022). Furthermore, iterative or serial CM fosters reflection, analysis, and synthesis, thereby promoting both cognitive flexibility (CF) and self-regulated learning (Khudhur et al., 2025).

Despite these promising associations, the relationship between CM and executive functions (EF)- particularly IC- remains underexplored in empirical research. Most existing studies focus on academic performance and understanding, but they pay much less attention to the cognitive processes (CP) that actually drive these improvements.

Understanding how CM contributes to the development of IC may therefore provide new insights into how instructional design can cultivate EF alongside subject-matter learning. The present study aims to examine this relationship by investigating the effects of CM strategies on learners' IC and related CP within the context of secondary education (SE).

2. LITERATURE REVIEW:

Moilanen et al. (2010) examined how IC develops in young children between ages 2 and 4. Their findings showed that IC increases progressively at this period, with children demonstrating consistent and reliable improvement from ages 2 to 3 and again from ages 3 to 4. The researchers also discovered how demographic factors and early caregiving experiences at age 2 influence IC. They found that girls and children exposed to lower levels of harsh parenting began with higher levels of IC. In addition, kids who received more supportive parenting at age 2 showed faster growth in IC across the two-year period. However, African and American children displayed slower growth in IC compared to their non–African American peers. Finally, the study investigated whether children's race or ethnicity affected how childcare experiences related to their starting levels of IC and their developmental growth. This helped clarify how early environments and background factors shape the development of IC in early childhood.

Jaeger (2013) examined why adolescents often show impulsive behaviour and poor decision-making, which can lead to risks such as substance use, unsafe sexual behaviour, and other harmful actions. To better understand the brain mechanisms behind these difficulties with IC, the author reviewed all available functional MRI (fMRI) studies on this topic found in the PsycINFO, PubMed, and Web of Science databases. The review displayed that, compared with adults, adolescents display lower activity in several brain parts involved in IC. That reduced activation in these areas may help explain why adolescents often struggle with self-control during this stage of development.

Berkman et al. (2014) investigated how IC and its supporting brain systems change with training. Although IC has been widely studied, it is still unclear how much it can be improved or how the brain adapts during training. Earlier research shows that people can get better at IC tasks with practice, but these gains rarely transfer to other tasks, and the brain mechanisms behind such changes remain unclear. In this study, participants were randomly assigned to either an IC training group (N = 30) or a sham-training CG (N = 30). Both completed ten sessions of a stop-signal task (SST) over three weeks, with fMRI scans conducted before and after training. The training group showed significantly greater improvement on the SST. Brain results supported a "proactive control" pattern: key IC-related regions, such as the inferior frontal gyrus, became active earlier in each trial after training. Higher behavioural gains were linked to increased cue-related activation and reduced activation during stopping in the dorsolateral prefrontal cortex. Overall, the study provides clear evidence of how IC training alters brain activity and clarifies why previous research has shown inconsistent transfer effects.

Houde and Borst (2014) argue that Jean Piaget both underestimated the cognitive competencies of infants and young children and overestimated the reasoning abilities of adolescents and adults, whose thinking is frequently influenced by intuitive, overlearned, and often illogical strategies. This raises a central question: why do older children, adolescents, and even adults continue to perform poorly on many reasoning tasks despite decades of evidence demonstrating early-emerging knowledge of physical and mathematical principles in infancy and early childhood? The authors propose that the inhibition of simplistic or heuristic responses, mediated by the prefrontal cortex, constitutes a domain-general executive function that enables the development of higher-order conceptual understanding characteristic of later Piagetian stages, such as number conservation and class inclusion. They further oppose that this inhibitory capacity remains essential across the lifespan, noting that adults may also require forms of "prefrontal pedagogy" to suppress intuitive but misleading heuristics in deductive reasoning. Drawing on findings from their laboratory, Houde and Borst highlight how brain imaging and mental chronometry - particularly the negative priming paradigm - can be used to examine IC in cognitive development. They claim that this perception provides a productive framework for reinterpreting persistent errors commonly observed in classroom learning tasks.

