ESCALATING THE STRANDS OF MATHEMATICS PROFICIENCY WITHIN THE AMBIENCE OF THINKING MAPS.

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Abstract Mathematical knowledge is either declarative or procedural. Using the different graphic patterns of thinking maps both declarative form and procedural form can be depicted which helps in scaffolding students learning by translating abstract thinking processes into explicit and tangible visual representations. The present study focuses on the ambience of Thinking map strategy in unfurling mathematics proficiency among secondary school pupils. The findings conclusively point towards the fact that Thinking map strategy is a promising curriculum transaction modality in fueling mathematics learning scenario that culminates in better performance in achievement and heightened proficiency in mathematics among secondary school pupils.

Mathematics constitutes one of humanity's ancient and noble intellectual traditions. It is the pivot of all civilizations and contributing factor in the prosperity of human race. It is an all embracing and all pervading discipline for all of science and technology, providing powerful tool for analytical thought and the concepts and language for creating precise quantitative descriptors of the world. Mathematics is increasingly a prerequisite for full participation in our technology oriented society and hence learning of mathematics is momentous for all from computation skills to high problem solving skill. If students are to become proficient in mathematics the instructional dynamism must create opportunities to have layers of understanding about concepts, learn the procedures meaningfully, solve problems using efficient strategies, defend and justify their reasoning and engage and challenge mathematical investigations positively. Even though the constructivist approach prevailing in the educational landscape has made a radical revolution in the concepts of learning from dissemination of knowledge to the construction of knowledge, it is observed that mathematics learning scenario is struggling to stretch its arms to the set forth transformation. Learners often confronted with many impediments and challenges to acquire the expected competency in mathematics as it is multifaceted discipline with multi strategic procedures. The pedagogic dynamisms infused with a culture of cognitive mapping embrace the opportunity to analyse tasks they have performed or to speculate about how a certain chain of events might takes place under certain conditions and become adept at describing the skills and strategies they use to solve complex problems and apply those in variety of contexts with a transformed perspective.

Generating ambience of Thinking Maps: Visual tools are nonlinguistic symbol systems used by learners, teachers and leaders for graphically linking mental and emotional associations to create and communicate rich patterns of thinking [Hyerle, 2009]. They are a natural bridge between brain and mind and high intellectual performance supported all learners in transforming static information into active knowledge, thus offering a complimentary representational system. On a global level Thinking maps can be described as a synthesis of three types of visual tools viz. brain storming webs, graphic learners in transforming static information into active

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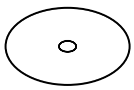
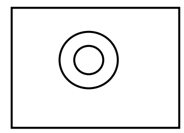
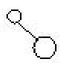
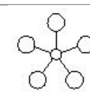
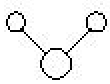
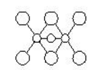
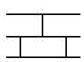
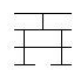
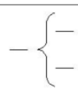
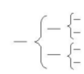
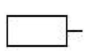
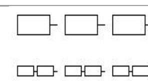
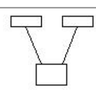
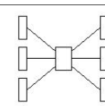
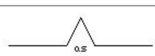
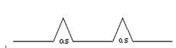
knowledge, thus offering a complimentary representational system. On a global level Thinking maps can be described as a synthesis of three types of visual tools viz. brain storming webs, graphic organizers and thinking process tools such as concept mapping. Synthesizing the best qualities of these types of visual tools;the creative dynamisms of brain storming webs, the organizing structure of graphic organizers, and the deep cognitive processing found in concept maps that Thinking maps have evolved as a powerful language for learning

Thinking maps-How it works

Thinking maps are eight visual-verbal learning tools, each based on a fundamental thinking skill defined and animated by maps and introduced as a common visual language for thinking and learning across whole learning communities(Hyerle 2004). These visual tools are used together as a set of tools for showing relationships and as a common language for meaningful learning.Thinking maps as a language are eight cognitive skills' each represented and activated by graphic primitives. Each of the graphic primitives that visually define and animate each cognitive process is closely attuned to and reflects the cognitive pattern. The primitives and their specificities are explained in Table 1.

