

Strategic Content Learning Approach to Promote Self-Regulated Learning in Mathematics

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Advocacy that individuals learn when they are proactive, self-organized, self-reflecting, and, in turn, self-regulating has been examined and summarized in this paper. An instructional approach: 'Strategic Content Learning' was adapted to promote self-regulated learning skills for problem solving in mathematics. Understanding average mathematics performers' beliefs and knowledge about mathematics as a subject, their understanding of "mathematical problems", and helping these average performers to select, adapt or invent strategies that help them in becoming better self-regulated solvers in non-routine mathematical problems was the main objective of the study. Concomitantly the students were also helped to develop their personalized strategies that they could transfer across problems and time. As a result of strategic content learning, they improved in their monitoring skills, circumventing on their weaknesses and capitalizing their strengths to achieve active control over their chosen tasks.

It had always been a challenge for the educationists and learning psychologists to study and devise ways and methods that would facilitate the teaching learning process. For years educationists have been working hard to make children self-learners who would also be aware of their cognition and beliefs. The purpose of such endeavours is to work towards making students more resourceful and aware of their strengths and weaknesses; consequently, making them self-regulated learners.

It has been observed that in teaching and learning of mathematics, the perfunctory process that occurs is: selection of a task by the teacher, introduction to a "technique" through illustration followed by more exercises for practice in the illustrated skill (Schoenfeld, 1992; Gandhi & Varma, 2007).

This results in a lack of understanding of problem solving skills as an essential component in promoting mathematical thinking among learners. So the unanswered concerns of mathematics teachers and educators at large are to devise ways to make mathematics interesting, hunt for better pedagogies of mathematics that may make students better at the subject, to provide solution to their learning problems, delineating and suggesting ways and strategies that they can adopt to help their students become better self-learners.

Students' self-regulating activities emerge out of social interactions between teachers (more generally adults or mature learners) and students. From this perspective, learning is construed as a social, as well as individual activity (Stone, 1998). Sociocultural models view strategic activities as inherently goal oriented. Therefore, social dialogue regarding strategy use is conducted within the context of meaningful tasks. Adult or peer support is provided in students' zone of proximal development (Vygotsky, 1978), that is, on tasks that students cannot yet perform independently, but can perform with adult support. Students and teachers collaborate to complete tasks, while learners assume more and more responsibility for guiding their own implementation of strategies. Eventually, students internalise the cognitive activities in the instructional routines and begin to self-regulate.

This paper summarizes the methodology and results obtained through a study conducted to help average achievers of mathematics to become self-regulators by adapting an instructional approach: Strategic Content Learning (SCL). The study intended to understand average mathematics performers' beliefs and knowledge about mathematics as a subject, their understanding of "mathematical problems",

and helping these average performers to select, adapt or invent strategies that may help them in solving mathematical problems. The purpose was also to improve students' metacognitive knowledge about tasks (mathematics) and strategies (problem solving strategies) by increasing their involvement in developing, implementing and transferring personalised as well as task specific strategies across problems and across time. Within the course they were helped to articulate their learning in their own words and self-monitor their work to devise personalized strategies that they would apply next time by understanding their weaknesses and capitalizing their strengths to achieve control over their chosen tasks.

Instructional Dynamics of Strategic Content Learning

Strategic Content Learning is based on an analysis of self-regulated or strategic performance. Key instructional goals, including students' construction of metacognitive knowledge, motivational beliefs, and self-regulated approaches to learning are defined. In making students self-regulated, a central instructional guideline is for teachers to support students' reflective engagement in cycles of self-regulated learning (i.e., task analysis, strategy implementation, self-monitoring). For example, to support the sampled group of students in solving problems in mathematics, the teacher started by helping them analyze the common task selected (problems in mathematics). They were asked to interpret available information (e.g. information given in the problem). They were guided to identify and implement strategies for meeting task requirements (e.g. organizing the given information, finding relationship between the given information and what has been asked for in the problem). Finally, the students were supported to self-evaluate outcomes in light of task criteria (e.g. how quickly were they able to solve the problem? Can there be any other method of doing the same problem?) And to refine their task-specific strategies so as to redress problems or challenges encountered (e.g. is their chosen method an elegant one, to judge the most appropriate solution strategy for solving the problem?).