The National Survey of Child and Adolescent Well-Being (NSCAW, 2014) is a large, nationally representative, longitudinal study that follows children and families involved with Child Protective Services. This methodological brief focuses on how young children entering school—who had been reported to the child welfare system during infancy—performed on two computerized IC tasks. The goal was to evaluate whether these tasks are practical and valid for use in a large survey and whether they effectively measure IC in this population. The brief also explored how IC relates to age, gender, and behavioural problems. Of the 1,186 eligible children, 859 completed at least one IC task. At Wave 5, the children were on average 68 months old, with ages ranging from 59 to 83 months. Most were in kindergarten (79%), while 13% were in first grade. Boys and girls were represented equally. The sample included 40% Black children, 34% White children, and 19% Hispanic children. Based on caseworker reports at baseline, the most common forms of alleged maltreatment were physical neglect (41%), supervisory neglect (22%), and physical abuse (18%). By Wave 5, 54% of the children lived with a biological parent, 25% with an adoptive parent, and 5% in foster or kinship care. Children completed two computerized IC tasks previously used with both adults and children: the shape go/no-go task and the color flanker task. Both tasks were administered on laptop computers, with verbal instructions provided by NSCAW field representatives. To ensure that children understood the tasks, they completed 8–10 practice trials and received verbal feedback on their performance before beginning the actual tasks.

Tynan (2014) conducted a study on behavioural inhibition (inhibition of proponent response, motor inhibition, and delayed gratification) and the classroom behaviour of kindergarten children. Participants included 5-6 years old kindergarten students (N=64), 35 boys and 29 girls, at two public elementary schools. Behavioural inhibition was assessed with the Night and Day test, Yes or No test, Draw-ALine-Slowly task and a measure of Delayed Gratification. Classroom behaviour was measured using the Teacher-Child Rating Scale. The results presented no significant gender differences in performance on behavioural inhibition tasks or teacher ratings of classroom behaviour. Positive correlations were found between children’s performance on the measure of motor inhibition and teacher’s ratings on the social skills and tasks orientation. Positive correlations were also found between inhibition of proponent response and teacher ratings on behavioural control and task orientation. This study did not find any significant correlations among the direct measures of behavioural inhibition. Out of the four behavioural inhibition tasks, motor inhibition was the only significant predictor of teacher ratings on task orientation and performance on one inhibition of proponent response (Night and Day) was the only significant predictor of behavioural control in the classroom.

Ibbotson and Kearvell-White (2015) investigated whether individual differences in IC predict variation in children’s grammatical abilities. In their study, 81 five-year-old children completed two well-established tasks: the Past Tense task from linguistics and the Stroop task from psychology. The results showed that IC was a stronger predictor of grammatical performance than either age or vocabulary size. The authors suggest that accurate responding in both tasks relies on a shared cognitive mechanism—the ability to suppress competing, yet inappropriate, responses. Their findings highlight the value of examining the development of language in tandem with non-linguistic cognitive processes, particularly executive functions. The study also aligns with existing evidence that children with Specific Language Impairment (SLI) show difficulties both in constructing past-tense forms and in performing tasks that require inhibition. The observed association between grammatical errors and Stroop performance supports the idea that a common inhibitory process underlies both linguistic and non-linguistic behaviour. Overall, the study strengthens the argument that language development is shaped by interactions between linguistic knowledge and broader cognitive capacities. Specifically, it suggests that the complexity of grammatical acquisition emerges through the gradual coordination of language processes with executive control mechanisms.

Gagne and Saudino (2016) studied how genes and the environment influence the development of IC in early childhood. They followed more than 300 pairs of twins when the children were 2 and 3 years old, using both parent reports and observations in the lab. Parent ratings showed that genetic factors played a large role, explaining about 60% of the differences in children’s IC at both ages. Many of these genetic effects stayed the same over time, but some new genetic influences also appeared at age 3. This means that genes contributed both to stability and to changes in parent-reported IC. However, the lab-based observations told a different story. Genetic influence was moderate at age 2 (38%) but almost disappeared by age 3 (6%). Instead, environmental factors—both things twins shared and things unique to each child—were mainly responsible for changes in observed IC between ages 2 and 3. Overall, the study shows that different ways of measuring IC may reflect different aspects of the skill. Parent reports and observational tasks may not capture the same parts of inhibitory control, leading to different conclusions about how IC develops.