Table 1. Graphic Primitives and their Specificities

Primitives	Name of Map	Specificities	Expanded Maps
	Circle Map	• Used for seeking context • Effective brain storming tool • Frame of reference	
	Bubble map	• Process of describing attributes • Identify traits • Identify properties	
	Double Bubble Map	• Comparing two things • Contrasting two things • Prioritizing information	
	Tree Map	• Inductive and deductive classification • Categorize • Sort • Organize	
	Brace Map	• Identifying part-whole relationships • Analyse • Break into parts • Support spatial reasoning	
	Flow Map	• Sequencing ,Ordering • Showing time lines, cycles, actions, steps, • Relations between sub stages	
	Multi Flow Map	• Seek cause-effect • Shows inter relationships of feedback effects	
	Bridge Map	• Creating and interpreting analogies • Develops analogical reasoning • Metamorphic concepts of deeper content learning	

The learners energize thinking and represent their cognitive processes using these graphic primitives. They are used together, linked together and visually scaffold to create other products of learning such as a piece of writing. Learners and teachers shape and reform the static content knowledge by transforming it into maps.

Mathematical knowledge is either declarative or procedural. Using the different graphic patterns of thinking maps both declarative form and procedural form can be depicted which helps in scaffolding students learning by translating abstract thinking processes into explicit and tangible visual representations. Students and teachers indicated that thinking maps fostered students' ability to articulate how they were thinking or to reflect with a metacognitive stance in order to assess.

Statement of the problem

This study was mainly meant to establish the effectiveness of thinking map strategy in unfurling mathematics proficiency among secondary school pupils

Objectives of the Study

1) To test the effectiveness of thinking map strategy in improving the academic performance in mathematics of pupils at secondary school level.

2) To explore the effect of of thinking map strategy in augmenting the set levels of mathematics proficiency of pupils at secondary school level.

Hypotheses of the Study

1) The select thinking map strategy is effective in improving the academic performance in mathematics of pupils at secondary school level.

2) The select thinking map strategy is effective in augmenting the set levels of mathematics proficiency of pupils at secondary school level.

Methodology in brief

The present study attempted to empower the student folk at secondary level with mathematics proficiency by exposing them to thinking map strategy. For attaining the set objectives of the study both quantitative and qualitative methodology were adopted. The quasi-experimental design with pre test posttest non equivalent group design was employed for the quantitative segment and the analytic rubric for synchronized assessment in mathematics proficiency for the qualitative segment.The sample or participants of the study primarily consisted of 149 pupils at secondary school level

Analytical supports of the study.

1) Achievement test in Mathematics

2) Analytic rubric for synchronized assessment of mathematics proficiency

3) Lesson design based on Thinking map strategy

Analytic Rubric for Synchronized Assessment of Mathematics Proficiency

As the investigators intended to assess the relative strengths and weakness of the learner's performance of mathematics competence through a detailed feedback in addition to the experimental test scores, they have developed, validated and employed an analytic rubric for synchronized assessment in mathematics proficiency among the secondary school pupils. In this study mathematics proficiency was described as the intertwined rope of the five strands namely conceptual understanding, procedural fluency, adaptive reasoning, strategic competence and productive disposition put forward by NRC, 2001.(Figure 1).

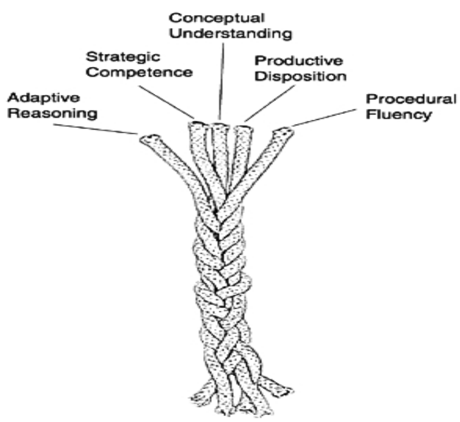


Figure 1. Five Strands of Mathematics Proficiency

These five strands are interconnected and a synchronized working of them is needed in building an individual who is mathematically proficient. The assessment of mathematics proficiency using the set forth rubric captures these conceptions of proficiency and the interactive engagement of them to accomplish the set mathematical tasks. The data thus gathered through this validated instrument have been analysed qualitatively .

Statistical procedures employed

T-test , ANCOVA, Adjusted means, Percentage computations

Analysis and Interpretation

The investigator analyzed the pre test and post test scores of the control group and experimental group who were exposed to Thinking map strategy to find out the effectiveness of it in improving the academic performance of pupils at secondary level.

To find out whether any significance difference exists between the experimental group and control group, the mean and standard deviations of the posttest scores of achievement were estimated. The critical ratios were found out based on the data presented in Table 2.

Table 2. Test of Significance of the Mean Post test Scores of Achievement.