A primary emphasis was not on teaching predefined strategies for completing academic tasks but to think about what the students would have done on their own if the teacher was not there. The teacher guides students in their cognitive processing so that they become successful. Teacher intervenes only when required. No direct explanations of the concepts are given. From a theoretical perspective it could be argued that if instruction focuses primarily on the direct explanation of predefined strategies, students may be inadvertently excluded from the problem-solving process

central to self-regulation (Butler, 1993, 1995). If it were the teacher who has analyzed a task, anticipated problems, and defined useful strategies, then students would have little opportunity to solve problems themselves and learn new strategies. To avoid this problem, the teacher co-constructs strategies with students, bridging from task analysis. The teacher and the students worked collaboratively to find "solutions" (i.e., strategies) to the given problem. So, for example, when defining strategies for solving a mathematical problem, the students were to consider strategy alternatives in light of task demands (e.g., what strategies will they adopt to solve the problem, will they make a table, draw a diagram or do guess and check, etc.). Then, while working through the task collaboratively, the students were supported to try out strategy alternatives (e.g., to apply different problem solving strategies to solve the problem), judge strategy effectiveness (e.g., whether they found the ideal, most appropriate problem solving strategy), and modify strategies adaptively. Over time, through these iterative processes, the students (ideally) learnt how to construct personally effective strategies for coping with a variety of problems in mathematics.

Implications for instruction based on this integrated view are that teachers should (a) collaborate with students to complete meaningful work (to generate a context for communication), (b) diagnose students' strengths and challenges by listening carefully to students' sense making as they grapple with meaningful work, (c) engage students in collaborative problem solving while working towards achieving task goals, (d) provide calibrated support in given students' areas of need to cue more effective cognitive processing, (e) use language in interactive discussions that students might employ to make sense of experience, and (f) ask students to articulate ideas (e.g., about task criteria, productive strategies) in their own words to promote distillation of new knowledge.

For instance, to support average mathematics performers with their math problem solving, each group and the teacher worked collaboratively on the mathematical problems to set a context for communication (collaborating to complete meaningful work). The instructor/ researcher¹ began by observing students solve one or two problems, asking them to think aloud and discuss with their peers as they worked (diagnosing students' strengths and challenges). Attention focused on how they interpreted their task (the given problem), grasped mathematical concepts, represented problems, identified solution strategies, implemented procedures,

¹ In this paper researcher and teacher connotes the same person who conducted this study.

and monitored their work collaboratively. Then, as described earlier, the teacher assisted the students to work recursively through cycles of task analysis, strategy use, and self-monitoring (collaborative problem solving while working towards task goals). When the group did well, the teacher supported them to recognize their success and reflect on the strategies they just used that worked (articulating ideas).

The students documented the strategies applied by them in their personal math journals that they could review, test, and refine over time. When they encountered difficulties, the teacher assisted them to solve problems more effectively (with support). For example, sometimes the researcher directed attention to a sample problem and supported them to interpret that information. The students were helped to verbalize new insights and to try out new ideas (articulating ideas). It is noteworthy that, depending on the whole group's areas of difficulty, the discussion focused on problem-specific strategies (e.g., how to solve an algebraic equation), strategies useful for solving math problems generally (e.g., always checking your work in between the steps, seeing patterns), and/or strategies focused on learning math more independently (e.g., working through simpler examples if stuck, breaking the problem in parts, plan sub-problems while working, computing on smaller numbers instead of large numbers).

Thus the instructions were inherently individualized given that students co-constructed personalized strategies based on interactive discussions in dyads (teachers and/or peers or groups). The researcher tried to build from student's existing knowledge and skill while acting as facilitator of their cognitive processing.

Methodology

Strategic Content Learning approach is an empirically validated instructional model designed to promote Self-Regulated Learning (Butler 1993; 1994; 1995; 1998a; 1998b). This paper summarizes the inferences drawn from the qualitative data obtained when the mathematics instruction and intervention were carried out in small-group situations (5 students in each group) of class VIII. These students were average performers in mathematics. Both boys and girls were drawn from 5 different typical English medium schools through multistage purposive sampling.

A unique characteristic of the implemented instructional dynamics was that the task specific strategies were not determined in advance. Instead, students and teachers established an understanding of the task, defined task goals, and then, using task goals as a foundation for decision-making, selected, adapted, or invented task-specific strate-

gies. Factors that go into the decision making about strategies also included the specific difficulties students had with the task, students' processing strengths and weaknesses, and students' preferences. Therefore, an essential component of the study was students' internal motivation and voluntary participation. So in the first stage of sampling only those students were selected who voluntarily felt the need of assistance in learning mathematical problems. Gradually through multistage sampling average achievers in mathematics (60-65 % in last two years annual exams in mathematics) with average intelligence (45-55 percentiles on Cattle's Culture Fair Intelligence Test: Scale II) were finally selected.

To achieve the desired objectives of the study, the intervention was embedded within a pre-post research design. During pre- and post test sessions, same questionnaires, observations, and interviews were employed to measure effects across students and groups.