Liu et al. (2015) studied how training in response inhibition can support the development of IC in preschool children. IC grows quickly during the preschool years and is important for many areas of early thinking and learning. In their study, one group of children (N = 20; 12 boys; mean age 4.87 years) played the tablet game "Fruit Ninja" for 15 minutes a day, four days a week, over three weeks. A second group (N = 20; 10 boys; mean age 4.88 years) played a coloring game for a much shorter time—10 minutes a day for one to two days each week.

To see whether the training helped other skills, the researchers used tasks that measured IC, WM, and fluid intelligence. They also recorded brain activity using EEG while the children completed a go/no-go task. Children who received the training improved noticeably on the game they practiced, and they also showed a small increase in reasoning ability on Raven's Progressive Matrices. EEG results showed that the N2 response during the go/no-go task increased after training, especially for girls. Overall, the study provides early evidence that practicing response inhibition can help improve reasoning skills and that boys and girls may show different brain changes during such training.

Alley, (2016) conduct a study on IC, a salient component of self-regulation, predicts child academic and social competency into the college years. Typical measures of self-regulation (including teacher report, direct assessment, and observation) focus on IC and are each susceptible to unique flaws. The current study examined whether informant bias or differential contextual environments influenced the resulting measure of IC in preschool children and whether this varied by child gender. Three measures of IC were given to 22 pre-schoolers in the Pacific Northwest. The results suggest that context has a greater effect on measured IC than does teacher bias, and that this tendency may be stronger for girls than for boys. Child IC may be a reaction to contextual cues as much as an innate capacity. Acknowledging the flexibility of self-regulatory skills may allow teachers to draw out hidden potential in their students and to prevent the destructive labelling that can lead to self-fulfilling prophecies.

3. OBJECTIVES:

1. To find out the effect of CM strategies on learners' IC of secondary-school (SS) students.
2. To find out the effect of CM strategies on the predictors of learners' IC of secondary-school (SS) students.

4. METHODOLOGY:

The present study adopts an experimental research design to examine the effectiveness of the use of the CM strategies on students' executive functioning, with particular emphasis on the role of IC in their cognitive development and academic performance.

Participants: Purposive-sampling method was used by the researchers, to select 60 class IX students for the study from three English-medium SSs of the three different districts of Assam. These students were allotted to both the CG and the EG. The study adopted a quasi-experimental (QE) research design.

Design of the study: The researchers employed a QE research design to examine the impact of CM strategies on students' EF, with particular emphasis on IC. A pretest–posttest quasi-EG design was utilised to capture changes in IC over time. Prior to the intervention, both the EG and CG completed a pretest to establish baseline levels of IC. The EG subsequently acknowledged instruction through CM strategies, whereas the CG was taught using as-usual methods. After a one-month intervention period, a posttest using the same instrument was administered to both groups to find out the efficacy of the CM-based instructional approach in enhancing students' IC.

Tools: Two distinct instructional approaches were employed to investigate their effects on students' EF, specifically IC. The CG acknowledged instruction through as-usual teaching methods, characterised by lecture-based presentation of content, textbook-driven activities, and predominantly teacher-centred classroom interactions. This approach emphasised content delivery and repetition without explicit emphasis on the organisation of knowledge or metacognitive reflection. Conversely, the EG acknowledged instruction through the CM strategy, which encouraged students to actively construct, visualise, and interrelate concepts within the learning material. To ensure consistency and validity of implementation, the researchers developed detailed activity plans, and instructional materials aligned with the respective teaching strategies. The intervention program was conducted over one month, consisting of regular instructional sessions integrated into the students' classroom schedules. Each instructional session was systematically organised to facilitate collaborative learning, guided discussion, and timely feedback, particularly for the EG involved in concept mapping activities. Additionally, an achievement test on IC was developed and administered to both groups. This test was designed to assess students' ability to manage attention, resist distractions, and regulate cognitive responses during learning. The combination of distinct instructional approaches and systematic assessment allowed the researchers to assess the relative effectiveness of CM in enhancing IC as an aspect of executive function.