Sl.	Sample	Control group	Experimental group	Critical	Level of

No.		Mean	SD	N	Mean	SD	N	Ratio	significance %
1	Total	19.51	7.32	75	29.03	10.70	74	5.11	0.01
2	Urban	20.60	7.46	36	29.12	10.94	35	3.81	0.01
3	Rural	19.20	7.28	39	28.93	10.61	39	4.59	0.01
4	Male	19.6	6.88	37	28.87	9.09	37	4.73	0.01
5	Female	20.15	7.73	38	29.17	12.15	37	3.87	0.01

This result indicates that the performance of the experimental group and control group in the post achievement test are not similar. The table values show that the higher mean scores are associated with the experimental group. This means that experimental group shows better performance than the control group in their achievement for the total sample, locale wise and gender wise sub samples.

Single factor ANCOVA with pre experimental status in achievement as covariate was employed to investigate the effectiveness of Thinking maps strategy in promoting reflective learning practices in mathematics over present activity oriented approach. The details are given in Table 3.

Table 3. Summary of ANCOVA of Pre test and Post test Achievement Scores of Total Sample

Source	Type III sum of squares	df	Mean square	F-value	Significance level %
Model	49582.194(a)	1	49582.194	239.016	0.01
Post control	49582.194	1	49582.194	239.016	0.01
Error	13483.81	65	207.443		
Total	63066.00	66			
a R squared = 0.786 (Adjusted R squared = .783)					

The F- ratio obtained (239.016) is significant as the level of significance is 0.01%.

The result obtained from the covariance analysis shows that after a linear adjustment was made for the effect of variation due to differences in the pre experimental status in mathematics achievement as measured by the covariate there is statistically significant difference exists between the experimental group and control group in the post test scores for the total sample. This means that the experimental group performed better than the control group in their post achievement test.

Adjusted means of achievement for the experimental group were calculated using regression equations for the total sample. The details are given in Table 4.

Table 4. Adjusted Mean of the Post test Scores of Experimental Group for Total Sample.

Sl. No.	Sample	Mean of control group	Mean of experimental group	Adjusted mean of experimental group
1	Total	19.69	29.03	28.76

The obtained adjusted means of experimental group for total sample are found greater than the corresponding means of control group with regard to the post achievement scores. This accrual in performance is due to the effectiveness of Thinking maps strategy, which was treated to experimental group in promoting reflective learning practices in mathematics. Thus, it is evident from the analysis that Thinking maps strategy enhances the achievement level in mathematics of secondary school pupils.

Effectiveness of Thinking maps strategy in accommodating the select levels of Mathematics proficiency.

The investigator conducted a qualitative analysis to substantiate the findings drawn through the quantitative analysis of the data. The self assessment analytic rubric was administered to the experimental group which was treated with Thinking maps strategy before and after the experimentation and the number of pupils fall under each of the select level of performance for each criteria was estimated. The corresponding percentage of pupils and their averages were computed and is described in Table 5.

Table 5. Percentage of Pupils under Novice, Basic, Proficient and Advanced levels of Performance .

Levels of performance	Novice		Basic		Proficient		Advanced	
Criteria	Pre-test %	Post test %	Pre-test %	Post test %	Pre- test %	Post test %	Pre-test %	Post test %
Conceptual understanding	70	22	23	48	6	22	1	8
Procedural fluency	73	19	22	53	4	21	1	7
Strategic competence	71	16	24	51	5	25	Nil	8
Adaptive reasoning	76	25	20	47	4	18	Nil	8
Productive disposition	71	28	26	48	3	15	Nil	9
Average	72.2	22	23	49.4	4.4	20.2	0.4	8.4

Table 4 indicates that there is a considerable increase in the percentage of pupils coming under Advanced, Proficient and Basic level of performance after the experimental treatment of Thinking maps strategy. The percentage of pupils under Novice levels of performance decreases after the treatment of Thinking maps strategy. These results lead to the inference that the Thinking maps strategy is effective in enhancing the level of performance of pupils from Novice level to Advanced level in mathematics proficiency.

Major Findings and Conclusions

- Thinking map strategy is effective in improving academic performance in mathematics of secondary school pupils.
- Thinking map strategy is effective in upbringing the set levels of mathematics proficiency.

Discussion of results

The effectiveness of the Thinking map strategy has examined mainly by exposing the learners to the teaching learning endeavors embedded in Thinking map strategy subsequently analyzing the academic performance in mathematics displayed by the pupils. The experimental intervention of the select Thinking map strategy demanded the learners to indulge in and interact with the set sequential phases of Thinking map strategy which leads to the framing of an empowered networking and patterning capacity of mathematical thinking and actions of energizing the knowledge hub of mathematics education. The better status of performance shown by this experimental group over the control group may be due to the potential of the instructional dynamisms suggested by the select strategy to make the learners vibrant and closer to a sound knowledge with self generated non linear tools for activating fluent thinking, which reflects the holistic networking capacity of the human brain. These visual tools acted as the most compatible and effective devises for making an upward mobility from the basic organization of information to basic skills instruction and content specific learning in mathematics among the stakeholders.

