Increasing Human Potential of Computation through Indian Intellectual Traditions of Vedic Algorithms

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Abstract

The ultimate aim of Education is the overall development of the learner. Education is the divine force that leads us from darkness to light, from ignorance to knowledge, from the unreal to the real.

The present-day world places high demands on human potential: qualities such as efficiency, speed, accuracy, decision-making power, logical reasoning, high-powered thinking, and confidence of personality, are all required. Even though education has undergone a tremendous change with the development of modern science and technology, much still needs to be improved upon for the holistic development of the learner. It is the need of the hour to revisit our ancient treasure of rich intellectual traditions found in the Vedic algorithms.

This paper attempts to create awareness of the vast potential of Vedic/Ancient Indian Mathematics. It presents and discusses the results of a study that was conducted on a sample of Secondary School Students (Class VIII) of select schools of Thiruvananthapuram and Kollam districts (N=240) of Kerala, India. The sample for the study was selected on the basis of the Random Sampling Technique. The study aimed at testing the effectiveness of a prepared Learning Package of Vedic Mathematics Sutras for enhancing a Positive Mathematics Attitude and Computational Speed among Secondary School students in certain select areas. The investigator selected the Non-equivalent Pre-test/Post-test Control Group Design (Gay, 1987) which is one of the strongest of the Quasi Experimental Designs. The required data was collected using appropriate tools which were standardized by the investigator. The effectiveness of the package was tested by comparing the pre-test/post-test scores using appropriate statistical techniques including ANCOVA, Repeated ANOVA, LSD test of post hoc comparison, and were interpreted accordingly. The findings of the study emphasize the desirability of immediate

inclusion of Vedic Mathematics applications in the present curriculum for grooming our students in order to achieve success in their future life by completely reducing their Mathematics anxiety. This anxiety plays a key role in their skill in computation and decision making.

Key Words: Vedic Mathematics, Mathematics Attitude, Computational Speed

INTRODUCTION

Human Potential

Inherent in the notion of human potential, is the belief that, in reaching one's full potential, an individual will be able to lead a happy and more fulfilled life. As human beings, we want to develop and cultivate our untapped potential for a happy, healthy, creative and fulfilling life. The super-computing power and software capabilities for multi-scale modeling of the human brain are still untapped. The knowledge explosion has resulted in various technological inventions in computational techniques. But all these have resulted in making man completely dependent on machines, rather than 'Man Making', living from full human potential. Mathematics as a subject of cognitive exercise and logical thinking has a great role to play, and carries capacity for significant social impact with respect to enhancing human potential. The astounding Vedic technique of computation is the real catalyst for enhancing human potential without any dependence on technology.

Ancient India: A Lighthouse for Scientific and Mathematical Discovery

India remained a lighthouse for the advance of civilization long after the classical Vedic period. The modern zero-based number system (the place-value number system) was first developed in India. This inspired Albert Einstein to say, "We owe a lot to the Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made."

The value of "pi" was first calculated in India by means of the Budhayana long before it was known in Europe. It was through the Budhayana that a mathematical way to calculate the hypotenuse of a right-angled triangle was introduced. The Shulba Sutra (the Budhayana) written prior to the eighth century BC in India, used the theorem about two centuries before it was

introduced by Pythagoras into Greece in the sixth century BC. Major centers of learning operated in ancient India. The World's first major university and trade school was in Taxila (Takshila) then in northwestern India, around 700 BC. The University of Nalanda, established in the fourth century BC, was also a major center of learning in the ancient world. The Indian astronomer and mathematician Bhaskaracharya in the 5th century BC calculated the time taken by the earth to orbit the sun to nine decimal places (according to Bhaskaracharya's calculations). Algebra, trigonometry, and calculus were first set forth in ancient India.

Aryabhata the Elder (476-550 AD) gave a summary of Indian Mathematics that covers astronomy, spherical trigonometry, arithmetic, algebra and plane trigonometry. Aryabhata also gave a formula for finding the areas of a triangle and a circle. His main work, the Aryabhatiya, contains continued fractions, quadratic equations, sums of power series and a table of sines. Aryabhata gave an accurate approximation for "pi" of up to 3.1416 and was one of the first to use algebra. (Aryabhata also introduced the versine (versin = 1 - cos) into trigonometry). His most important achievement was the invention of the "0," which enabled the development of the place-number system.