5. RESULTS:

Table 1: Descriptive statistics of CM gap test and IC achievement-test (AT) posttest score

	N	Mean	SD	SE-Mean
CM gap test score	30	11.5667	1.40647	.25679
IC AT Score	30	15.1000	1.93605	.35347
Valid N (listwise)	30			

Table 2: Analysis of paired sample statistics of CM gap test score and IC AT score of class IX students

	Paired Differences			T	df	Sig. (2-tailed)
	Mean	SD	SE-Mean			
CM gap test score – IC achievement test Score	-3.53333	1.99540	.36431	-9.699	29	.000

Tables 1 and 2 interpreted the posttest performance of the CM gap test has (n=30, mean = 11.5667 and SD = 1.40647), and the posttest performance of the IC AT has (n=30, mean = 15.1, SD = 1.93605). To analyse the relationship between posttest scores of the CM gap test and the IC AT, the researcher has conducted a paired sample t-test. Result indicate that the t value is -9.699 and $P = 0.00 < 0.05$. Hence, a significant relationship exists between the CM gap test and the IC AT posttest score (*See Tables 1 and 2*).

Table 3 Descriptive statistics of CM and factors of IC of class IX students

	N	Mean	SD	Variance
CM score	30	11.5667	1.40647	1.978
Processing-speed	30	3.0000	.69481	.483
Selective-attention	30	3.2667	.73968	.547
Automaticity	30	3.0000	.58722	.345
Timing and kinematics	30	2.6000	.62146	.386
Tendency to response the stimulus	30	3.1333	.62881	.395

Table 4 R, R^2, and Adjusted R^2 of CM and the factors of IC class IX students

					Change Statistics				
Mode	R	R Square	Adjusted R Square	SE- of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.353[a]	.125	.093	1.33929	.125	3.982	1	28	.056
2	.468[b]	.219	.161	1.28826	.094	3.262	1	27	.082
3	.530[c]	.281	.198	1.25947	.062	2.249	1	26	.146
4	.538[d]	.290	.176	1.27650	.009	.311	1	25	.582
5	.751[e]	.564	.473	1.02128	.274	15.056	1	24	.001

a. Predictors: (Constant), Processing-speed
b. Predictors: (Constant), Processing-speed, Selective-attention
c. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity
d. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity, Timing and kinematics
e. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity, Timing and kinematics, Tendency to response the stimulus

Table 5 ANOVA of CM and the sub factors of IC of class IX students

Model		Sum of square(SS)	df	Mean Square(MS)	F	Sig.
1	Regression	7.143	1	7.143	3.982	.056[b]
	Residual	50.224	28	1.794		
	Total	57.367	29			
2	Regression	12.557	2	6.279	3.783	.036[c]
	Residual	44.810	27	1.660		
	Total	57.367	29			
3	Regression	16.124	3	5.375	3.388	.033[d]
	Residual	41.243	26	1.586		
	Total	57.367	29			
4	Regression	16.630	4	4.158	2.552	.064[e]
	Residual	40.736	25	1.629		
	Total	57.367	29			
5	Regression	32.334	5	6.467	6.200	.001[f]
	Residual	25.032	24	1.043		
	Total	57.367	29			

a. Dependent Variable: CM score
b. Predictors: (Constant), Processing-speed
c. Predictors: (Constant), Processing-speed, Selective-attention
d. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity
e. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity, Timing and kinematics
f. Predictors: (Constant), Processing-speed, Selective-attention, Automaticity, Timing and kinematics, Tendency to response the stimulus

Table 6 Unstandardized β co-efficient, standardized β co-efficient, and t-test of the factors of IC of SS students

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	SE	Beta		
1	(Constant)	9.424	1.101		8.557	.000
	Processing-speed	.714	.358	.353	1.996	.056
2	(Constant)	11.211	1.450		7.734	.000
	Processing-speed	.756	.345	.374	2.191	.037
	Selective-attention	-.585	.324	-.308	-1.806	.082
3	(Constant)	10.135	1.588		6.381	.000
	Processing-speed	.676	.342	.334	1.981	.058
	Selective-attention	-.788	.344	-.414	-2.288	.031
	Automaticity	.659	.439	.275	1.500	.146
4	(Constant)	10.170	1.611		6.313	.000
	Processing-speed	.717	.354	.354	2.027	.053
	Selective-attention	-.692	.390	-.364	-1.776	.088
	Automaticity	.739	.468	.309	1.579	.127
	Timing and kinematics	-.274	.491	-.121	-.557	.582
5	(Constant)	5.406	1.780		3.037	.006
	Processing-speed	.771	.283	.381	2.723	.012
	Selective-attention	-.592	.313	-.311	-1.894	.070
	Automaticity	.924	.378	.386	2.447	.022
	Timing and kinematics	-.285	.393	-.126	-.725	.475
	Tendency to response the stimulus	1.197	.309	.535	3.880	.001