To maximize the validity of the study, the indicators of self-regulation were assessed both qualitatively and quantitatively. This provided an in-depth view of each student's progress and a record of process of the instructional intervention. It also allowed for an explicit tracing of the relationships between instruction and outcome. Promotion of self-regulation was a gradual process that unfolded with the progress of the study. Therefore, data collection was an ongoing process that assessed students' continual success in becoming self-regulated through gradual betterment in the indicators of self-regulation, viz. improved task performance, shifts in students' knowledge and beliefs, metacognition skills, perception of self-efficacy, causal attributions for performance, ability to transfer strategies across problems and time, and shift in increased self-initiation.

The qualitative inputs were obtained through observations, researcher's field notes and comments, audio tapes and students' math journals; where as the quantitative data was obtained through questionnaires prepared on metacognition, general self-efficacy and mathematics specific self-efficacy, and on perceptions for causal attributions that students generally state for their good or poor performance in the chosen task (problem solving). The same questionnaires were administered during the pre and post-intervention situations. In addition to above, a set of parallel forms of mathematical problem set was also made for the pre and post test to assess students' accomplishment in solving mathematical problems.

In each of the 5 schools the fieldwork was conducted for 15 days with their respective small group of students (1 day for informal introduction, 2 days for pre-test, and 10

days for SCL intervention, 2 days for post test). Each session lasted for one hour. Hence the total field work/ data collection (including the pre and post intervention) was conducted for 15 hours on each group.

Results and Discussion

On the basis of the indicators of Self-Regulated Learning the data was obtained from various sources that included quantitative (questionnaires) as well as qualitative sources (e.g. math journal of the students, audio tapes and researcher's field notes and comments). The findings related to of each indicator were obtained in conjunction with quantitative scores and anecdotes from all the qualitative sources. (Data collected from both the sources of data collection showed positive results but this paper is limited to discussion of only the qualitative data).

One of the most consistent findings across the five groups was a shift in student's knowledge and beliefs related to the process of learning. It was found that students gradually developed a positive shift towards their mathematical knowledge and beliefs. In each group it was observed that students had developed a focused understanding about mathematical problems and problem solving strategies. For instance, a shift in comments of one of the students can be observed through his annotations taken from his math journal. There were instances of positive shifts in student's metacognitive understanding revealing his better understanding about mathematical problems, problem solving strategies and management of learning.

In the initial phase he commented on one of the problems as:

I didn't find this problem interesting. My friends could do it, but somehow I did not understand anything. It was stupid of me to think in those terms... I felt a little awkward as the problem was over, because it was stressing me.

By the middle of the study, his reflections were more insightful and less judgemental about himself:

I needed help from my group members...Don't ever try to work any sum in mind. It is good to write and think.

In the late sessions his reflections were:

It was an easy problem. I could break the problem into sub parts; I understood the method to solve it. It was great. I liked this problem.

A noticeable increase was also observed in improved self-efficacy perceptions of students as the intervention progressed. By the end of intervention students had gained confidence in their work and in their learning styles. They were more positive and contented with their performance.

For example, a positive shift can be observed from the transcripts taken from the audiotapes. In early phase the interactions were:

Students: Ma'am we are really bad in mathematics.

Teacher: What makes you think that?

Student1: Ma'am I study a lot but when I see the paper I go blank.

Student2: I don't think I can do well in math.... I can't remember the formula.

Student3: I do lot of careless mistake. I just can't get the answer.

Teacher: What do you think would help you to improve?

Student1: I don't think I can ever like the subject.

Student2: We always get low marks.

A conversation of the same group, taken from middle phase of interactions:

Students: Ok, if we would have thought of it a little more we would have definitely done it.

Teacher: How do you feel after doing this question?

Student1: Good, Confident.... I think I can now do better in my exams. Ah! (Relaxed)

And comparing this to the audiotape transcript from last phase of intervention session reveals a positive shift:

Students: Ma'am we know how to do this. Please don't help us. Give us time we will show you.

(They worked in the group for 5-10 min)

Students: Ma'am we have done and checked the answer too. We know we are right.

As the intervention progressed, students had developed personalized strategies that targeted their solution to the tasks. To trace changes in student's strategic approaches to problems in mathematics, their strategy descriptions were chronicled over time and related to their specific difficulties with tasks. Analyses also depicted that most of the students had independently transferred strategies across contexts, time and problems. Transcripts of one such observation from one of the groups had been discussed below.

Early Phase: We don't know how to solve it; we have never seen such problems.

Middle phase: O.k. now let's think... First, let's break the problem and understand what it says...