Aryabhata also wrote a text on astronomy, the Siddhanta, which taught that the apparent rotation of the heavens was due to the rotation of the Earth on it axis. Aryabhata gave the radius of the planetary orbits in terms of the radius of the Earth/Sun orbit as essentially their periods of rotation around the Sun. He believed that the Moon and planets shone by reflected sunlight, and he taught, incredible though it may seem, that the orbits of the planets around the sun are ellipses. This was a thousand hundred years before Copernicus and Kepler came up with the same discovery in Europe. He also correctly explained the causes of the eclipses of the Sun and the Moon and calculated the value for the length of the year as 365 days 6 hours 12 minutes 30 seconds.

Brahmagupta (598-670 AD, an estimated date that may be somewhat inaccurate), head of the astronomical observatory at Ujjain - the foremost Mathematical center of ancient India - developed algebraic notation, and gave remarkable formulas for finding the area of a cyclic quadrilateral and for the lengths of the diagonals in terms of the sides. Brahmagupta also studied arithmetic progressions, quadratic equations, theorems on right-angled triangles, surfaces and volumes, and calculated the length of the year as 365 days 6 hours 12 minutes 36 seconds.

Quadratic equations were first discovered by Sridharacharya in the 11th century. Then Bhaskara (1114-1185 AD) reached an understanding of the number systems that solved equations which were not solved in Europe until several centuries later.

Ayur-Veda, the earliest known system of medicine and surgery, was developed in the Vedic period in India. Sushrut, the father of surgery, developed surgical procedures including cesareans, cataract removals, the setting of fractures, removing urinary stones and even plastic and brain surgery.

The first pioneer of wireless communication was Jagdeesh Bose - not Marconi as commonly taught in the West. India's most substantial gift to world civilization was, however, the discovery of pure consciousness and the mapping out of the architectonic structure of pure knowledge. All other achievements derive from this great awakening of knowledge that took place in ancient Vedic India.

Mathematics and School Education

The majority of our school children consider Mathematics a difficult and dry subject; the perception still exists that it is only for the intelligent. This perception is prevalent right through school to college levels, and leads to an observation that our present Mathematics understanding fails to achieve the major objective of Mathematics education, namely the attainment of self-reliance in Mathematics.

Lack of understanding of the subject creates backwardness and phobia in students, resulting in students who not only get scared, but also develop an aversion for the subject. Even at the school stage where the objective of Mathematics teaching is to develop computational ability, it is doubtful whether the goal is being reached as expected. Surely this is not the fault of anyone who deals with the subject, but rather due to the fact that the system we follow is "Conceptual Based" rather than "Computational Based"**.** In this regard, Vedic/Ancient Indian Mathematics with its wonderful concepts, methods and techniques which have stood the test of time, comes in handy for imparting a holistic, creative education in Mathematics. The incorporation of Vedic Mathematics in the curriculum of School and College education is to be done as soon as possible.

Positive Attitudes Lead to Persistence in Mathematics

Generating positive attitudes towards Mathematics among students is an important goal of Mathematics education. Research conducted over the last two decades has shown that positive attitudes can impact on students' inclination for further studies and careers in Mathematics-related fields (Haladyna et al., 1983; Maple and Stage, 1991; Trusty, 2002). For example, a recent study using the Third International Mathematics and Science Study (TIMSS) data from Canada, Norway and the United States found attitude toward Mathematics as the strongest predictor of student participation in advanced Mathematics courses (Ercikan, et al., 2005).

Addressing student Mathematical disposition, including students' confidence, interest, perseverance, and curiosity in learning Mathematics, is particularly important in the middle years of school and above (ages 12 to high school graduation). Researchers have reported that it is in the middle years of school that students' level of enjoyment of Mathematics tends to decline considerably, and the gender difference in Mathematics confidence widens during this period, favouring boys over girls (Dossey et al., 1988; Strutchens et al., 2004; Seegers & Boekaerts, 1996). For students to persist in advanced Mathematics, teachers need to develop students' positive attitudes - not just their concepts and skills. Developing positive attitudes creates fertile ground in which teachers can sow the seeds of deeper Mathematics learning and cultivate independent, advanced Mathematic learners.