a. Dependent Variable: CM score

Table 3 depicts the descriptive-analysis resulting in the mean and SD of the CM and the factors of IC of class IX students. It resulted that CM of 30 class IX students mean (11.5667), SD (1.40647) and variance (1.978) which was higher than the factors of IC mean ranging from 2.6 to 3.2667, SD ranging from .58722 to .73968, and variance ranging from .345 to .547. Here the Mean of selective-attention, tendency to respond the stimulus, and processing-speed, automaticity factors of IC was greater than timing and kinematic (*See Table 3*). The regression of CM on the basic model 1 ($R = 0.353$, $R^2 = .125$ and adjusted $R^2 = .093$ $P > .05$) has no significant relationship with processing-speed ($\beta = .353$, $t = 1.996$ $P > .05$) while the F value (df1/28, 3.982 $p > .05$) has no significant relationship with CM. And the regression of CM on the basic model 2 ($R = .468$, $R^2 = .219$, adjusted $R^2 = .161$, $P > .05$) has no significant relationship with selective-attention ($\beta = -.308$, $t = -1.806$ $P > .05$) has not significant, where processing-speed ($\beta = .374$, $t = 2.191$, $P < .05$) has significant, where as a whole selective-attention F value (df2/27, 3.783 $p < .05$) has significant relationship on CM. The regression of CM on the basic model 3 ($R = .530$, $R^2 = .281$, adjusted $R^2= .198$, $P> .05$) has no significant relationship with automaticity ($\beta = .275$, $t = 1.5$, $p >.05$) has no significant, where selective-attention ($\beta = -.414$, $t = -2.288$, $P < .05$), and processing-speed ($\beta = .334$, $t = 1.981$, $P > .05$) has no significant, where as a whole automaticity F value (df3/26, 3.388 $p < .05$) has significant. The regression model of CM on the basic model 4 ($R = .538$, $R^2 = .290$, adjusted $R^2 = .176$ $p > .05$) has no significant relationship with timing and kinematics ($\beta = -.121$, $t = -.557$ $p > .05$) has no significant, where automaticity ($\beta = .309$, $t = 1.579$, $P > .05$) has no significant, selective-attention ($\beta = -.364$, $t = -1.776$, $P > .05$) has no significant, and processin-speed ($\beta = .354$, $t = 2.027$, $P > .05$) has no significant, where as a whole timing and kinematics F value (df4/25, 2.552 $p > .05$) has not significant. The regression model of CM on the basic model 5 ($R = .751$, $R^2 = .564$, adjusted $R^2 = .473$ $p < .05$) has significant relationship with tendency to response the stimulus ($\beta = .535$, $t = 3.88$ $p < .05$) has significant, where timing and kinematics ($\beta = -1.26$, $t = -.725$, $P >.05$) has no significant, and automaticity ($\beta = .386$, $t = 2.447$, $P < .05$) has significant, and selective-attention ($\beta = -.311$, $t = -1.894$, $P > .05$) has not significant, and processing-speed ($\beta = .381$, $t = 2.723$, $P < .05$) has significant, where as a whole tendency to response the stimulus F value (df5/24, 6.2 $p < .05$) has significant (*See Table 4, 5, and 6*).

6. DISCUSSION:

The results shows the supportive evidence for the cognitive and metacognitive benefits of CM strategies in enhancing students' EFs, particularly IC. The mean difference between the posttest scores of the CM gap test and the IC AT identify that learners, who engaged in CM developed greater capacity to suppress irrelevant stimuli, manage attention, and maintain focus on goal-directed tasks. This result supports previous studies, emphasising the role of CM in improving self-regulation, metacognitive awareness, and strategic learning behaviors (Davaribina & Asl, 2017; Tajeddin & Tabatabaei, 2016).