Last phase: (Each student was equally participating in the solution. Each one of them gave a suggestion and after much discussion they came to a common consensus):
Yes this is the shortest and easiest way. Let's start.

Verbatim from audiotapes showed a gradual transformation of learners into 'strategic performers' as the intervention sessions progressed. They knew about problems in mathematics and could understand problems more quickly, think of problem solving strategies that were useful in solving problems and could justify and verify their strategies. Initially students didn't have faith in their working but gradually they became active participants who could control their thinking. They had better understanding of their strategies and could judge their own working. Excerpt of one of the groups have been discussed below:

Early Phase Interactions

Students: What should we do?

Teacher: Think...

Students: We can't, Ma'am.

Teacher: It is better if you first rethink on what you have already done.

(No response)

Teacher: At least try to think on your steps. Ok let's see what is given....

(No action taken)

Teacher: Ok let's do it altogether again. Let's try to put whatever has been asked for.

Middle Phase Interactions

Teacher: Why did you work backward?

Students: because the problem is like that.

(Students work on the problem.)

Students: See it becomes easier like this...Ma'am we have checked the answer.

Last Phase Interactions

Students: This was a good problem. We enjoyed it.

Teacher: What did you learn?

Students: That this problem was not as difficult as we thought. We solved each subpart in an order. We just have to have faith in us. Nothing is difficult.

As the sessions progressed, it was observed that students' quantum of interest in their work increased. They had all, eventually, learned to think about the task, devise or plan the strategies that would be most appropriate in solving the problem. They often provided convincing logical arguments in support of the claim they made in selecting or choosing their problem solving strategies. It was observed that in initial sessions students took lot of time to solve a problem. They usually took 10-15 min in only grappling with the problem with no concrete idea of the starting strategy to begin with. Peer discussions were also limited and not all the students were equally involved. Students generally relied on the instructor for solution. In gradual sessions, it was observed that students took less time to solve the problems and finally in the latter sessions it was observed that students could efficiently organize their strategies and hence could come to the solution in much less time and with fewer instructions from the researcher. This decrease in the number of instructions with passage of time may be attributed to students' becoming better mathematics problem solvers. The data, as a whole, advocates improvements in students' awareness of selection, adaptation or invention of personalized or task specific strategies.

Strategies that the students developed included steps focused on each of the cognitive processes central to self-regulation. For example, students' strategies included steps related to problem analysis (e.g. "find out what the problem is asking for"); strategy selection based on problem requirements (e.g. "I think we need to make a table"); strategy use (e.g. "avoid careless mistakes"); self-evaluation (e.g. "re-read and think about how my equation relates with given information of the problem, reads the problem to find where we went wrong") and strategic adjustments given progress perceived (e.g. "if confused, take a break and rethink about the underlined data").

As suggested earlier, the strategic learning may be best evidenced when students responsively adapt strategic approaches based on task demanded. Thus, a good measure of shifts in self-regulated approaches would be student's independent development of strategies. In this study, students were observed to add steps to their developing strategies that targeted such activities as task analysis, strategy selection, self-evaluation, and self-monitoring.

Evidence for changes in student's self-regulated approaches was also provided by student's descriptions of how they transferred strategic approaches for use across problems. In many cases, students described adapting specific strategy steps from their previously attempted strategies. For instance, while attempting a problem they commented:

"Oh! This is similar to the one we had done before; the

only difference is... This should be simple to solve.”

Another example can be drawn from the math journal of one of the students:

“I knew what Ma’am wants us to do, so, I told my friends what we should do first... I was happy that we were right. I knew we should work systematically because if we do not plan we can’t get it right. Yes, after sometime we can get the answer but it will take lot of time.”

Consistent shifts in student’s attributions indicated that students were more likely to attribute successful performance to internal factors like ability, effort, strategy use, motivation rather than the external factors like luck, help from others or conditions in the environment.

The composite, qualitative and detailed study of the data on mathematical learning and problem solving strategies led to the finding that the participants not only developed and mastered task-specific strategies, but also learned how to self regulate more effectively.

Conclusion

This research had served to introduce the Strategic Content Learning approach as a successful strategy or instructional dynamics for promoting Self-Regulated Learning in average performers of mathematics of class eight. Notable results were consistent gains in task performance, perceptions of task specific self-efficacy, and metacognitive awareness about mathematical tasks and strategies. Also important were the findings that all the students got actively involved in developing task specific strategies for themselves, and that the majority of students reported adapting strategic approaches for use across mathematical tasks. These data suggest that students assumed a strategic attitude towards tasks.

Thus, the study appears to support self-reflective practice by average performers in mathematics i.e. the students were actively involved, they had developed a reflective thinking and could deliberately organise their learning activities in the areas of important contexts.

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