Hence, along with promoting educational achievement, it is obligatory on the part of the school to equip the child with the skill of logical thinking and reasoning which will enable him/her to cope effectively with whatever state of world he/she will encounter later in life. A curriculum which impacts training in these aspects, is the need of the hour. The incorporation of Vedic Mathematics into the present Issue-Based approach, makes the system both conceptual and computational based. The present study focuses on enhancing a positive Mathematics Attitude in secondary school students through a conceptual cum computational approach, by incorporating Vedic Mathematics Sutras in the prevailing Issue-Based Strategic approach.

Swami Bharati Krishna Tirthaji

Swami Bharati Krishna Tirthaji recreated a system of Mathematics that is popularly known today as 'Vedic Mathematics'. Born to highly learned and pious parents in 1884 at

Tirunelveli in the (then) Madras Presidency, Venkatraman was an exceptionally brilliant boy. Vedic Mathematics is based on Sixteen sutras and Thirteen sub-sutras which Swamiji claimed to have 're-discovered' from the Vedas.

Vedic Mathematics

Vedic Mathematics offers a new approach to resolve the current crisis in Mathematics education (Puri & Weinless, 1988; Puri, 1988). It is not simply a collection of new computational techniques - rather, it provides an entirely different approach to Mathematical computation, based on pattern recognition (Puri, 1991). Vedic Mathematics provides very easy, one-line mental and super-fast methods, along with a magical speed cross-checking system (Puri & Weinless, 1988). As such, Vedic Mathematics is a very useful tool to use in competitions. Vedic methods are easy to understand, and their variety, speed and ease bring joy in the heart and a smile on the face of students.

Literature Review and Studies on Applied Vedic Mathematics

Mathematics educators and researchers indicate that mental computation is one of the best ways to help children become independent in memorization techniques and to gain deeper insights into the number system (Hope, 1987, 1986; Williams, 1991, 1984; Trafton, 1978; Beberman as cited in Josephina, 1960). Trafton points out that mental arithmetic adds a new dimension and vitality to computation, increases flexibility, gives new insights into numbers and number relationships, and develops problem-solving skills (Trafton, 1978). Williams notes that "mental calculation sharpens the mind and increases mental agility and intelligence", which he believes is evident to anyone who has practiced or taught mental calculation (Williams, 1991).

In spite of its value, mental computation is not developed enough in the classroom (Cockcroft, 1982; Trafton, 1987; National Council of Teachers of Mathematics, 1986). Mathematics education generally teaches one basic approach to each operation, and relies too heavily on paper and pencil exercises. Regarding the rigid, rule-bound approaches to computing, Hope observed that "children are enslaved to a technique and that alternative methods of solution are not known, or they have been rejected by the user as being somehow 'improper'"(Hope, 1986). Perhaps it is due to this rigid approach that only 55 percent of 17 year olds were able to

multiply numbers, like 90 and 70, in their head (National Assessment of Educational Progress, 1983).

Williams (1991) believes that the reason for the lack of mental Mathematics today is the complexity and unrelated nature of the formulas of modern Mathematics. However, he explains that Vedic Mathematics actually encourages mental Mathematics due to the naturalness and coherence of its techniques. "Vedic mathematics provides a coherent structure for Mathematics; the Vedic methods are beautifully interrelated and complementary. While modern Mathematics is a hodgepodge of unrelated techniques, bewildering in their complexity, the Vedic system offers unifying and natural principles whose effect is to transform Mathematics into an easy and delightful activity" (Williams, 1991).

RESEARCH FRAMEWORK

The present study aimed to test the effectiveness of a Learning Package of Vedic Mathematics prepared with the application of "**Ekadhikena Purvena",** "**Antyayordasakeapi",** "**Ekanyunena Purvena"** and ''**Urdhva Tiryagbhyam''** Sutra for multiplication, towards enhancing a Positive Mathematics Attitude and Computational Speed among Secondary School students.

The **main questions** addressed were:

Can Vedic Mathematics be considered an alternate strategy for enhancing a positive Mathematics attitude among students?

Do Vedic Mathematics applications enhance the computational speed in students?

In an attempt to answer these questions the following **objectives** were sought:

1. To find out the effectiveness of Vedic Mathematics in enhancing a Positive Attitude towards Mathematics among secondary school students.

2. To identify the impact of Vedic Mathematics in enhancing Computational Speed of secondary school students.

The following **hypotheses** were formulated by the investigator leading the study:

1. Vedic Mathematics applications have a high impact in enhancing a positive attitude towards Mathematics among secondary school students.
2. Vedic Mathematics applications are very effective in enhancing the Computational Speed of secondary school students.