The results obtained through the analysis of data procured through the analytic rubric for synchronized assessment of mathematics proficiency elucidate that the select Thinking maps strategy worked out very positively in uplifting the learners from Novice level of mathematics proficiency to Advanced levels. Before the experiment the pupils at Novice level were found to be very inactive and inconsistent thinkers and problem solvers. They showed limited awareness in detecting, patterning and reorganizing relationships among the varied constituents of the mathematical event and in deriving meaning from the experiences thus obtained .While the learners are exposed to the select Thinking maps strategy they were invoked to compare intentions of a task with accomplishments, search for casual factors that produced the learning effects and summarise the impressions about the event which in turn produces modifications for future actions. As the select strategy is embedded with high quality visual mappings the learners were able to assimilate and accommodate new information and concepts into previously held scheme. They could easily bridge between patterning mind and the outward representation of their forms of mathematical thinking. Thus the select strategy energize the integration of analytical and creative thinking to work easily with mathematical complexities and hindrances in framing and applying mathematical procedures that honors the pathways of varied strands of mathematics proficiency form Novice to Basic, Proficient and Advanced levels.

These findings are supported by the results of Chiou&Chei (2008) and Chiou (2008) which reported that mapping strategy could stimulate individual reflection, generate new knowledge, provide scope for viewing knowledge from another angle and can enhance student's learning achievement. Fraser and Spinner (2002) reported that concept mapping strategy could make dramatic results in the understanding of mathematical concepts, attitude towards mathematics and perception of the classroom environment. Hu & Wu (2012) in their study examined whether or not concept mapping can be used to help students to reduce their learning cognitive load. The results indicated that concept mapping can help students to understand and clarify concepts included in the curriculum, and also enhanced considerably their interests in studying food science.

In a nutshell, the investigator derived a concluding remark from the varied spectrum of the study to validate the efficiency of the select Thinking map strategy that it is a promising curriculum transaction modality in mathematics.

Implications of the Study

1) Mathematics education should broadly embrace the view that learning is not a solo and internal activity; rather learning efforts are distributed over the individual learner's mindful and effortful involvement. Success in mathematics learning requires being positively disposed toward the subject. If students are to learn, act, and apply mathematics expertise effectively, they should see it as a subject in whom things fit together logically and sensibly and they need to believe that they are capable of figuring it out. Students who are proficient in mathematics become more confident of their expertise to learn the subject. They need to believe that they can develop understanding of the mathematical concepts, strategize solution procedures, reason out propositions and be positively disposed towards the subject. Educators are to be cautious in arranging every pedagogical endeavors that should address the integrated strands of proficiency to make knowledge stronger more durable more adaptable more useful and more relevant.

2) The findings of the study set the stage for more ambitious exploration of the role of Thinking maps for activating habits of mind in the entire realm of school education as well as higher education. Thinking maps is a significant educational reform measure since it marks a departure from prevailing activity oriented pedagogical model to cartographic mode of knowledge processing and accommodation. The enculturation process into this new design of instruction requires both cognitive and psychological realignment of the contextual constructs of the set task. Learners have to call upon to become more open minded and receptive of cognitive networks and patterns of the exercise tasks. In order to adapt to this new design implementation facilitators should assume a multifaceted guiding role and create an interactive classroom learning culture through discussion and discourses. When learners combine the use of visual tools with the habits of mind to crystallize their thinking, they could see their own accommodating ideas and thus gain new sense of themselves as efficacious thinkers and problem solvers. Educators and instructional facilitators need to ensure that learners consciously apply Thinking maps into their daily learning by redesigning the materials they already use in their classrooms. Educational administrators, policy analysts, scenario planners and knowledge managers should promote appropriate training programme for all the stake holders of this innovative pedagogical tool is another indispensable condition for the implementation of thinking maps design.

3) A powerful contribution to self initiated learners who continue to pursue learning as a lifelong endeavor is the activation of self assessment mode of evaluating learning gains . These self assessment strategies that are intended to help students to be self referring, self monitoring and self modifying that provides timely feedback about their behavior and can determine for themselves how to improve. As one of the self assessment modes, rubrics provide a concrete vision and explicit language for goal setting and personal mastery. It is a systematic way to chart growth and improvement of the behavior anchors of the learning output and empowers them to analyse where they need to focus to improve. Hence, the study implies a systematic orientation, development and practice of distinct self-assessment modalities in the educational sector by all the practitioners at all levels.

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