The regression-analyses exposed that specific dimensions of inhibitory control—namely processing-speed, automaticity, and tendency to respond to stimuli—significantly contributed to CM performance. These results suggest that CM activates and reinforces essential executive processes involved in information selection, response inhibition, and efficient cognitive processing. Students who were able to manage their responses and process information more fluently demonstrated higher CM scores, highlighting the reciprocal relationship between mental control mechanisms and conceptual organization skills. This aligns with the theoretical perspectives of Campbell (2022) and Welter et al. (2022), who observed that CM encourages higher-order thinking, reflective judgment, and flexible cognitive engagement—all of which are foundational to effective inhibitory control.

In contrast, selective-attention and timing and kinematics did not individually exhibit significant predictive power, suggesting that while attentional control contributes to learning processes, its isolated influence on CM outcomes may be limited. Instead, IC appears to function as an integrated system in which cognitive speed, controlled response, and habitual regulation play more central roles in facilitating conceptual learning. This interpretation supports the domain-general view of executive functions proposed by Borst and Borst (2021), wherein IC shares overlapping neural and cognitive mechanisms with other components of executive functioning.

The study's results underscore the pedagogical value of incorporating CM as a structured cognitive tool in SE. By engaging students in organizing, linking, and reflecting on information, CM fosters deeper comprehension and facilitates the internalization of content knowledge through active processing. Furthermore, it enhances learners' metacognitive monitoring, helping them identify misconceptions and redirect their attention—skills essential for developing inhibitory control. These outcome are reliable with the broader educational literature that positions CM as a method for strengthening executive functions, including planning, WM, and CF (Khudhur et al., 2025; Palermo & Bartoli, 2020).

7. CONCLUSION:

The outcome of the study confirm that CM strategies significantly enhance students' IC, a key component of EF. The results indicate that students who engaged in CM performed better on measures of IC than those taught through traditional-approach. Regression analyses revealed that processing-speed, automaticity, and tendency to respond to stimuli were significant predictors of CM performance, highlighting their essential roles in cognitive regulation and conceptual learning. These outcomes suggest that CM not only improves content understanding but also strengthens learners' ability to manage attention, control impulses, and engage in purposeful thinking.

The study further supports the notion that CM promotes metacognitive awareness, self-regulation, and higher-order thinking, aligning with existing research that links CM to the growth of executive functions (EF). From an educational perspective, integrating CM into classroom instruction can enhance students' CF and self-directed learning. Overall, the results demonstrate that CM is an effective pedagogical tool for fostering both academic achievement and cognitive control in SE.

8. LIMITATIONS:

Despite its valuable findings, the present study is subject to certain limitations that should be acknowledged. First, the research was directed with a comparatively small sample of 60 students drawn purposively from three SS, which may limit the generalizability of the results to broader student populations. Second, the study employed a quasi-experimental design without random assignment, which may have introduced potential biases related to group equivalence and uncontrolled external variables. Third, the intervention period of one month may not have been sufficient to capture the long-term effects of CM on IC and other EF. Additionally, the study focused exclusively on English medium schools within specific districts of Assam, thereby constraining the cultural and linguistic diversity of the sample. Finally, the assessment of EF was limited to IC, excluding other crucial components such as WM and CF, which could provide a more inclusive understanding of learners' EF.

9. RECOMMENDATIONS

The results demonstrated the important effect of CM approach on students' IC and overall EF, several recommendations are proposed for educational practice, curriculum design, teacher training, and future research.

Integration into Classroom Instruction: CM should be systematically incorporated into classroom teaching, particularly in subjects requiring higher-order thinking and problem-solving, such as science and mathematics. Its use can foster improved self-regulation, inhibitory control, and conceptual understanding among learners.

Teacher Professional Development: Instructors should be provided with professional training on the effective design and implementation of CM strategies. Workshops and in-service training programs can help educators integrate these strategies into daily instructional practices to enhance students' cognitive engagement and metacognitive awareness.

Curriculum Development: Curriculum planners and educational policymakers should consider embedding CM activities within the school curriculum as part of constructivist and learner-centered pedagogical frameworks. This can promote active learning and strengthen Ef across disciplines.

Use of CM in Assessment: CM can also serve as an effective formative assessment tool to evaluate students' understanding, organization of knowledge, and cognitive processing skills, particularly in monitoring the development of EF.

Future Research Directions: Future studies may extend the investigation to other components of EF, such as WM and CF, to gain a more inclusive understanding of how CM influences overall cognitive development. Additionally, research may be conducted across different grade levels, subjects, and cultural contexts.

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