Purpose and Method of study

The present study aimed at testing the effectiveness of a Learning Package of Vedic Mathematics prepared with the application of Vedic Sutras for enhancing Mathematics Attitude and Computational Speed among Secondary School students in certain select areas. The investigator selected the Non-equivalent Pre test-Post test Control Group Design (Gay, 1987) which is one of the strongest of the Quasi Experimental Designs.

Population and Profile of the sample

The sample for the study was selected on the basis of the Random sampling technique, consisting of secondary students (Class VIII) of select schools of Thiruvananthapuram and Kollam districts (N=240).

Methodology and Instrumentation

The tools used for the study were:

1. Learning Package prepared on Vedic Mathematics "**Ekadhikena Purvena",** "**Antyayordasakeapi",** "**Ekanyunena Purvena" and ''Urdhva Tiryagbhyam''** Sutra for multiplication.
2. Mathematics Attitude Scale developed and standardized by the investigator.
3. Computational Speed Test

The Mathematics Attitude Scale and Computational Speed Test were initially administered to the groups as Pre-tests and the scores were used for comparisons. The experimental group was exposed to usage of Vedic mathematics, and the control group was given the existing system of computation for the duration of one week. Thereafter a Post-Test was administered and the scores were collected. After an interval of 1 month, a Retention test was given without any notice. The same tools were used for administering the Retention test. The scores obtained from both experimental and control groups were collected. The effectiveness of the Package was tested by comparing the Pre-test/Post-test scores with that of the Retention test using appropriate statistical techniques like ANCOVA, Repeated ANOVA, LSD test of post hoc comparison, and interpreted accordingly.

DATA ANALYSIS

Mathematics Attitude

Effectiveness of the Learning Package of Vedic Mathematics in enhancing a Positive Mathematics Attitude among students of Secondary Schools (Using ANCOVA)

The Scores obtained from Mathematics Attitude Scale were collected and analyzed statistically using ANCOVA to determine the effectiveness of the prepared Learning Package of Vedic Mathematics in enhancing a positive Mathematics Attitude of the students of secondary schools. To compare the Mathematics attitude of experimental and control groups, mean and standard deviations of both post test scores and retention test scores were established. The detail:

Table 1

Mean and Standard Deviations of Mathematics Attitude Scale scores in Post and Retention Tests of Secondary School students in the experimental and control groups

Test	Group	N	Mean	SD
Post Test	Experimental	120	176.45	14.35
	Control	120	84.81	12.87
Retention Test	Experimental	120	176.44	14.41
	Control	120	81.69	12.68

Table 1 indicates that the mean of the experimental group in the Post Test (176.45) was higher than that of the control group (84.81). In the Retention Test, the mean of the experimental group (176.44) was again higher than that of the control group (81.69).

Table 1 indicates that the mean scores of the experimental group in both the Post and Retention Tests were higher than those of the control group. In order to find out whether the difference in the test scores is significant, the adjusted mean scores obtained by these groups in both the tests were compared using the technique of Analysis of Covariance (ANCOVA) and the obtained F–value was tested for significance. The pre-test was the covariate. The results of the analysis are given in Table 2.

Table 2

Summary of ANCOVA of Mathematics Attitude Scale scores in Post and Retention Tests of students in the experimental and control groups

Test	Source	Sum of Squares	df	Mean Squares	F-ratio
Post Test	Pre Attitude	332.99	1	332.99	1.80
	Between Groups	538797.02	1	538797.02	2908.00**
	Within Groups	43905.08	237	185.25	
	Corrected Total	582702.33	239		

Retention Test	Rt Rt Attitude Between Groups	377.90 539028.84	1 1	377.90 539028.84	2.06 2939.00**
	Within Groups	43469.28	237	183.42	
	Corrected Total	582500.93	239		

**significant at 0.01 level

Table 2 indicates that in the Post Test, the obtained F-ratio for the Between Groups is 2908.00 ($F_{(1,237)} = 2908.00$, $p < 0.01$). This shows that the mean difference between the experimental and control group is statistically significant. The obtained F-ratio for the between groups in the retention test is 2939.00($F_{(1,237)} = 2939.00$, $p < 0.01$) which again reveals that the mean difference between experimental and control group is statistically significant even in the retention tests. It can therefore be concluded that the prepared Learning Package of Vedic Mathematics is effective in enhancing a positive Mathematics Attitude of students at the secondary level.

Retention Effect of the Learning Package of Vedic Mathematics in enhancing Mathematics Attitude of students of Secondary Schools using pre, post and retention tests scores (using Repeated ANOVA)

The scores obtained by pre, post and retention in the Mathematics Attitude Scale were tabulated and analyzed statistically using Repeated ANOVA to determine the retention effect of the Learning Package of Vedic Mathematics in enhancing Mathematics Attitude of students of secondary schools. To compare the Mathematics Attitude of the experimental and control group, mean and standard deviations of the three test scores, namely Pre-test, Post-test and Retention test, were calculated. The details are given below in Table 3.

Table 3

Mean values and Standard Deviations of Mathematics Attitude scores in pre, post and retention tests of secondary students in the experimental and control groups

Group	N	Mean	SD
Pre Experimental	120	81.62	13.11
Post Experimental	120	176.45	14.35
Retention Experimental	120	176.44	14.41
Pre Control	120	82.48	12.68
Post Control	120	84.81	12.87
Retention Control	120	81.69	12.68

Table 3 shows that the mean of Retention Test score of the experimental group was 176.44 and that of the Post Test score was 176.45. These values were much higher than that of Pre -test mean (81.62).

Thus from Table 3 it is clear that the mean scores of the three tests vary from each other. But it does not reveal whether there is any significant difference in the scores of these three tests. In order to find out whether the difference is significant, the mean scores of the three sets of scores (repeated scores from same sample) were compared using the technique of Repeated Analysis of Variance (Repeated ANOVA) and the obtained F-value was tested for significance. The results of the analysis are given below in Table 4.

Table 4

Summary of Repeated ANOVA of Mathematics attitude scores in pre, post and retention tests of secondary school students in the experimental and control groups

Group	Source of variation	Sum of Squares	df	Mean squares	F-ratio
Experimental	Between Groups	1450.44	2	725.22	
	Between Subjects	89095.06	119		
	Error	33991.56	238	142.82	5.08**
	Total	124537.06	359		
Control	Between Groups	47.57	2	23.79	
	Between Subjects	25772.79	119		
	Error	32217.09	238	135.37	0.18
	Total	58037.45	359		

**Significant at 0.01 level

The obtained F-ratio of the experimental group ($F_{(2,238)} = 5.08$, $p < 0.01$) was found to be significant at 0.01 level which reveals that there is a significant difference among the three sets of scores of Mathematics Attitude tests in the experimental group only. This means that the Mathematics Attitude of the same group measured in three different tests is not similar. However, the result does not help to identify exactly the pairs of scores which differ significantly. In order to overcome this, it was decided to apply the Least Significant Difference (LSD) test of post hoc comparison. The result of the analysis done in this regard is given in Table 5.

Table 5

Results of LSD Test for significance between pairs of mean scores of Mathematics Attitude Scale of secondary school students of the experimental group

Sl No	Pairs	Mean values	Mean Difference
1	Pre-Experimental Post-Experimental	81.62 176.45	94.83**
2	Pre-Experimental Retention Experimental	81.62 176.44	94.82**
3	Post-Experimental Retention Experimental	176.45 176.44	0.01

Significant at 0.01 level

The LSD test yielded significant mean differences at 0.01 levels, in the first two pairs of experimental groups (pre, post; pre, retention). The higher values of mean difference in the first two pairs indicate that the Mathematics Attitude in both these occasions increased significantly. No significant difference between post and retention scores was evident, indicating that the Learning Package is effective in retaining Mathematics Attitude of secondary school students in the experimental group.

Computational Speed

Table 6

Mean values and Standard Deviations of computational speed scores in pre, post and retention tests of secondary students in the experimental and control groups

Group	N	Mean	SD
Pre Experimental	120	17.71	3.48
Post Experimental	120	8.10	0.88
Retention Experimental	120	10.00	0.18
Pre Control	120	16.13	3.46
Post Control	120	14.17	3.69
Retention Control	120	15.81	3.93

Table 7

Summary of ANCOVA of Computational Speed scores in Post and Retention Tests of students in the experimental and control groups

Test	Source	Sum of Squares	df	Mean Squares	F-ratio
Post Test	Pre Speed	254.90	1	254.90	41.53**
	Between Groups	2437.44	1	2437.44	397.14**
	Within Groups	1454.57	237	6.14	
	Corrected Total	3917.73	239		
Retention	Rt Rt Speed	129.22	1	129.22	17.83**
Test	Between Groups	1474.75	1	1474.75	203.53**
	Within Groups	1717.29	237	7.25	
	Corrected Total	3200.25	239		

**significant at 0.01 level

Table 8

Summary of Repeated ANOVA of Computational Speed scores in pre, post and retention tests of secondary school students in the experimental and control groups

Group	Source of variation	Sum of Squares	df	Mean squares	F-ratio
	Between Groups	6213.94	2	3106.97	
Experimental	Between Subjects	510.20	119		716.95**
	Error	1031.39	238	4.33	
	Total	7755.53	359		
	Between Groups	242.642	2	121.32	
Control	Between Subjects	2974.93	119		15.14**
	Error	1907.36	238	8.01	
	Total	5124.932	359		

**Significant at 0.01 level

Table 9

Results of LSD Test for significance between pairs of mean scores of Computational Speed Test of secondary school students of the experimental group

Sl No	Pairs	Mean values	Mean Difference
1	Pre-Experimental Post-Experimental	17.71 8.10	9.61**
2	Pre-Experimental Retention Experimental	17.71 10.00	7.71**
3	Post-Experimental Retention Experimental	8.10 10.00	1.90**

** Significant at 0.01 level

Table 10

Results of LSD Test for significance between pairs of mean scores of Computational Speed Test of Secondary School students of the Control group

Sl No	Pairs	Mean values	Mean Difference
1	Pre-Control Post-Control	16.13 14.17	1.96**
2	Pre-Control Retention Control	16.13 15.81	0.32
3	Post-Control Retention Control	14.17 15.81	1.64**

** Significant at 0.01 level

DISCUSSION

When the results of the Analysis of Covariance of Post-test scores on the Computational Speed Test of participants in the experimental and control groups were calculated, the difference between the means was found to be statistically significant ($F_{(1,237)} = 397.14$; $p < 0.01$). The Analysis of the Covariance of Retention test scores in the Computational Speed Test of experimental and control groups showed significant difference between the means ($F_{(1,237)} = 203.53$; $p < 0.01$).

Research on the effects of Vedic Mathematics for improving Computational Speed includes the works by Nicholas, Williams & Pickles (1984), Hope (1987), Muchlman (1994), and Haridas (2004) who concluded that "Vedic Mathematics provides very easy, one line, mental and superfast methods".

FINDINGS

1. The Vedic Method of multiplication is effective in improving Computational speed and positive mathematics attitude of secondary students.
2. Application of Vedic Sutras is more effective than the existing system of Mathematics instructional procedure in improving computational speed and a positive mathematics attitude.
3. The Vedic Sutra for Multiplication is effective for Secondary School Students in retaining their Computational Speed and a positive Mathematics Attitude.

EDUCATIONAL IMPLICATIONS

Education is a process of human enlightenment and empowerment for the achievement of a better quality of life, of achieving greater human potential. To reach this goal of a positive Mathematics Attitude, students should be highly motivated to develop the skills of Mathematics aptitude, logical thinking, reasoning and so forth. Mathematics education is crucial to the entire developmental process of the country. Mathematics is generally poorly taught and badly learnt; it

is little more than a burdening of the mind with dead information, and it could degenerate even into a new superstition.

Mathematics has added a new dimension to education and to its role in the life of the nation, but central to all of this is the quality of education. This rediscovery of the great applications of Vedic Mathematics should enlighten educational authorities to devise instructional strategies across the curriculum to enhance the Mathematics Attitude of students. This, in turn, will go a long way towards the upliftment of the society and enrichment of education through our rich cultural heritage of Vedic applications.

CONCLUSION

This study clearly supports the skilful application of Vedic Mathematics in our secondary Mathematics classes. During the study it emerged that the majority of students tended to work with large portions of a problem - or an entire problem - just mentally. This is a shift away from concrete procedures and representations toward more abstract mental procedures and representations. Also, with this shift toward more self-referral computation, results indicate that there was an improvement in mental processing of mathematical information. There was also an increase in enjoyment of calculating, and more problems were solved correctly. Thus the speed, Mathematics Attitude and ease of computation improved, and there was a decrease in the number of perceived steps in solving a mathematical problem. This indicates a holistic improvement in the application of a positive attitude towards Mathematics.

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